Genetically Enhanced Postproduction Quality in Regal Pelargonium

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Abstract

Ethylene-induced petal abscission is a significant problem during commercial shipping and handling of Regal pelargonium (*Pelargonium* × *domesticum*). A genotype of Regal pelargonium was found which has exceptional production and postharvest characteristics. Individual floret longevity in this plant is about twice that of current commercial genotypes. Two progeny also displayed superior floral longevity. Although the three genotypes still respond to exogenous ethylene, they have significantly reduced rates of ethylene production and reduced ethylene responsiveness in comparison with the other genotypes evaluated. The newly bred genotypes exhibited dramatically prolonged whole plant longevity, and displayed more than twice the number of florets, compared with other evaluated genotypes. Floret longevity was strongly correlated with ethylene sensitivity (r^2=0.93), but not with ethylene production. Therefore, reduced ethylene responsiveness is the most important determinant of enhanced postproduction performance in these superior genotypes.

INTRODUCTION

Floral longevity of many species is often terminated by ethylene induced flower senescence or abscission (Abeles et al., 1992). Petal abscission results from a combination of ethylene synthesis by flower parts (Deneke et al., 1990) and the increase of ethylene responsiveness of tissue as florets age (Evensen, 1991). Geraniaceae is particularly sensitive to ethylene, and species within this family were consistent in showing immediate petal abscission in response to applied ethylene (Woltering and van Doorn, 1988; van Doorn, 2001). Continuous exposure to 1.5 $\mu l \cdot l^{-1}$ ethylene caused complete abscission of petals in ivy geranium within 2 hours (Cameron and Reid, 2001).

Regal pelargonium (*Pelargonium* × *domesticum*) is a flowering potted plant with good aesthetic quality. However, postproduction quality of Regal pelargonium is greatly reduced by rapid petal abscission within 1 to 2.5 hours in response to as little as 1 $\mu l \cdot l^{-1}$ ethylene (Deneke, et al., 1990; Olson and Evensen, 1990), which can easily occur during shipping and handling. Petal abscission not only reduces the quality of product, but also increases the incidence of botrytis and other saprophytic pathogens when abscised petals fall on the leaves (Cameron and Reid, 2001). Therefore, a reduction in ethylene responsiveness and ethylene production could dramatically improve postproduction quality of flowers sensitive to ethylene.

In the breeding program at the Pennsylvania State University, a genotype of Regal pelargonium (99-128-1) has been selected for exceptional production and postharvest characteristics. Further, two progeny from 99-128-1 also had enhanced postproduction quality compared to current commercial genotypes.

The objectives of this study were to compare longevity and postproduction quality of Penn State (PSU) seedlings with extended floret longevity with commercial genotypes. In order to investigate the mechanism of delayed petal abscission in PSU breeding lines, we tested ethylene synthesis and ethylene responsiveness associated with increased floral age in comparison with other genotypes.

MATERIALS AND METHODS

Rooted cuttings from culture virus-indexed propagative stock of current

commercial Regal pelargoniums were obtained from Oglevee (Oglevee Ltd., Connellsville, PA). Cuttings of PSU bred lines, 99-128-1, 00-43-1 and 00-43-2, were taken from stock plants maintained in the Penn State horticulture greenhouses and rooted for 4 weeks in a greenhouse equipped with bottom heat and intermittent mist. Rooted cuttings were placed under natural light supplemented with 110 ± 10 µmol m^{-2} s^{-1} from high intensity discharge metal halide lamps (Sylvania GTE, Manchester, NH, USA) for 4 weeks to stimulate flower initiation. Maximum midday irradiance reached 1400 µmol m^{-2} s^{-1} on clear days and 500 µmol m^{-2} s^{-1} on heavily cloudy days. Photoperiod during the growth period was 18 h with 21/16°C day/night temperatures. The plants were potted in 15 cm azalea pots with Aggregate Plus Media – Sunshine Mix-4 (SUN GRO Horticulture, Bellevue, Washington) and placed under the same light scheme as described above. The plants were alternately fertilized at each irrigation with Peters Professional Foliar Feed, 27-15-12, and Miracle-Gro Professional Excel, 15-5-15 CAL-MAG (Scotts-Sierra, Marysville, Ohio).

Dates of anthesis and senescence (defined as 50% or greater abscised petals when touched gently) were recorded for individual florets. Flower longevity, defined as the number of days between anthesis and senescence, was measured on intact plants in the greenhouse with more than 30 replicates per genotype.

For ethylene production measurements, individual florets were kept in a 5 ml vial for an hour. Ethylene was sampled with 1 cm^3 syringes from the head space of the sealed container and the concentration was determined by Hewlett-Packard gas chromatograph equipped with activated alumina column and a flame ionization detector. Ethylene production (nl/g FW/h) was calculated on the basis of fresh weight of the floret. Sample fresh weight was measured before the ethylene measurement.

For ethylene treatments, florets of known ages were harvested and placed in a plastic rack installed inside a 3.9 L plastic container containing 0.9 L of distilled water, arranged so that the pedicels were in water. Ethylene was added to the chamber and it was kept at room temperature for 90 minutes. The chamber was opened and the flowers held for an additional 60 min until evaluation of abscission. Abscission rate was calculated based on the proportion of total petals shed when the florets were shaken lightly.

To evaluate duration of whole plant longevity, plants with various floret ages were moved to a simulated consumer environment (SCE). The environment of SCE was maintained at 22.5 ± 0.1 °C, 50% RH with light from fluorescent lamps at 40 ± 0.5 µmol m^{-2} s^{-1} for 12 h daily. The duration of the floral display was defined as the number of days from the placement in SCE until five or fewer healthy florets remained on the plant. Four plants of each genotype were evaluated for floret longevity and duration of floral display. Statistical analyses were performed by ANOVA at $P<0.05$ with StatView (SAS Institute).

RESULTS

The Penn State genotypes 99-128-1 and 00-43-2 displayed about twice the average floral longevity, compared with several commercial genotypes (Fig. 1). The floral longevity of 00-43-1 was about 1.5 times higher than that of most other genotypes. ‘Maiden Lilac’ showed shortest floral longevity among the evaluated genotypes.

When the florets of various ages were exposed to 0.015 µl l^{-1} ethylene for 90 minutes, large variation in petal abscission was observed among the genotypes (Table 1). All genotypes except 99-128-1 and 00-43-2 responded to ethylene as low as 0.015 µl l^{-1} with a high rate of petal abscission. 00-42-1 showed intermediate response to the exogenous ethylene and even 6-day-old florets did not abscise all petals. 99-128-1 and 00-43-2, however, were not responsive to 0.015 µl l^{-1} ethylene. 99-128-1 was significantly less sensitive to ethylene than any other genotype evaluated and even with 1 µl l^{-1} ethylene exposure for 90 minutes, petal abscission remained less than 50% (Fig. 2). In contrast, substantial abscission occurred even in freshly opened florets of ‘Ballet’ exposed to 0.015 µl l^{-1} ethylene. Abscission rate following ethylene treatment increased with floret age. We defined ethylene sensitivity as abscission rate of 3-day-old florets in response to 0.015 µl l^{-1} for 90 minutes. The results showed that individual floret longevity

was strongly correlated to ethylene sensitivity (Fig. 3).

Ethylene production rates of Regal pelargonium florets were quite low, ranging from 0.2 to 1.1 nl/g FW/h (Table 2). The ethylene production rate varied with stage of development and genotype. Generally, freshly opened florets produced a higher rate of ethylene compared to florets at stage 2. Freshly opened florets of 99-128-1 and 00-43-2 displayed relatively low ethylene production rates compared to other genotypes, while 00-43-1 produced significantly higher ethylene along with 'Maiden Orange', 'Maiden Rose Pink' and 'Maiden Lilac' (Table 2). There was no correlation between ethylene production rates and ethylene sensitivity (data not shown).

The PSU breeding lines developed and maintained a large number of florets in a simulated consumer environment (Fig. 3). In particular, the genotype 99-128-1 retained more than 80 florets even at 3 weeks in a simulated consumer environment.

Whole plant longevity, defined as the number of days from placement in the simulated consumer environment until fewer than 5 healthy flowers remained, was significantly better for 99-128-1, 00-43-1 and 00-43-2 compared to other genotypes (Fig. 4). Whole plant longevity of the PSU breeding lines was 3-4 weeks, while that of the commercial genotypes was only 1-2 weeks (Fig. 5).

DISCUSSION

Postproduction quality of Regal pelargoniums varies significantly among genotypes. Exceptional postharvest characteristics including dramatically prolonged whole plant longevity and increased floret number have been demonstrated in PSU genotypes compared to commercial genotypes.

Regal pelargonium is classified one of the ornamental species most responsive to ethylene (Woltering, 1987; Deneke et al., 1990). In our experiments, commercial genotypes showed significant petal abscission in response to treatment with exogenous ethylene at concentrations as low as 0.015 $\mu l \cdot l^{-1}$ and ethylene-treated 'Ballet' florets abscised petals even on the day of anthesis. This concentration is extremely low compared to what has been tested in other experiments (Woltering, 1987; Woltering and van Doorn, 1988; Evensen, 1991; Cameron and Reid, 2001; van Doorn, 2001) and demonstrates the reason for the poor shipping performance of most genotypes of Regal pelargonium. Commercial genotypes may show petal abscission due to very small amounts of ethylene resulting from stresses imposed during shipping or handling, or exogenous sources.

The differences among genotypes in ethylene responsiveness can explain much of the genetic variation in postproduction quality in Regal pelargoniums. 99-128-1 and its progeny 00-43-2 displayed remarkably long floret life, which was strongly associated with reduced ethylene sensitivity (Fig. 3). Since there was no correlation between ethylene production and floret longevity at stage 2, when abscission actually begins, we concluded that ethylene production is not a determining factor in floral longevity of Regal pelargoniums.

Variation in whole plant longevity was observed among the evaluated genotypes, and the longevity was highest in the PSU breeding lines (Fig. 5). The increase in whole plant longevity results from the greater individual floret longevity in those genotypes (Fig. 1) and the fact that the PSU lines produce more florets than the other genotypes (Fig. 4). Both of these variables were closely correlated with whole plant longevity (data not shown). It is not known whether reduced ethylene sensitivity and enhanced floret production are genetically linked.

Our results show that there is large variation in ethylene responsiveness among genotypes of Regal pelargonium, and that the enhanced postharvest performance of PSU breeding lines is derived from reduced ethylene responsiveness. Therefore, selection based on reduced ethylene responsiveness can be used in a breeding program for improved postproduction quality.

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Tables

Table 1. Effects of genotype and floret age on ethylene-induced petal abscission. Each point represents the percent abscission of at least 6 florets.

Floret age (days)	99-128-1	00-43-2	00-43-1	Maiden Lilac	Maiden Orange	Baroness	Ballet
0	0%	0%	0%	0%	0%	0%	47%
1	0%	0%	0%	0%	30%	53%	100%
2	0%	0%	0%	83%	38%	100%	100%
3	0%	0%	20%	87%	48%	100%	100%
4	0%	0%	27%	90%	54%	100%	100%
5	0%	0%	40%	93%	100%	100%	100%
6	0%	0%	60%	100%	100%	100%	100%

Table 2. Ethylene production rate by florets at different stages of development. Stage 0 and 2 are flowers harvested at the day of anthesis and after stigmatic lobes begin separating, respectively. Each point is the average ethylene production rate (nl/g FW/h) of at least six replicates ± SE.

Cultivars	Ethylene production rate (nl/g FW/h)	
	Stage 0	Stage 2
99-128-1	0.454 ± 0.056	0.260 ± 0.021
00-43-1	0.826 ± 0.073	0.315 ± 0.024
00-43-2	0.509 ± 0.082	0.268 ± 0.039
Maiden Orange	1.096 ± 0.084	0.395 ± 0.072
Maiden Rose Pink	0.706 ± 0.074	0.232 ± 0.050
Maiden Lilac	0.903 ± 0.064	0.331 ± 0.065
Baroness	0.354 ± 0.035	0.304 ± 0.060
Dandy	0.499 ± 0.043	0.256 ± 0.041

Figures

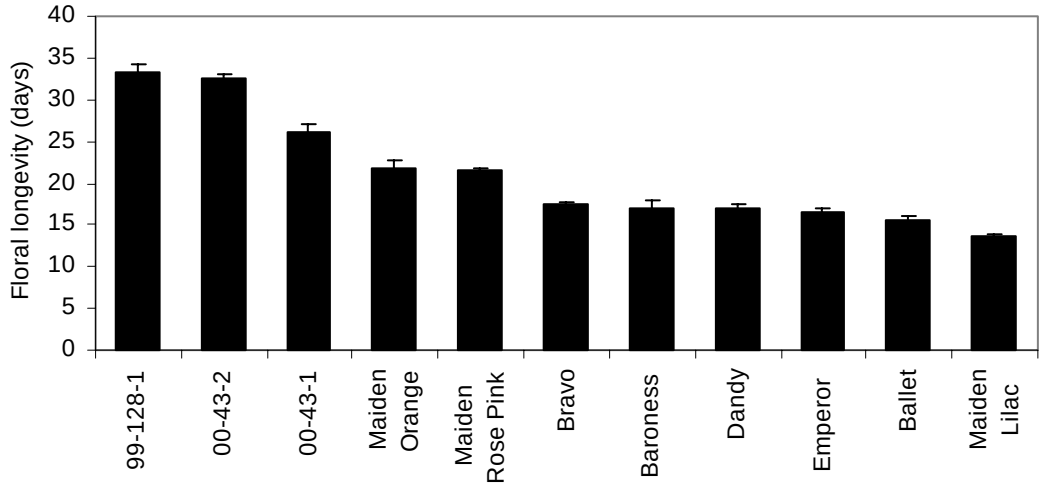

Fig. 1. Floral longevity of 11 genotypes evaluated. Data refer to intact plants in the greenhouse. Data shown are means of at least 30 florets, ± SE.

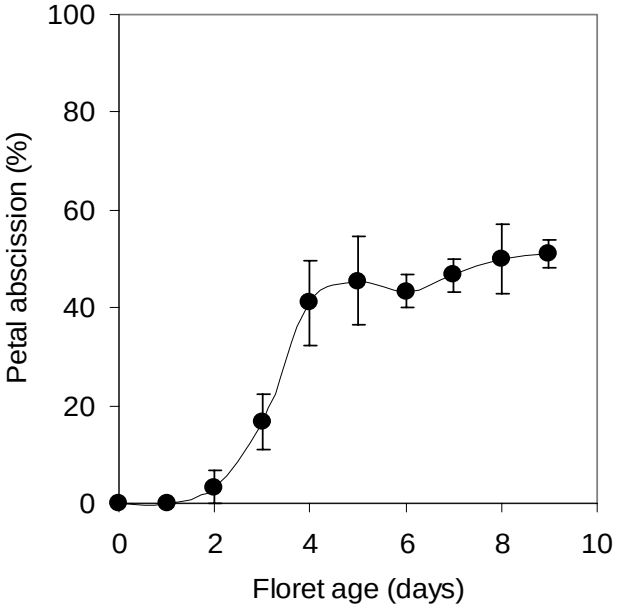

Fig. 2. Effects of floret age on ethylene-induced petal abscission of 99-128-1. Excised florets were exposed to 1 $\mu l \cdot l^{-1}$ ethylene treatment for 90 minutes at 22.5 °C, and petal abscission was measured at 1 hour later. Each point represents the mean abscission rate of at least 18 florets ± SE. More than 6 florets were used in a single experiment and the experiment was repeated three times.

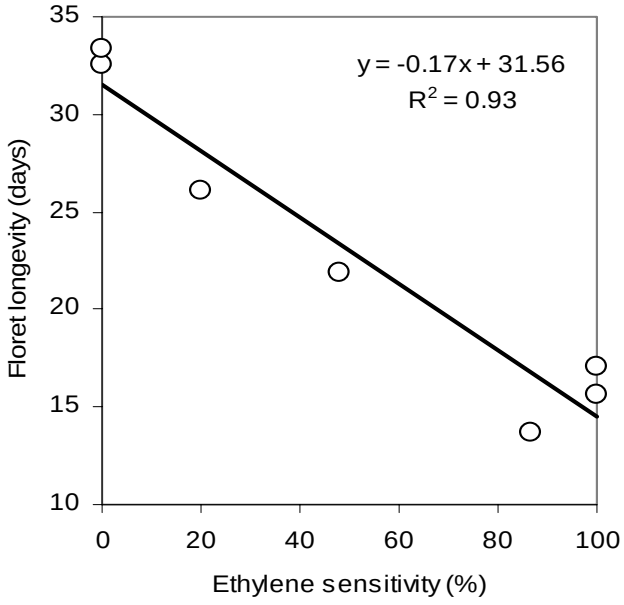

Fig. 3. Relationship between ethylene sensitivity and floret longevity. Ethylene sensitivity was defined as the abscission rate of 3-day-old florets in response to 0.015 $\mu l\ l^{-1}$ for 90 minutes.

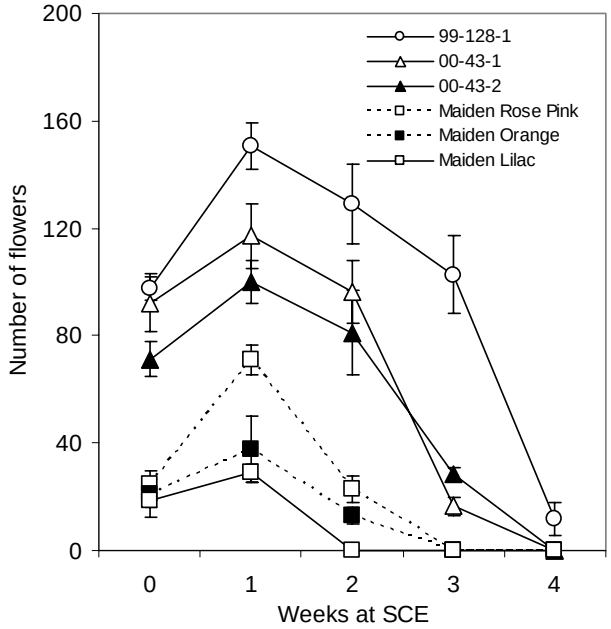

Fig. 4. Changes in flower number produced by each genotype during 4 weeks in a simulated consumer environment. Values shown are average number of flowers of at least 4 plants ± SE.

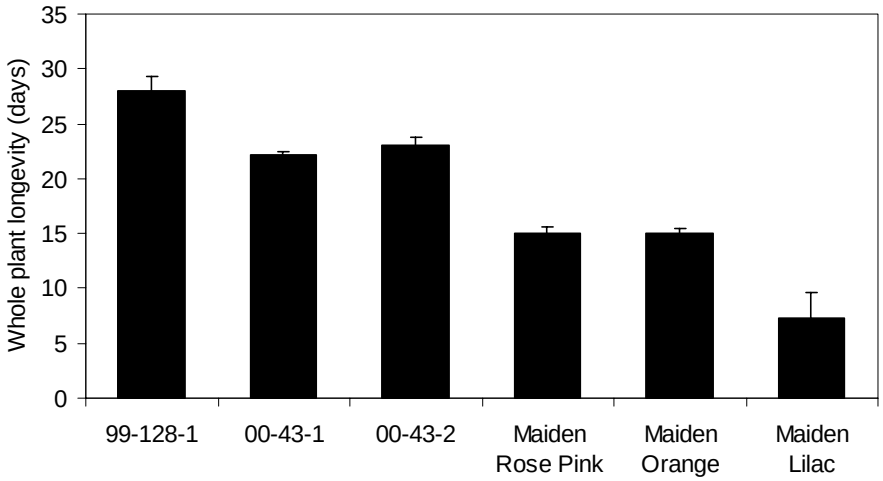

Fig. 5. Whole plant longevity of six genotypes in a simulated consumer environment. Values shown are the average plant longevity of at least 4 plants ± SE.