

Corolla Abscission and Petal Color in Cut Phlox Flower Heads: Effects of Sucrose and Thidiazuron

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Abstract

Phlox paniculata L. 'John Fanick', a superior selection for Texas landscapes, bears attractive and long-lasting clusters of flowers which have several colours, dense deep red, pink and white. We investigated its potential as a cut flower. Vase life was limited by shedding of turgid corollas. Inclusion of 2-chloroethylphosphonic acid (CEPA) in the holding solution, which releases ethylene, considerably hastened corolla abscission, reduced opening of new buds and decreased flower size. Sucrose and thidiazuron (TDZ) both reduced corolla abscission and promoted bud opening during vase life. Petal colour of control flowers turned to bluish, but after sucrose treatment petal colour was maintained. Both TDZ and sucrose counteracted several effects of CEPA (and thus of endogenous and exogenous ethylene during shipping and handling), and greatly improved overall postharvest display life and longevity.

INTRODUCTION

Of the 67 species of *Phlox* (Polemoniaceae), about 15 species are widely grown in gardens throughout the world (Wherry, 1955). Among these, the perennial *P. paniculata*, bearing dense terminal clusters of flowers in shades of white, pink, lavender, red, light blue and salmon, is still a popular plant for midsummer color in either home or commercial landscapes. The attractive blooms also have great potential as a specialty cut flower crop.

Recently, superior selections of perennial phlox have been identified for Texas landscapes. *P. paniculata* 'John Fanick' is a promising new selection which produces dense terminal clusters of flowers in shades of red, pink, and white with a dark red eye. It exhibits a relatively high tolerance to several environmental stresses including intense heat and blooms for an extended period during the hot summer in Texas (Sankhla et al., 2003).

Previously, we reported that thidiazuron (N-phenyl-N'-1,2,3-thiadiazol-5-ylurea, TDZ), a phenylurea derivative with strong cytokinin-like activity considerably reduced flower abscission and leaf senescence in cut phlox inflorescences (Sankhla et al., 2003). This study was initiated to evaluate the effect of sucrose and TDZ, alone and in combination, on parameters related to postharvest performance such as flower abscission, flower senescence, flower bud opening, flower color and vase life of cut flower heads of phlox 'John Fanick'.

MATERIALS AND METHODS

Plant Material

Phlox paniculata L. 'John Fanick' plants were clonally multiplied in vitro from selected superior stock plants. After acclimation in the greenhouse and nursery, the plants were grown in the Coordinated Educational Marketing and Assistance Program (CEMAP) trial garden at Agricultural Research Center, Texas A&M University, Dallas (Sankhla et al., 2003). The cut flower heads with 4-6 leaves were brought to the laboratory and used for experimentation.

Treatments

Flower heads, with their freshly recut stem bases, were placed in glass vases

containing 400 ml deionized water or an equivalent amount of aqueous solution of TDZ (5-45 μM), 2-chloroethylphosphonic acid (CEPA, 10-100 μM) and sucrose (30-240 μM). All vases also contained 100 mg.l^{-1} 8-hydroxyquinoline sulphate (HQS).

Anthocyanin Concentration

Petals from fully open flowers were cut into small pieces, ground to an even consistency in 5 ml 1% HCl in methanol, and kept at 4°C in the dark for a day. The absorbance of the solution, after suitable dilution, was measured at 530 nm using a spectrophotometer.

Experimental Conditions

The vases containing flower heads were kept at 22-24°C with 30 $\mu\text{mol.m}^{-2}.\text{sec}^{-1}$ irradiance using cool-white fluorescent lamps. Observations on number of open flowers, flower abscission, flower senescence and flower color were recorded regularly for a period of 10-14 days. The vase life was determined as the time in days from harvest until the flower heads ceased to have any decorative value.

Statistical Analysis

An experiment consisted of four replicates per treatment and was repeated at least two times. Standard error was calculated using Microsoft Excel software package.

RESULTS

Effect of Sucrose

In phlox, flower abscission is limited to the shedding of the sympetalous funnel-shaped corolla with epipetalous stamen. We observed that the presence of sucrose in the vase solution considerably reduced flower abscission (Table 1). Addition of sucrose to the vase solution also enabled more flower buds to open fully, many of which without sucrose only open partially or do not open at all. Flower size also increased greatly in the presence of sucrose.

A characteristic, but undesirable, feature of 'John Fanick' flowers relates to change of petal colour during vase life from red, pink and white to bluish. The new flowers that open during vase life even fail to develop significant colour and appear almost white. In flowers that were already open, sucrose greatly improved the maintenance of original colour. During vase life, sucrose treatment even resulted in maintenance of up to 90% of the initial anthocyanin concentration.

Even the new flower buds that open during vase life in the presence of sucrose, in contrast to those opening in control, developed deep red-pink-white color and appeared very similar to freshly harvested flowers. Preliminary studies indicated that these flowers had considerably greater amount of total anthocyanins than those opening in control. It thus appears that sucrose affects both maintenance and synthesis of anthocyanins in cut flower heads of phlox.

Incorporation of sucrose in the vase solution not only reduced corolla abscission, but also significantly increased flower size. Additionally, it enabled many more flower buds to open fully, thereby improving the postharvest quality and longevity of cut inflorescences. Sucrose (60-120 μM) appeared to be the optimum concentration because higher concentrations resulted in leaf yellowing and damage, and induced (osmotic) wilting and early flower senescence.

Effect of TDZ

Corolla abscission was significantly reduced after inclusion of TDZ in the vase solution (Table 2). More flower buds opened during vase life than in the control. However, unlike sucrose, TDZ failed to maintain the original petal colour. This was true for flowers that were already open prior to TDZ treatment, and for the buds that opened following TDZ treatment. Newly opened flower buds were either light blue or almost

white. TDZ treatment resulted in newly opened flowers with long corolla tubes and it also resulted in considerable increase in flower size, compared with the untreated control.

Effect of CEPA

Various concentrations of CEPA (10-100 μM) were included in the vase solution. Increasing concentrations of CEPA strongly accelerated corolla abscission and greatly reduced vase life. In some treatments with high doses of CEPA most of the corollas (of flowers that were open prior to treatment) abscised within 96 hours of treatment. CEPA also drastically inhibited opening of new flower buds and greatly reduced flower size. The few flowers that opened in the presence of CEPA were very small and almost white. In comparison to the control, treatments with CEPA also slightly hastened leaf yellowing.

Effect of TDZ and CEPA in Combination

When TDZ and CEPA were used in combination, TDZ partially reversed the effect of CEPA on corolla abscission. This was true especially for relatively low concentrations of CEPA (<50 μM). TDZ also tended to counteract the effect of CEPA on leaf yellowing during the later phase of vase life.

Effect of Sucrose and CEPA in Combination

In the presence of low concentrations of CEPA, sucrose almost completely suppressed the effect of CEPA. Sucrose not only reduced CEPA-induced corolla abscission, but also counteracted the effect of CEPA on opening of new flower buds. The newly opened flowers, as well as the flowers that were already open, exhibited the characteristic petal colours as observed in a treatment of sucrose alone. The results indicate that sucrose effectively counteracted the effects of CEPA.

DISCUSSION

A unique feature of flower abscission in phlox is that the abscission is limited to the shedding of turgid sympetalous corolla with epipetalous stamen (Sankhla et al., 2003.). Other parts of the flower, such as calyx and gynoecium, are not shed. Apparently, the active abscission zone is located at the base of the funnel-shaped corolla. Also, flowers of many species do not abscise a turgid corolla, but instead wilt before dropping desiccated petals (van Doorn and Stead, 1997). Flowers in those families in which most species showed petal abscission, rather than petal wilting, also usually had a high ethylene sensitivity (Woltering and van Doorn, 1988). In a number of phlox cultivars, Woltering and van Doorn (1988) indeed noted high ethylene sensitivity of corolla abscission. This was corroborated in phlox cv. Rembrandt flowers (Porat et al., 1995). Our results similarly indicate high sensitivity of phlox 'John Fanick' to CEPA (ethylene) supplied via cut stem.

Abscission is induced by many factors, such as hormone levels and sensitivity to hormones (Taylor and Whitelaw, 2001; Brown, 1997; Sexton, 1997, Taylor and Whitelaw, 2001). Although in some species abscission may be initiated in response to GA, ABA and cytokinins (Aneja et al., 1999; Patterson, 2001), it is predominantly thought to be driven by ethylene, and auxin appears to fine tune the process (Sexton, 1997; van Doorn and Stead, 1997).

We observed that TDZ considerably delayed corolla abscission and leaf yellowing in phlox 'John Fanick'. TDZ also reduced corolla abscission caused by CEPA. Previously, Porat et al. (1995) also observed that both STS and 1-MCP, inhibitors of ethylene action, completely inhibited ethylene-induced flower abscission in phlox cv. Rembrandt. It is therefore likely that, as previously reported for the purine-type cytokinins (Cook et al., 1985; Zakarias and Reid, 1990), TDZ, a non-purine cytokinin, is able to reduce ethylene sensitivity.

The exact mode of action of TDZ is not known. It has been suggested that TDZ modifies the metabolism of endogenous cytokinins, thereby mimicking an auxin response, and/or modulating the effects of other endogenous hormones such as ethylene

and ABA (Murthy et al., 1998; Mok et al., 2000). The high activity of TDZ, relative to purine cytokinins, has been attributed to its extreme stability both in a free and conjugated form within the plant tissues (Mok et al., 2000; Murch and Saxena, 2001).

Although TDZ exhibits the unique property of mimicking both auxins and cytokinins, it is structurally quite different from both.

Petal colour of open flowers changed considerably during vase life and newly opened flowers were only light blue or almost colourless. In the presence of sucrose in the vase solution, the flowers retained their original colour. Even the newly opened flowers exhibited good colour, in contrast to those opening in the controls, or in the treatments with TDZ or CEPA. Sugars are known to prevent the anthocyanin content and to prevent early petal bluing, in several cut flowers (Ichimura and Hiraya, 1999; Han, 2003), partially by promoting the expression of anthocyanin biosynthesis genes (Hara et al., 2003). Additionally, supply of sugars is crucial for the anthocyanin glycosylation.

Petal colour is a result of a complex interaction among anthocyanins, co-pigments, pH of the vacuole, concentrations of metals, that are co-factors, and the shape of the petal cells (Mol et al., 1998; Oren-Shamir et al., 2001). Each of these factors may cause a shift in the absorption spectra of anthocyanins leading to a change in the reflective color of the flowers from reddish or pink to blue (Brouillard, 1988). In rose flowers the change in vacuolar pH was the main cause of petal bluing during vase life. Sucrose delayed bluing by maintaining the pH (Oren-Shamir et al., 2001).

In phlox 'John Fanick', addition of sucrose to the vase water promoted flower bud opening, reduced flower abscission, and delayed flower senescence. Sucrose also counteracted the effects of CEPA and ACC (unpublished results). The reversal of ethylene-induced effects by sucrose in 'John Fanick' may partially relate to the effect of sucrose on ethylene production and/or sensitivity (Mayak and Dilley, 1976; Ichimura and Hiraya, 1999).

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Tables

Table 1. Effect of sucrose on vase life parameters of *Phlox* 'John Fanick'.

Treatment (µM)	Percent after 7 days			Petal color	Vase life (days)
	FA*	FS*	BO*		
Control	55 ± 4**	8 ± 1	25 ± 2	Light blue	7 ± 1
30	30 ± 2	10 ± 2	70 ± 3	Pink white	9 ± 1
60	20 ± 1	10 ± 2	85 ± 5	Deep pink white	16 ± 2
120	15 ± 2	12 ± 2	92 ± 4	Deep pink white	14 ± 2
240	25 ± 4	30 ± 3	94 ± 3	Deep pink white	12 ± 1

*FA= Flower abscission; FS= Flower senescence; BO= flower bud opening

** Standard Error

Table 2. Effect of CEPA, TDZ and sucrose on vase life parameters of *Phlox* 'John Fanick'.

Treatment (µM)	Percent after 7 days			Petal color	Vase life (days)
	FA*	FS*	BO*		
Control	55 ± 4**	8 ± 1	25 ± 2	Light blue	7 ± 1
CEPA 50	85 ± 5	20 ± 2	14 ± 2	Light blue/white	4 ± 1
TDZ 45	20 ± 2	0	55 ± 3	Light blue/white	10 ± 1
Sucrose 120	15 ± 2	5 ± 1	92 ± 4	Deep pink white	14 ± 2
CEPA+TDZ	40 ± 3	10 ± 1	30 ± 4	Light blue/white	6 ± 1
CEPA+Sucrose	25 ± 2	12 ± 2	90 ± 5	Pink white	12 ± 2

*FA= Flower abscission; FS= Flower senescence; BO= Flower bud opening

** Standard Error

