intensity and quality are also altered when passing through the treeshelter. The manufacturer states that light intensities can be reduced by 40%, and this may partly be responsible for the elongation response observed in our trees.

The change in shoot : root ratio suggests a differential partitioning of photosynthate. It appears that shoot growth is promoted while root growth is inhibited in trees grown in treeshelters. This problem may diminish as the tree grows out the top of the shelter during the second and third year in the nursery and/or in the landscape. The reduced root growth and development are of most concern in terms of transplantation ease and success.

Water use characteristics were not affected with the use of the treeshelter. While there were indications that slightly less water was used by trees grown in shelters, these differences were not significant.

### Literature Cited


Evans, J. and M.J. Potter. 1985. Treeshelters-A new aid to tree establishment. Plasticulture 68:7-20.

Frearson, K. and N.D. Weiss. 1987. Improved growth rates with tree shelters. Quart. J. For. 81(3):184-187.

Potter, M.J. 1988. Treeshelters improve survival and increase early growth rates. J. For. 86(6):39-41.

Potter, M.J. 1991. Treeshelters. For. Commission Hdbk. 7. HMSO Publications, London.

Saltveit, M.E., Jr., and T. Strike. 1989. A rapid method for accurately measuring oxygen concentrations in milliliter gas samples. HortScience 24( 1): 145-147.



HortScience 27(1):32–34. 1992.


# Selective Removal of Floral Buds from *Camellia* with Ethephon


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*Additional index words.* potted flowering plants, plant export, thinning, maturity, temperature, floriculture



***Abstract.*** **Six concentrations of ethephon were applied to plants of 'Donation' and 'Anticipation' *Camellia* (L.) at two times (late summer and autumn) and three times (late summer, autumn, and midwinter) of the year, respectively. Abscission of leaves and floral and vegetative buds was determined. Sensitivity to ethephon varied markedly among plant organs. Greater sensitivity of floral buds indicated that ethephon could be used to selectively remove these with minimal abscission of other plant organs. Proportion of abscised organs varied with cultivar and time of application. Chemical name used: (2-chloroethyl)phosphonic acid (ethephon).**


The climate in New Zealand is suited to the commercial production of *Camellia* plants. One- to four-year-old container-grown plants may be exported to the Northern Hemisphere between February and April (late summer to autumn). Floral macrobuds are present on *Camellia* plants at this time. However, vegetative budbreak and subsequent shoot extension is required on arrival because floral buds are initiated on shoots produced under long days and high temperatures in the Northern Hemisphere summer (Scott, 1977). Ideally, floral buds should be removed before export. In addition, fungal infections may arise from in-transit abscission of floral buds when plants are sea-freighted. **A** similar problem with hydrangeas led to the requirement for defoliation before storage to decrease *Botrytis cinerea* Pers. incidence (Bailey, 1990). Floral buds in *Camellia* can be removed manually before transport, but this has a high labor requirement and resulting wounds provide ideal entry points for fungal diseases.

Ethephon has been used for selective removal of floral buds in apple (Edgerton and Greenhalgh, 1969). Development of a similar procedure for *Camellia* could reduce production costs and disease incidence. The ability of ethephon to promote selective abscission (thinning) is determined by both its ethylene-release kinetics and the greater sensitivity of the target organ than that of other plant organs (Beaudry and Kays, 1987).

Rate of release of ethylene from ethephon is influenced by various environmental factors. An increase in air temperature increases the rate of ethylene release (Klein et al., 1978). Olien and Bukovac (1978) derived a $Q_{10}$ of 7.0 for ethylene release from ethephon-treated *Prunus* leaves over the range of 10 to 40C. Relative humidity (RH) may influence ethylene release at extremes but does not appear to be responsible for variable field results (Klein et al., 1978).

Many factors influence the sensitivity of plant organs to ethylene. Physiological age affects sensitivity to released ethylene. For example, floral buds of *Begonia* **x** *cheimantha* Everett (Moe and Smith-Eriksen, 1986) and grape (Weaver and Pool, 1969) become more sensitive to ethephon as they develop to anthesis. Sensitivity to ethephon is also genetically determined. Cultivars of olive (Hartmann et al., 1970) and apple (Edgerton and Greenhalgh, 1969) differ in abscission sensitivity to both ethephon concentration and physiological maturity of the plant organ.

Temperature also influences tissue sensitivity to ethylene gas itself. Ethylene promotion of *Philodendron* leaf and stipule abscission increases with higher temperature (Marousky and Harbaugh, 1979). It has also

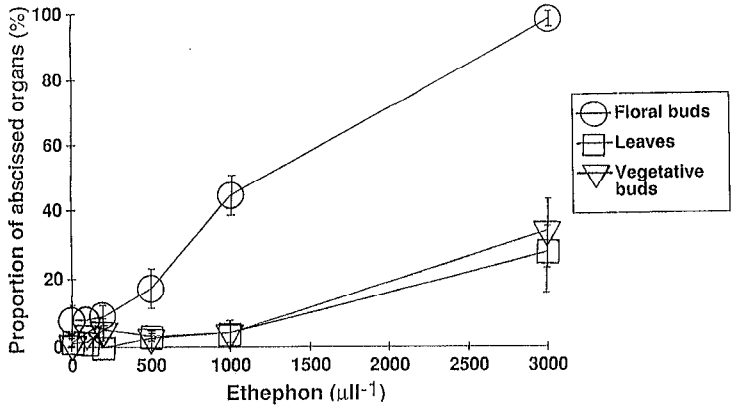


Fig. 1. Abscission of plant organs from 'Anticipation' *Camellia* 32 days after application of ethephon on 1 June 1988 (midwinter). Leaf age pooled. Vertical bars represent SE of the mean.


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Table 1. Summary of temperature and relative humidity for three ethephon application times.

| Time of application | Temp (°C) | | | Relative humidity (%) | |
|---|---|---|---|---|---|
| | At spraying | Mean min. | Mean max. | At spraying | Mean |
| 1 June 1988 | 10 | 5 | 13 | ---[z] | ---[z] |
| 3 Mar. 1989 | 29 | 15 | 30 | 55 | 51 |
| 14 Apr. 1989 | 19 | 12 | 26 | 67 | 62 |

[z]Relative humidity not measured in 1988.

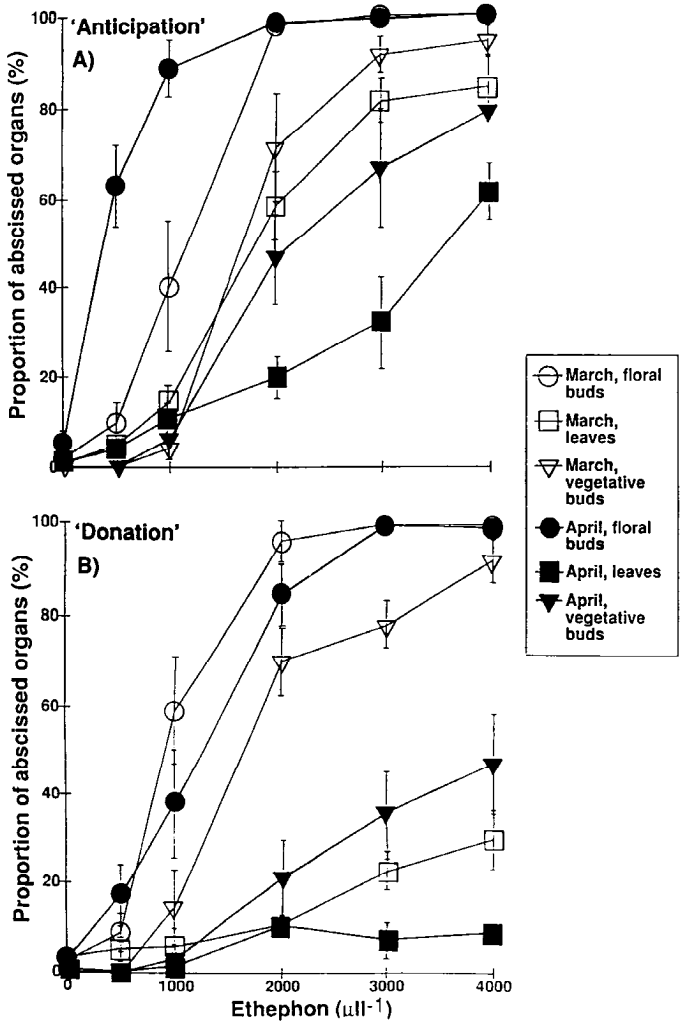


Fig. 2. Abscission of plant organs from (**A**) 'Anticipation' and (**B**) 'Donation' *Camellia* 14 days after application of ethephon on 3 Mar. (late summer) and 14 Apr. (fall) 1989. Vertical bars represent SE of the mean.

been found that higher temperatures promote ethylene-stimulated flower senescence in carnation (Woltering and Harkema, 1987).

The objective of this work was to determine whether ethephon could be used for selective removal of floral buds from potted *Camellia* plants with minimal damage to other plant organs.

Three-year-old *Camellia* plants (15 to 20 floral and vegetative buds/plant) were obtained (Duncan and Davies Nurseries, New Plymouth, N.Z.) in 2-liter plastic pots. All plants were sprayed to runoff ( ≈ 20 ml/plant) using a 2-liter hand-held sprayer. Temperature and RH at time of spraying and minimum/maximum temperature and RH were recorded daily (3:00 PM). Mean minimum/maximum temperature and mean RH were calculated for the period of each experiment (Table 1). Abscission proportion data were analyzed to obtain means and standard errors and subsequently converted to percent form for graphing.

'Anticipation' *Camellia* was used in the first experiment to investigate the effect of ethephon on the abscission of leaves and floral and vegetative buds. Ethephon (Ethrel 48, Rhone-Poulenc, Wellington, N.Z.) was applied as a foliar spray containing Tween 20 [0.5% (v/v)] at six concentrations (0, 50, 200, 500, 1000, and 3000 µ1 a.i./liter) on 1 June 1988. Plants were treated and arranged in the open in a completely randomized design with five whole-plant replicates per treatment. Water was applied to the pots by hand every 4 days, as plant water potential has been shown to influence uptake and translocation of ethephon (Klein et al., 1978).

After 32 days, the abscission rate had dropped to that of the control plants, and the number of leaves and floral and vegetative buds remaining on each plant were recorded. Effect of leaf age on abscission sensitivity was also examined by determining leaf abscission proportion on three shoot ages [l-(current season), 2-, and 3-year-old wood]. All plants were subsequently placed in conditions promoting vegetative budbreak and shoot extension (15 to 25C and 16-h daylength) to determine the influence of applied ethephon and induced abscission on subsequent growth.

In a second experiment carried out in Fall 1989, the effect of ethephon concentration, timing of application, and cultivar were investigated. Ethephon was applied to 'Anticipation' and 'Donation' *Camellia* at six concentrations (0, 500, 1000, 2000, 3000, and 4000 µl·liter$^{-1}$) on 3 Mar. and 14 Apr. A split-plot design pooled over time was used. Cultivars were randomized in the split plots and 10 whole-plant replicates used for each cultivar. A second population of previously untreated plants was used at the second application time. After ethephon application, plants were placed under a plastic-covered shelter (13% shade) to eliminate any effect of rain on ethephon-promoted abscission (Hartmann et al., 1970). Hand-watering was carried out every 2 days. After 14 days, the abscission rate had dropped to that of the control plants, and the numbers of leaves and floral and vegetative buds remaining on each plant were recorded.

Application of ethephon to 'Anticipation' *Camellia* caused the abscission of leaves, floral buds, and vegetative bud scales. Increasing ethephon concentration promoted greater abscission of all organ types (Figs. 1 and 2). In many cases, the response curve was approximately sigmoidal, similar to that found for olive (Lavee and Martin, 1981).

Leaves and floral buds abscised intact at the base of the petiole or peduncle following ethephon application. Vegetative buds, in contrast, were either killed or damaged by ethephon. At ethephon concentrations of 1000 to 2000 µl·liter$^{-1}$, bud scales surrounding the small, unelongated shoot tended to abscise, leaving the unexpanded leaves exposed (Fig. 3). At higher concentrations (3000 to 4000 µl·liter$^{-1}$) most of the vegetative buds were killed but did not fall from the plant, as did affected floral buds. Both damaged and killed vegetative buds were regarded as abscised and pooled for the purpose of this work. *Camellia* plants grown after ethephon application showed no decrease in vegetative budbreak or subsequent shoot growth, as was the case with defoliated apple rootstocks (Cummins and Fiorino, 1969).

Plant organs differed in their sensitivity to ethephon. Floral buds were the most sensitive, vegetative buds were intermediate, and leaves the least sensitive (Figs. 2 A and B). In mid-April, application of 2000 µl ethephon/liter to 'Donation' resulted in 84% of floral buds abscising, while only 21% and 11% of vegetative buds and leaves abscised, respectively (Fig. 2B). This trend of sensi-

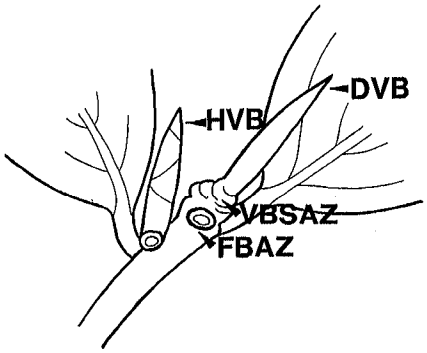


Fig. 3. Apex of stem of 'Anticipation' *Camellia* with vegetative bud damaged by application of 1000 to 2000 µl ethephon/liter. (HVB) healthy vegetative bud; (DVB) damaged vegetative bud; (VBSAZ) vegetative bud scale abscission zone; (FBAZ) floral bud abscission zone.

tivity held true in both cultivars and at all times of ethephon application at concentrations > 1000 µl·liter$^{-1}$. A trend of increasing sensitivity with increasing physiological age of leaves similar to that observed in olive (Klein et al., 1978) was also found in Camellia. The differences, however, were not significant, and leaf age data were pooled for comparison with floral bud and leaf data (Fig. 1).

Time of application of ethephon had a significant effect on abscission of the three plant organs. In both cultivars, later application (April) of ethephon (1000 to 4000 µl·liter$^{-1}$) resulted in a lower proportion of abscised vegetative buds and leaves than earlier application (March) (Figs. 2 A and B). However, our results suggest that, for some cultivars, later application may result in a higher incidence of abscission of floral buds. In 'Anticipation', the proportion of floral buds abscised was higher in April than in March at ethephon concentrations of 500 and 1000 µl·liter$^{-1}$ (Fig. 2A). In contrast, in 'Donation', later application resulted in less floral bud abscission for 1000 and 2000 µl ethephon/liter (Fig. 2B).

At concentrations of 1000 to 4000 µl·liter$^{-1}$, vegetative buds and leaves of 'Anticipation' were more sensitive than those of 'Donation', except for March application to vegetative buds (Figs. 2 A and B). However, floral bud abscission was only higher in 'Anticipation' at 1000 µl·liter$^{-1}$ for the March application, and at 500 to 1000 µl·liter$^{-1}$ for the April application. Cultivar differences also occur in olive, where sensitivity of leaves to ethephon correlates positively with fruit abscission (Hartmann et al., 1970).

Sensitivity to ethephon varied markedly among leaves and floral and vegetative buds, the floral buds being the most sensitive. This made the selective removal of floral buds from *Camellia* possible. Differences in sensitivity of plant organs in *Camellia* were comparable to peach, where abscission of 100% of the flowers but only 20% of the leaves occurs after application of 450 µ1 ethephon/liter (Edgerton and Greenhalgh, 1969).

Lang and Martin (1985) suggested that differences in sensitivity between fruits and leaves of olive could be explained in terms of their genetic programming. Fruits are seasonal reproductive organs, whereas leaves are photosynthetic organs programmed for a 3-year existence. In the genus *Camellia, flow*ers abscise after opening in winter, vegetative bud scales at budbreak in the following spring, and the leaves senesce and abscise after 2 to 3 years. Thus, the relative sensitivity to ethephon of these three organs follows the same pattern as their proximity to natural abscission. The trend of greater sensitivity with increasing age of *Camellia* leaves also supports this hypothesis.

Time of application influenced abscission of all plant organs. Later application of ethephon resulted in consistent reduction in abscission of vegetative buds and leaves in both cultivars. This effect was most probably due to decreased air temperature, which would cause less ethylene release to occur from ethephon (Olien and Bukovac, 1982), and lower ethylene sensitivity of the plant organ (Beaudry and Kays, 1987). Floral buds of 'Anticipation' abscissed more at the later time of application. Although lower temperature caused lower ethylene release and reduced sensitivity of plant tissue, increase in ethylene sensitivity as a result of greater maturity was most likely the overriding factor. The effect of time of application could also potentially be due to the influence of RH. However, it seems unlikely that a difference in RN of 11% (Table 1) would strongly affect ethylene release as RH is not a major factor in the field application of ethephon (Klein et al., 1978).

Ethephon can be used to remove floral buds with minimal abscission of leaves and vegetative buds. From the cultivars, concentrations and times tested, a mid-April application of 1000 to 1500 µl ethephon/liter for 'Anticipation' and 1500 to 2000 µl·liter$^{-1}$ for 'Donation' are likely to be optimal for the selective removal of floral buds before export of *Camellia* in autumn.

## Literature Cited

Bailey, D.A. 1990. Gibberellic acid enhances chemical defoliation of hydrangeas, HortScience 25:580.

Beaudry, R.M. and S.J. Kays. 1987. Effects of physical and environmental factors on the release kinetics of ethylene from (2-chloroethyl)phosphonic acid and (2-chloroethyl)-methylbis(phenylmethoxy)silane. J. Amer. Soc. Hort. Sci. 112:352-359.

Cummins, J.N. and P. Fiorino. 1969. Pre-harvest defoliation of apple nursery stock using Ethrel. HortScience 4:339-341.

Edgerton, L.J. and W.J. Greenhalgh. 1969. Regulation of growth, flowering and fruit abscission with 2-chloroethanephosphonic acid. J. Amer. Soc. Hort. Sci. 94:11-13.

Hartmann, H.T., A. Tombesi, and J. Whisler. 1970. Promotion of ethylene evolution and fruit abscission in the olive by 2-chloroethanephosphonic acid and cycloheximide. J. Amer. Soc. Hort. Sci. 95:635-640.

Klein, I., E. Epstein, S. Lavee, and Y. Ben-Tal. 1978. Environmental factors affecting ethephon in olive. Scientia Hort. 9:21-30.

Lang, G.A. and G.C. Martin. 1985. Ethylene-releasing compounds and the laboratory modeling of olive fruit abscission vs. ethylene release. J. Amer. Soc. Hort. Sci. 110:207-211.

Lavee, S. and G.C. Martin. 1981. In vitro studies on ethephon-induced abscission in olive. I. The effect of application period and concentration on uptake, ethylene evolution and leaf abscission. J. Amer. Soc. Hort. Sci. 106:14-18.

Marousky, F.J. and B.K. Harbaugh. 1979. Interactions of ethylene, temperature, light and CO, on leaf and stipule abscission and chlorosis in *Philodendron scandens* subsp. *oxycardium.* J. Amer. Soc. Hort. Sci. 104:876-880.

Moe, R. and A. Smith-Eriksen. 1986. The effect of ethephon and STS treatment on flower malformation and flower bud abscission in *Begonia* × *cheimantha* Everett. Acta Hort. 181:155-160.

Olien, W.C. and M.J. Bukovac. 1978. The effect of temperature on the rate of ethylene evolution from ethephon and from ethephon-treated leaves of sour cherry. J. Amer. Soc. Hort. Sci. 103:199-202.

Olien, W.C. and M.J. Bukovac. 1982. Ethylene generation, temperature responses, and relative biological activities of several compounds with potential for promoting abscission of sour cherry. J. Amer. Soc. Hort. Sci. 107:1085-1089.

Scott, M.A. 1977. Methods of improving flower bud initiation in camellias. Expt. Hort. 29:80-93.

Weaver, R.J. and R.M. Pool. 1969. Effect of Ethrel, abscisic acid and a morphactin on flower and berry abscission and shoot growth in *Vitis vinifera.* J. Amer. Soc. Hort. Sci. 94:474-478.

Woltering, E.J. and H. Harkema. 1987. Effect of exposure time and temperature on response of carnation cut flowers to ethylene. Acta Hort. 216:255-262.