# Efficacies of Commercial Anti-ethylene Products for Fresh Cut Flowers

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*Summary.* Three commercially available "anti-ethylene" treatment solutions were tested for their effectiveness in protecting carnations *(Dianthus caryophyllus* L. 'Improved White Sim', 'Atlantis', and 'Nora'), Beard-Tongue (Penstemon hartwegii x *P.* cobaea 'Firebird'), and Delphinium sp. from external ethylene levels ranging from 0.01 to 1.2 ppm. Flowers were treated according to label directions and then exposed to ethylene for 20 or 24 h at 20 to 23C after a 0-, 24-, or 48-h delay. Only the product containing silver thiosulfate (STS) provided protection against ethylene injury, whereas products containing inhibitors of ethylene synthesis identified as analogs of either aminooxyacetic acid (AOA) or aminoethoxyvinyl glycine (AVG) offered little or no protection. The safe commercial use of products containing STS is discussed.

Low concentrations of silver, in the form of silver nitrate, were shown to prevent or reduce the deleterious effects ofethylene on plants (Beyer, 1976). However, this form of silver was often phytotoxic when used as a spray, and it was translocated so slowly in cut flower stems that it was ineffective when used in vase solutions. It was discovered later that silver thiosulfate ion complex (STS) translocated easily in plants, was not phytotoxic at effective concentrations (Veen and van de Geijn, 1976), and therefore, was ideal for protecting flowers fromethylene (Reid et al., 1980; Veen, 1979).

More than 400 articles have been published subsequently on the effectiveness of STS on floral crops. Major findings reported in these articles include: ≈1.0 µmol of silver per stem is required for maximum protection (Reid et al., 1980); maximum STS benefits are realized when flowers are treated soon after harvest, but protection also is provided when STS treatments are delayed for days (Nichols et al., 1982); and STS inhibits the action of ethylene, regardless of ethylene source(s) (Lin, 1988; Veen, 1979).

Recently, two new types of "anti-ethylene" products believed to contain inhibitors of ethylene biosynthesis have been introduced to the floral industry (Nell, 1992). Specifically, these inhibitors of pyridoxal phosphate-mediated reactions can prevent the transformation of *S*- adenosylmethione to 1 -aminocyclopropane- 1 -carboxylic acid (ACC), the precursor to ethylene (Yang and Hoffman, 1984). These new commercial products have been suggested to be just as effective, safer, and to have the same mode of action as STS-based products (Nell, 1992). The research described here compared the relative effectiveness of these new anti-ethylene products with that of STS.

Three commercial anti-ethylene products were tested: EVB (Pokon & Chrysal B.V., Naarden, The Netherlands); Florish (Abbott Laboratories, North Chicago, Ill., lot 65736CF); and Silflor/RTU (Floralife, Inc., Burr Ridge, Ill.). All products were obtained directly from the manufacturers to ensure freshness. In some experiments, flowers were treated with laboratory-prepared STS as described by Reid et al. (1980).

Silflor/RTU is advertised to contain STS, which was confirmed using a calorimetric test (Gorin et al., 1985). EVB and Florish are believed to contain inhibitors of ethylene biosynthesis, AOA- and AVG-like compounds, respectively, in addition to components common to many floral preservatives, such as a carbohydrate. The presence of these ethylene biosynthetic inhibitors was confirmed using a range of analytical techniques, as follows.

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AOA was identified using type-100 cellulose thin-layer plates (250 µm thick, containing 2- to 20-µm fiber lengths) developed in 66.5% ethanol/water and visualized with ninhydrin as yellow spots. For gas chromatographic determinations, 1.0 ml each of hexamethyldisiloxane and trimethylsilylimidazole were incubated at 95C for 50 min with a 25-mg freeze-dried EVB sample. Samples were injected into an OV-17 180-cm column with a temperature program from 40 to 230C at 5.5C/min.

The same thin-layer system described above was used to identify AVG in Florish, except the developing solvent was ethanol-water-ammonia (4949-2) and the ninhydrin test produced orange spots, as reported in the literature (Pruess et al., 1974). AVG was identified further using infrared, nuclear magnetic resonance, and microbial inhibition tests. In all cases, Florish samples corresponded with known AVG and also were consistent with data reported previously (Pruess et al., 1974).

'Improved White Sim', 'Atlantis', and 'Nora' carnations were harvested at stage three (Downs and Lovell, 1986) and held dry under ambient temperature conditions until treatments were initiated, generally within 6 to 8 h. Flower stems were cut in air to 43 cm just prior to being placed into glass jars containing the various treatment solutions. A fresh flower food (1% Floralife Crystal Clear) was used as the control treatment. All solutions were prepared in deionized water, and no leaves were removed from the flower stems.

After an initial 1- or 2-h treatment, the STS-treated flowers were transferred to fresh flower food while the flowers treated with EVB or Florish, as well as the fresh flower food controls, remained in these solutions for the duration of the experiment. EVB and Florish contain a carbohydrate source; therefore, transfer to a fresh flower food solution was not required.

Flowers were exposed to ethylene 0, 24, or 48 h after the initial 1- or 2-h treatment period by placing them into 40-liter glass tanks with a continuous flow of air containing concentrations of ethylene ranging from <0.005 to 1.16 ppm for 20 or 24 h at 20 to 23C. The combinations of ethylene levels, temperatures, and exposure times were designed to emulate environments often encountered in the floral industry and in research experiments (Abeles and Heggestad, 1973; Barden and Hanan, 1972; Hanan, 1973; Maxie et al., 1973). Anti-ethylene and ethylene exposure treatments, as well as vaselife determinations, were conducted under normal room light (125 fc cool-white fluorescent for 16 h/day) and temperature (20 to 23C) conditions. Ambient ethylene levels during vaselife determinations after exposure treatments were <5 ppb.

Significant three-way interactions were obtained in two carnation experiments (Tables 1 and 2), mandating that all test variables (anti-ethylene treatments, ethylene exposure delays, and ethylene concentrations) be considered together when interpreting the results. Key findings obtained are:

1) STS-treated flowers lasted longer than controls or those held in solutions containing either AOA or AVG, regardless of ethylene levels when exposures were delayed for 24 or 48 h.

2) With no ethylene exposure delay and at lower ethylene concentrations (0.01, 0.08, and 0.36 ppm), flowers treated with STS lasted longer than controls or those treated with solutions containing AOA or AVG. At high ethylene levels, STS offered little or no protection, presumably because sufficient silver had not reached critical action sites (petal bases, ovaries, etc.) prior to exposure to ethylene (Harkema and Kalkman, 1984). This hypothesis is supported by the fact that, after 24 or 48 h of ethylene treatment delays, STS was effective, even at the highest ethylene levels.

3. Classical petal in-rolling was visible within an average of 1.6 days upon removal from ethylene exposures for all non-STS-treated flowers. Treatment differences were even more dramatic after 2 or 3 days (Fig. 1).

4) Neither the solutions containing AOA nor AVG analogs offered improved vaselife over the controls, even at low (0.01 and 0.08 ppm) ethylene levels (Tables 1 and 2). Using 'Atlantis' and 'Nora' carnations, the solution containing the AVG analog again offered no vaselife extension at ethylene levels as low as <0.005 ppm, whereas 0.4 and 1.0 ppm exposures for 24 h reduced vaselife by >75% as compared to STS-treated flowers (data not reported). At these low (0.01 and 0.08 ppm) concentrations and under the temperature and exposure times used in these tests, ethylene effects are generally minimal (Barden and Hanan, 1972; Maxie et al., 1973). Thus, AOA- or AVG-treated flowers would have been expected to last longer than controls-a hypothesis supported in the literature (Fujino et al., 1981), but not supported by the data in Tables 1 and 2.

5) STS greatly reduced or completely inhibited the abscission of flowers from both delphiniums and beardtongues, whereas the anti-ethylene solution containing the AVG analog only provided some abscission protection when ethylene levels were <0.005 ppm for *Penstemon,* while actually stimulating abscission in delphiniums (Table 3; Fig. 2).

The results obtained in these stud-

Table 1. The effects of STS (Silflor/RTU), AOA (EVB), or fresh flower food control (Crystal Clear); ethylene exposure levels; and ethylene exposure delays on the vaselife of 'Improved White Sim' carnations as measured in days from the initiation of the anti-ethylene treatments.[z]

| | Average ethylene exposure levels (ppm) | | | |
|---|---|---|---|---|
| Treatment | 0.01 | 0.08 | 0.27 | 0.53 |
| | *No exposure delay* | | | |
| Control | 10.0 | 10.2 | 1.5 | 1.1 |
| STS | 16.0 | 14.5 | 15.9 | 2.9 |
| AOA | 11.4 | 6.6 | 5.3 | 1.1 |
| | *24-h exposure delay* | | | |
| Control | 10.8 | 9.2 | 2.8 | 2.1 |
| STS | 15.6 | 15.7 | 16.5 | 14.9 |
| AOA | 10.0 | 11.7 | 5.3 | 2.8 |
| | *48-h exposure delay* | | | |
| Control | 10.6 | 8.1 | 4.3 | 3.1 |
| STS | 14.4 | 15.8 | 14.1 | 13.3 |
| AOA | 12.5 | 7.8 | 5.3 | 3.4 |

[z]Significant three-way interaction at $P < 0.05$.

Table 2. The effects of STS (Silflor/RTU), AVG (Florish), or fresh flower food control (Crystal Clear); ethylene exposure levels; and ethylene exposure delays on the vaselife of 'Improved white Sim' carnations as measured in days from the initiation of the anti-ethylene treatments."

| | Average ethylene exposure levels (ppm) | | | |
|---|---|---|---|---|
| Treatment | 0.08 | 0.36 | 0.86 | 1.16 |
| | *No exposure delay* | | | |
| Control | 5.4 | 1.8 | 1.1 | 1.1 |
| STS | 17.7 | 10.8 | 2.9 | 2.4 |
| AVG | 7.1 | 1.1 | 1.1 | 1.1 |
| | *24-h exposure delay* | | | |
| Control | 8.2 | 2.6 | 2.6 | 2.6 |
| STS | 17.8 | 18.1 | 17.4 | 16.5 |
| AVG | 8.2 | 3.0 | 2.7 | 2.4 |

[z]Significant three-way interaction at $P < 0.01$.

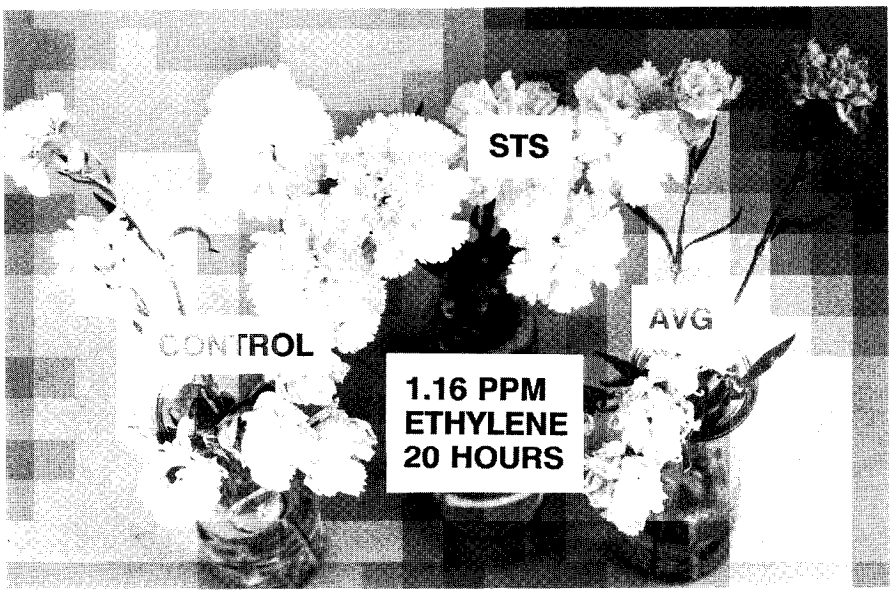


Fig. 1, The effects of a 20-h, 1.16-ppm ethylene exposure initiated 24 h after flowers were treated with either (left to right) fresh flower food control (Crystal Clear), STS (Silflor / RTU), or AVG (Florish) on 'Improved White Sim' carnations. Photograph taken 68 h after removal from ethylene exposure.

ies support the findings of other researchers indicating that STS inhibits ethylene action while AOA or AVG inhibit ethylene synthesis and not ethylene action (Broun and Mayak, 198 1; Dostaletal., 1991; Fujino et al., 1981; Nowak and Plich, 1981; Yang and Hoffman, 1984). Our findings also indicate that products containing STS offer much better protection than AOA- or AVG-based products. However, not all commercial products containing STS are effective, as at least one (Rogard-RS) is only somewhat better than a fresh flower food containing no STS (Newman et al., 1991; Reid, 1992).

While not an original goal of the research described in this paper, we believe that comments are in order relative to the safe use and disposal of STS because this aspect has been questioned (Nell, 1992). One way to address this issue is to compare STS used in the floral industry to the essentially identical STS used in the film-processing industry. For example, there is sufficient recoverable silver from processing one roll of most films to treat thousands of flowers. Since the average person in the United States and Canada has more than four rolls of film developed per year, there would be enough recoverable silver in 1 year associated with this amount of film to treat more than 4 trillion carnations: enough carnations to meet the needs of these two countries for tens of thousands of years.

If the film processing industry can safely use and dispose of tens of thousands of times more silver than the floral industry (Cooley, 1988), then floral industry members should be able to safely use STS simply by properly following label use and disposal instructions (Newman et al., 1991).

Finally, just because the anti-ethylene AOA and AVG products do not contain silver does not necessarily mean they are safer to use, as stated by Nell (1992). For example, as noted earlier, both AVG and AOA are known inhibitors of pyridoxal phosphate coenzyme reactions. These coenzymes are involved in nearly all reactions concerned with the transformations of amino acids (Mahler and Cordes, 1966). Therefore, it should be of no surprise that these inhibitors can interfere with the synthesis of numerous reactions involving amino acids. This knowledge was used to develop a pharmaceutical drug using AOA for the control of certain neurological disorders (Osuide, 1972; Van Gelder, 1966). However, this drug was taken off the market because of certain negative side effects it caused (Davanzo et al., 1964a, 1964b, 1966; Pont, 1987).

It also has been reported that AOA exhibits $LD_{50}$s in the range of 30

Table 3. The effects of STS (1.0 mmol), AVG (Florish), or fresh flower food control (Crystal Clear) and ethylene exposure levels on the percent flower abscission from 'Firebird' beard-tongues and delphiniums measured 24 h after the initiation of ethylene exposure.

| | | Average ethylene exposure levels (ppm) | |
|---|---|---|---|
| Species | Treatment | <0.005 | 0.4 |
| | – | *Abscission (%)* | |
| *Penstemon* | | | |
| | Control | 12 | 63 |
| | STS | 0 | 3 |
| | AVG | 3 | 48 |
| *Delphinium* | | | |
| | Control | 4 | 77 |
| | STS | 0 | 0 |
| | AVG | 33 | 72 |

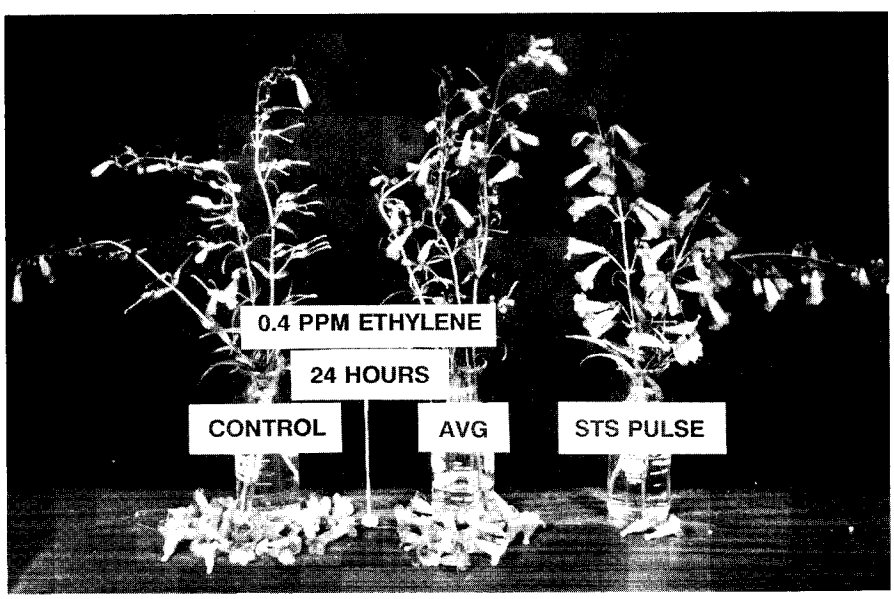


Fig. 2. The effects of a 24-h, 0.4-ppm ethylene exposure initiated 16 h after flowers were treated with either (left to right) fresh flower food control (Crystal Clear), AVG (Florish), or STS Pulse (1.0 mmol silver) on flower abscission from 'Fire bird' beard-tongue. Photograph taken at removal from ethylene exposure.

to 70 mg $kg^{-1}$ (Loscher, 1979; Loscher and Frey, 1978; Osuide, 1972), which is about the same or even lower than the $LD_{50}$ of some silver compounds. This is not to suggest that silver is completely safe, as certain silver compounds can be toxic (Sweet, 1987). Thus, care should be taken in making generalizations as to which products are safer to use.

In conclusion, the effectiveness of any anti-ethylene product should be based primarily on actual flower tests performed by the user, with less reliance on information printed on labels, in advertisements, or in trade press publications. Users of STS-based products should also implement proper silver recovery procedures, regardless of the brand used.

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