Progress Report

PRODUCTION AND POSTHARVEST PROTOCOLS FOR CUT PENSTEMON AND EUCOMIS

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Introduction

As the demand for locally grown food crops has increased, so has the demand for locally grown specialty cut flowers. New cut flower introductions are a necessity to maintain and increase consumer interest. Expanding the availability and knowledge about new cut flowers allows growers to pick species and cultivars ideally suited for their climates and consumer base. Many garden ornamental species and exotic, bulbous genera and cultivars are underutilized by the floral industry. Two examples include pineapple lily (*Eucomis sp.* L' Hérit.) and annual penstemon (*Penstemon grandiflorus* Nutt.). *Eucomis* has about fifteen species (Bryan and Griffiths, 1995), each with unique pineapple-like inflorescences with the potential to last for more than a month in vase (Regan, 2008). Annual penstemon has the largest flowers and the greatest color range (31 different distinct color shades) of all *Penstemon* species (Way et al., 1998). However, growers are hesitant to produce them commercially due to a lack of production and postharvest information. The objectives of this study were to develop production and postharvest procedures for *Eucomis* 'Coral,' 'Cream,' 'Lavender,' 'Sparkling Burgundy' and *Penstemon grandiflorus* 'Esprit' mix.


'Lavender' *Eucomis* in greenhouse

PRODUCTION

While both *Eucomis* and *Penstemon* are regularly grown for the perennial and annual bedding plant industry, little production information is available. The optimum production temperatures and planting densities for cut flower production need to be determined. In addition, the minimum age at which a young *Penstemon* plant can be transplanted successfully is essential to obtain quality plants and reduce production costs (Cavins et al., 2001; van Iersel, 1997). While it may be more economical to leave plants in plug trays for as long as possible to allow a greater number of crops to be harvested in a season, prolonged duration in the plug flats can stunt plant growth and reduce quality. Plants may have fewer, shorter and/ or thinner stems that do not produce quality flowers due to excessive root restriction (van Iersel, 1997).

POSTHARVEST

Postharvest information is needed to allow *Eucomis* and *Penstemon* to be properly handled after harvest. Initial work with *Eucomis* 'Sparking Burgundy' showed that cut stems could last for more than a month in vase (Regan, 2008). However, we need to examine ethylene sensitivity, anti-ethylene agents, optimum cold storage duration, pretreatments and pulses, vase solutions and substrates, and commercial preservatives.

Ethylene and anti-ethylene agents. Selected species of *Penstemon* are sensitive to ethylene, including *P. digitalis* (Redman et al., 2002). The application of exogenous ethylene (0.2 or 1.0 $\mu l \cdot l^{-1}$) to *P. digitalis* decreased its vase life, but treatment with STS (silver thiosulfate), an anti-ethylene agent, had no effect (Redman et al., 2002). Serek et al. (1995) found that the longevity of *P. hartwegii* x *P. cobaea* 'Firebird' increased by approximately 3 days when pretreated with 1-MCP (1-methylcyclopropane). Staby et al. (1993) also used *P*. 'Firebird' and found that STS greatly reduced or completely inhibited flower abscission, whereas an anti-ethlyene solution containing AVG (aminoethoxyvinyl glycine) analog only provided some abscission protection when ethylene levels were less than 0.005 ppm. These studies indicate that STS and 1-MCP have unique effects on each species of *Penstemon*. 1-methylcyclopropane (1-MCP) may be a better alternative to STS considering the growing concern for heavy metal contamination in the environment. Many growers are restricted by state regulations from using STS, so a more eco-friendly way to block the deleterious effects of exogenous and endogenous ethylene is needed for sensitive crops to be successful in the floral market.

Storage. Cooling retards the utilization of carbohydrates during respiration, which extends postharvest life and delays development in most species (Sacalis, 1993). Cold storage lengthens the season of availability by allowing production surpluses to be stored for later use (Hunter, 2000). Cold storage of *P. digitalis* 'Husker Red' at 4°C for 1 to 7 days reduced vase life slightly by less than two days, but the vase life increased from 11.7 to 14 days after 14 days in cold storage (Lindgren et al. 1988). This suggests that *Penstemon* may be tolerant to cold storage. Another study on *P. digitalis* found that there was no significant difference in stems stored at 2°C for 2 weeks when compared to the control (Redman et al., 2002).

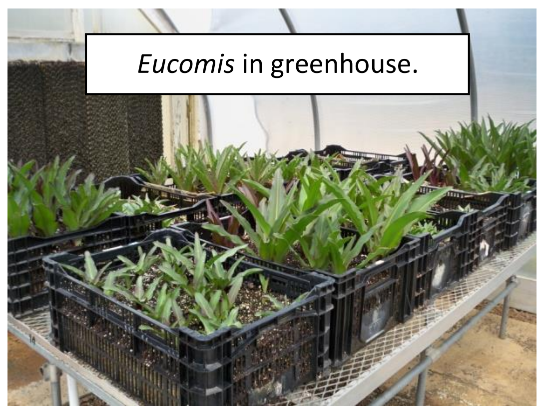
Crates of *Penstemon*

Pretreatments. Pretreatments are used prior to floral preservatives that aim to extend vase life (Hunter, 2000). However, *P. digitalis* pretreated for 24 h with an 8% sucrose concentration significantly reduced its vase life (Redman et al., 2002).

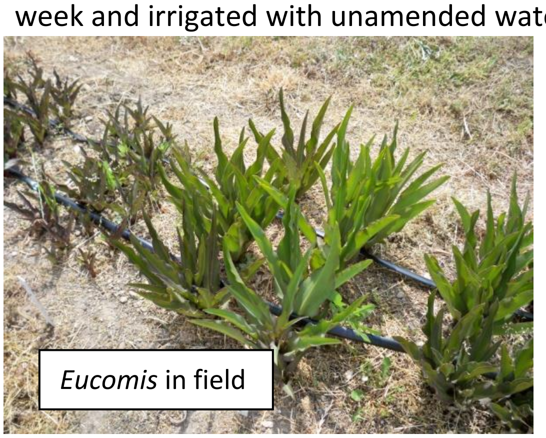
Commercial preservatives and substrates. In general, commercial preservatives extend the vase life of many species, but may have no effect on others. Ten species of *Penstemon* including, *P. digitalis, P. grandiflorus,* and *P. buckleyi* respond positively to the addition of Floralife (specific product unspecified) to their vase water, sometimes even doubling their vase life (Lindgren, 1986). *Eucomis* 'Sparkling Burgundy' was found to have the greatest vase life of 43 days in tap water and the use of preservative solutions significantly reduced vase life (Regan, 2008). The ability for new cuts to perform well in floral foam is also important, especially to florists. Different brands of floral foams can have differing effects on cut flower longevity (Sacalis, 1993). Floral foam has been shown to be beneficial for some species due to its acidifying properties (Regan, 2008).

Materials and methods

Production. *P. grandiflorus* 'Esprit Mix' seeds were directly sown into 105 plug flats using a commercial peat-based root substrate (Fafard 4P Mix, Agawam, MA) and germinated at 21°C. Plants were fertigated with 250 mg·L^{-1} N from a premixed commercial 20N-10P-20K fertilizer (Peter's, Allentown, PA) during the week and irrigated with clear water on the weekends. *Penstemon* seedlings were transplanted into lily crates (55.9 x 36.6 x 22.9 cm) at the appearance of 2-3, 5-6, or 8-9 pairs of true leaves. Fifteen plugs were planted per crate at 10 x 10 cm spacing. After transplanting, crates were placed at 10 or 20°F night temperatures. Day temperatures were 3-9°F higher than night temperatures. There were ten crates per treatment, randomized within each temperature treatment. Average daily temperature and light level were recorded for the duration of the experiment.


Eucomis in greenhouse.

Bulbs of 'Coral,' 'Cream,' and 'Lavender' *Eucomis* were received from a commercial supplier and held overnight. Plants were grown in either; a double layered polyethylene plastic-covered greenhouse or in an open field. In the greenhouse, bulbs were planted with bulb tips just showing at media surface in lily crates using a commercial peat-lite root substrate (Fafard 4P Mix, Agawam, MA) and grown at 20°C night temperatures. Plants were fertigated with 250 mg·L^{-1} N from a premixed commercial 20N-10P-20K fertilizer (Peter's, Allentown, PA) during the week and irrigated with unamended water on the weekends. Bulbs were planted with bulb tips just showing at the soil line into a field bed with loamy clay soil. Bulbs in each production environment were planted at six bulbs per crate (12.7 x 17.8 cm spacing) or twelve bulbs per crate (10.2 x 10.2 cm spacing). The equivalent spacing was replicated in the field. Ten replications (crates/ field plots) were included per treatment. Stem length and caliper**,** number of stems per replication (crate/ field plot)**,** number of marketable stems per replication**,** and harvest date were recorded. Stems were


Eucomis in field

deemed marketable if they were greater than 30 cm in length and had typical inflorescence morphology (multiple leaf-like bracts on top of inflorescence with ovate buds and star-shaped flowers along a smooth stem).

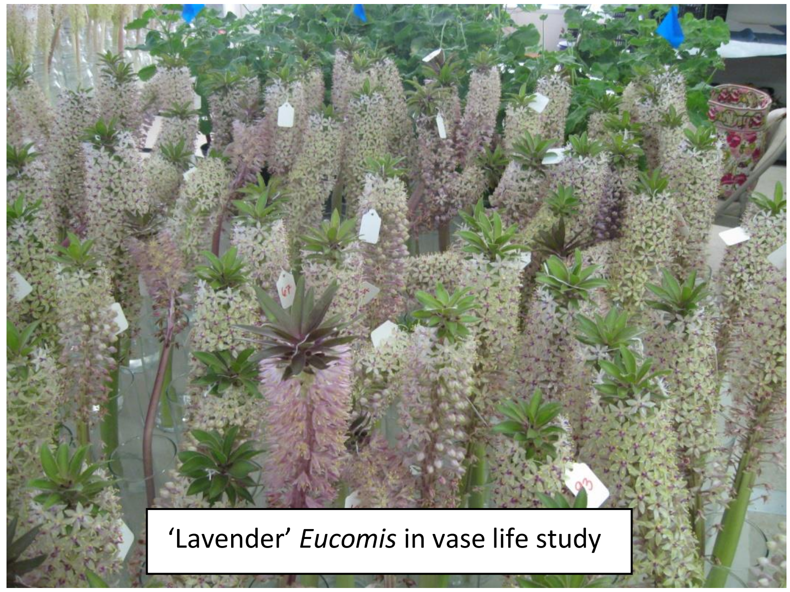
Postharvest handling. Flower stems were harvested when at least a quarter of the florets were open, placed in tap water, recut after hydration and placed in the appropriate treatments. Stem length and caliper, number of flowering plants per replication, number of marketable stems, and anthesis date were recorded. Unless otherwise indicated, the floral solution used in all experiments was 22°C DI water. After treatment, stems were placed at 21°C under 20 $mol·m^{-2}·s^{-1}$ light for 12 $h·d^{-1}$ at 40% to 60% relative humidity. Vase life after removal from treatment was measured. A *Penstemon* stem was considered ready to terminate when 50% of the florets had either wilted or abscised. A *Eucomis* stem was considered ready to terminate when 50% of the florets had either wilted or browned or when the stem bent at greater than a 90° angle. A completely randomized design was used with 5 to 15 stems per treatment; treatments arranged in a factorial where appropriate. Analysis of variance (SAS Institute, Cary. NC) was performed and means separated by LSD.

Ethylene sensitivity. Cut stems were pretreated for 4 h with STS [1 mL AVB (Pokon & Chrysal, Miami, FL) per L DI water], 1-MCP [400 mg Ethylbloc (Floralife, Walterboro, SC) dissolved in 50 ml DI water at 30 °C for a final concentration of 700 $µL·L^{-1}$], or DI water (control), then placed in DI water and subjected to 0, 0.1 or 1.0 $µL·L^{-1}$ethylene for 16 h. Stems were then recut and placed into DI water until termination.

Cold storage duration. Cut stems were held in tap water for 2 h then held for 0, 1, 2, or 3 weeks at 2°C either dry packed in floral boxes lined with newspaper or wet in buckets of DI water. The 0 week storage stems were placed directly into floral vases filled with DI water. At weeks 1, 2, and 3, 7 stems from each of the wet and dry treatments were randomly selected and placed in floral vases filled with DI water until termination.

Sucrose pulses. Stems received a 24 hr pulse of 0%, 10%, or 20% sucrose in DI water plus 7 $mg·L^{-1}$ Kathon CG (Rohm & Haas, Philadelphia, PA). After the pulse, stems were recut and placed into DI water until termination.

Vase solutions and substrates. Cut stems were placed in vases with or without floral foam and 0%, 2%, or 4% sucrose in floral solution also containing 0 or 7 mg·L^{-1} Kathon CG until termination.


'Lavender' *Eucomis* in vase life study

Commercial preservatives. Cut stems were pretreated for 4 h with one of three solutions: two commercial hydrating solutions [Chrysal Professional Hydrating Solution (Pokon & Chrysal, Miami, FL) or Floralife Hydraflor 100 (Floralife, Walterboro, SC)] or DI water and placed for 2 d in one of three holding solutions: two commercial holding solutions [Chrysal Professional 2 Holding Solution (Pokon & Chrysal, Miami, FL) or Floralife Professional (Floralife, Walterboro, SC)] or DI water. After the pretreatment stems were recut and put into DI water until termination.

Basic solutions (stage 1). Cut stems were placed into Floralife Hydraflor 100 (Floralife, Walterboro, SC) or DI water for four hours. The stems were then placed in either Floralife Professional (Floralife, Walterboro, SC), or DI water for two days and then placed into vases of DI water and vase life evaluated.


Penstemon in vase life study

Bulb-specific preservative. Stems were held for 2 d in either, Floralife Bulb Food, Floralife Professional, or DI water then placed into jars of DI water until termination.

Control solutions. Cut stems were placed in one of five solutions: tap water, DI water, DI water plus 7 mg·L^{-1} Kathon CG, DI water amended with citric acid to a pH of 3.5, or DI water plus 7 mg·L^{-1} Kathon CG amended with citric acid to a pH of 3.5 until termination.

<u>Results and discussion</u>

Penstemon. While it may be more economical to leave plants in plug trays for as long as possible to allow a greater number of crops to be harvested in a season, prolonged duration in the plug flats can stunt plant growth and reduce quality. Plants may have fewer, shorter and/ or thinner stems that do not produce quality flowers due to excessive root restriction (van Iersel, 1997). However, in the case of *P. grandiflorus* 'Esprit,' plugs transplanted with 8-9 sets of true leaves had longer stems (Table 1, 3). This is most likely due to competition for light while in the plug trays. Holding the plugs in the trays until 8-9 sets of true leaves form appears to have no negative effect on stem quality, in fact, plants flowered more quickly (Table 3).

Warmer (20°C) production temperature significantly decreased time to flower, but stems obtained from the 20°C treatment were thinner compared to stems from the 10°C treatment (Table 2). Additionally, in the 20°C treatment there was high plant mortality due to damage from thrips, spider mites, and root rot (personal observation). By June 18, 2009, 28% of the crates were culled due to insects and disease in the 20°C treatment, whereas no crates were culled from the 10°C treatment (data not presented). The warmer production temperature yielded 1 stem per crate, where as the cooler temperature yielded 8 stems per crate (data not presented). Thus, production was significantly reduced in the 20°C treatment. An increase in production temperature is detrimental to the survival of the plants due to increased insect and disease pressure.

Penstemon in greenhouse

The seed used was a mix of various colors and bicolors and the flowering time of each color varied. The raspberry, red, purple, and pink flower colors flowered quicker than white (Figure 1).

Sucrose pulses had no effect on vase life of *P. grandiflorus* (Table 5). However, treatments with 2% or 4% sucrose and 7 mg·L^{-1} Kathon CG in the vase solution gave the longest vase life, close to 9 d, of all the tested treatments (Table 6). This suggests that it would benefit to use a holding solution with a low concentration of sucrose rather than a high concentration pulse.

Cut stems could be stored wet or dry at 2°C for no more than one week. There was no difference in vase life between wet and dry stored stems (Table 4). Previous studies, in contrast, with *P. digitalis* show that it can tolerate 2 weeks of storage without a significant effect on vase life (Lindgren et al., 1988; Redman et al., 2002).

The use of a commercial holding solution increased vase life of *P. grandiflorus* 'Esprit' (Table 7), which is consistent with other reports. Ten species of *Penstemon* including, *P. digitalis, P. grandiflorus,* and *P. buckleyi* responded positively to the addition of Floralife (specific product unspecified) to their vase water, sometimes even doubling their vase life (Lindgren, 1986). The hydrator solution alone did not improve vase life. *P. grandiflorus* would be suited for various commercial uses since the use of floral foam does not have a significant effect on vase life. The addition of 7 mg·L^{-1} Kathon CG significantly increased vase life, mostly likely by keeping stem vasculature open and free from bacteria, yeast, and fungi.

The application of exogenous ethylene along with pretreatment with anti-ethylene agents to *P. grandiflorus* had no effect on vase life (data not presented). However, more open floret abscission was observed in treatments exposed to 0.1 or 1 µL·L^{-1} ethylene, but closed buds continued to open (personal observation). Various studies with *P. digitalis* and *P. hartwegii* x *P. cobaea* 'Firebird' showed differing sensitivities to ethylene and anti-ethylene agents (Redman et al., 2002; Serek et al., 1995; Staby et al., 1993).

Eucomis. The 12-bulb per crate density was more efficient for greenhouse space requirements. With the increased planting density more stems per unit area could be obtained. All of the *Eucomis* species in this study could be grown in either the open field or greenhouse and still produce highly marketable stems (Table 8, 9). This allows growers the flexibility to chose which location best suits their needs.

Higher initial production temperatures in the greenhouse allowed the plants to flower earlier than in the field. The extra heating costs may be worth the benefits of season extension. It is beneficial to have cut flowers available early in the season for Easter and Mother's Day sales. Fast growing cultivars like 'Coral' which had the shortest emergence in the 15 day time frame would be ideal to hasten the time to flowering (Table 10). To reduce the time to emergence bulbs should be stored in a cool place (<13°C) in their crates, undisturbed. The faster growth compared to bulbs removed from the substrate is most likely due to the root system remaining intact.

'Lavender' *Eucomis* in field after seed pods have formed.

None of the hybrids reacted positively to preservative treatments (Table 11). Therefore it would not only be best for vase life, but financially, not to use any preservative. The shortest vase life out of all the hybrids and treatments was 15 d for 'Lavender' stems from the greenhouse, but this is still longer than the 7 to 10 d vase life that is considered the minimum for a new cultivar (Table 12). If *Eucomis* stems are combined with other flowers in bouquets or arrangements that benefit from holding solutions, the *Eucomis* stems would probably last as long as the other flowers in the vase even with a minimum vase life of 15 d.

Conclusion

Penstemon. For successful production of *P. grandiflorus* 'Esprit' plants should be grown at temperatures less than 20°C to reduce insect and disease pressure. These low temperature requirements are indicators that *P. grandiflorus* may be suitable for unheated high tunnel production. Transplanting plugs when there are 8-9 sets of true leaves is economical without compromising quality. It may be possible to hold the plugs in the trays for a longer duration to further reduce costs and space requirements.

These postharvest results show that *P. grandiflorus* has acceptable commercial potential if treated properly. To achieve maximum vase life stems should be held in a commercial holding solution or a solution of 2% sucrose for no more than one week at 2°C. The addition of Kathon CG may be necessary to extend vase life. *Penstemon* also has the potential to be shipped dry and used in various retail arrangements with foam without compromising vase life. This data suggests that *P. grandiflorus* has many desirable postharvest characteristics, but its commercial potential may be restricted due to the fact that commercial preservatives or anti-microbial compounds are required to provide a vase life of at least 7 days. Consumers should receive sachets of commercial preservatives with their flowers and encouraged to use them. However, if the flowers are held by the retailer/ grower for at least 2 days in a holding solution, vase life should also be acceptable.


'Lavender' *Eucomis* in greenhouse

Eucomis. *Eucomis* offers growers versatility in production location and planting density. However, the effect of multi-year production at higher planting densities remains to be seen. *Eucomis* possesses an overall long vase life no matter the postharvest treatment, which allows for flexibility when being arranged and stored with other species and cost savings when held alone. More work needs to be done to determine the appropriate storage duration and temperature for optimal flowering.

<u>Still In Progress</u>

Ethylene sensitivity, commercial preservatives, bulb-specific preservatives, vase solutions and substrates, cold storage duration, sucrose pulses, and pretreatments and storage vase life studies for *Eucomis* are all still in progress. The stems have been in the postharvest vases for well over a month now so we can verify that *Eucomis* as a long vase life.

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Table 1: Effect of night temperature, transplant stage, and flower color on production characteristics of cut stems of *Penstemon grandiflorus* 'Esprit' mix. Plugs were transplanted at the appearance of 2-3, 5-6, or 8-9 sets of true leaves and grown at either 10°C or 20°C night temperatures.

Temperature (°C)	Transplant stage	Flower color	Length (cm)	Caliper (mm)	Sowing to harvest (d)	Transplant to harvest (d)
10	2-3	Pink	58.9	3.4	175	120
		Purple	59.1	3.8	165	110
		Raspberry	55.8	3.9	140	83
		Red	56.3	3.8	160	107
		White	59.2	3.6	224	172
	5-6	Pink	62.9	3.7	177	94
		Purple	62.4	3.5	156	75
		Raspberry	63.2	3.5	166	84
		Red	58.7	3.6	150	70
		White	58.3	3.4	178	95
	8-9	Pink	67.5	3.1	185	80
		Purple	68.2	3.5	177	72
		Raspberry	71.5	3.9	172	67
		Red	61.8	3.4	170	65
		White	59.0	2.7	190	85
20	2-3	Pink	54.0	3.6	161	105
		Purple	61.6	3.4	161	103
		Raspberry	-	-	-	-
		Red	60.5	2.7	181	140
		White	58.0	2.2	165	124
	5-6	Pink	50.7	3.4	153	73
		Purple	-	-	-	-
		Raspberry	-	-	-	-

	Red	-	-	-	-
	White	43.0	3.6	153	73
8-9	Pink	60.3	3.5	153	48
	Purple	57.0	2.8	153	48
	Raspberry	60.0	3.1	153	48
	Red	62.0	3.5	153	48
	White	-	-	-	-
Significance					
Temperature (T)		NS	0.0071	0.0403	NS
Transplant stage (S)		<0.0001	NS	NS	<0.0001
Flower color (C)		NS	NS	0.0002	0.0006
Significant interactions (P≤0.05)		none	T*S*C	none	none

NS, Nonsignificant.

Table 2: Effect of temperature on caliper and days to harvest from sowing of *Penstemon grandiflorus* 'Esprit' mix. Plugs were grown at 10 or 20°C night temperatures.

Temperature (°C)	Caliper (mm)	Days to harvest from sowing
10	3.6	172
20	3.3	158
Significance	0.0071	0.0403

Table 3: Effect of transplant stage on length and days to harvest from transplanting of *Penstemon grandiflorus* 'Esprit' mix. Plugs were transplanted when either 2-3, 5-6, or 8-9 sets of true leaves were present.

Transplant stage	Length (cm)	Harvest from transplant (d)
2-3	56.1 a	111 a
5-6	58.9 a	79 b
8-9	63.1 b	67 b
Significance	<0.0001	<0.0001

[a,b] Means followed by the same letter are not significantly different according to the HSD procedure at α = 0.05.

Table 4: Effect of cold storage and duration on vaselife of *Penstemon grandiflorus* 'Esprit' mix. Stems were stored either in tap water or a dry floral box for 1, 2, or 3 weeks prior to being placed in DI water until termination. Means are an average of 7 stems.

Storage condition	Duration (weeks)	Vase life (days)
Unstored	0	5.6
Dry	1	7.9 [NS Z]
	2	1.6 [***]
	3	1.0 [***]
Wet	1	7.4 [NS]
	2	2.4 [***]
	3	3.3 [NS]
Significance		
Storage condition (S)		NS
Duration (D)		0.0001
S*D		NS

[Z] Significant as compared to control treatments (unstored, 0 weeks) which were placed directly into DI water until termination.
[NS, ***] Nonsignificant or significant at P ≤ 0.001, respectively.

Table 5: Effect of sucrose pulses on postharvest characteristics of *Penstemon grandiflorus* 'Esprit' mix. Stems were placed in the sucrose solution for 22 hours prior to being placed in DI water until termination. Means are the average of 7 stems.

Sucrose (%)	Kathon ($mg \cdot L^{-1}$)	Vase life (d)
0	7	7.3 $^{* z}$
10	7	7.7 **
20	7	8.1 **
0	0	4.7
Significance		
Sucrose		NS
Kathon		0.05

^{z} Significant as compared to control treatments (0% sucrose, 0 $mg \cdot L^{-1}$Kathon) which were placed directly into DI water until termination.

$^{NS, *, **}$ Nonsignificant or significant at $P \leq 0.05$, 0.01, respectively.

Table 6: Effect of vase solutions and substrates on vase life of *Penstemon grandiflorus* 'Esprit' mix. Cut stems were placed in vases with or without floral foam and 0%, 2%, or 4% sucrose in floral solution also containing 0 or 7 mg·L^{-1} Kathon CG until termination. Means are the average of 10 stems.

Floral Foam	Sucrose (%)	Kathon (mg·L^{-1})	Vase life (d)
No	0	0	4.5 c
	0	7	6.0 bc
	2	7	8.4 ab $^{**\,z}$
	4	7	9.3 a ***
Yes	0	0	5.0 c
	0	7	6.4 abc
	2	7	8.6 ab ***
	4	7	9.4 a ***
Significance			
Foam (F)			NS
Sucrose (S)			<0.0001
Kathon (K)			0.0440
F*S			NS
F*K			NS

[z] Significant as compared to control treatments (0% sucrose, 0 mg·L^{-1}Kathon, no floral foam) which were placed directly into DI water until termination.

[a,b, c] Means followed by the same letter are not significantly different according to the HSD procedure at α = 0.05.

[NS, **, ***] Nonsignificant or significant at P ≤ 0.01, or 0.001, respectively.

Table 7: Effect of commercial holding solutions on the vase life of *Penstemon grandiflorus* 'Esprit' mix. Stems were held for 4 hrs in a commercial hydrating solution and then held for 2 days in a commercial holding solution before being placed in DI water until termination. Means are the average of 10 stems.

Holding Solution	Vase life (days)
DI water	4.3
Floralife Professional	7.0 ^{***z}
Chrysal Professional 2	5.9 **
Significance	0.0032

^{z} Significant as compared to control treatments which were placed directly into DI water until termination.
**, *** Significant at P ≤ 0.01, or 0.001, respectively.

Table 8. The effect of *Eucomis* hybrid cultivars on stem length, caliper and the number of marketable stems produced per bulb. Means are an average of 40 replications for 'Coral,' 'Cream,' and 'Lavender' and 8 replications for 'Sparkling Burgundy.' Year 1.

Cultivar	Length (cm)	Caliper (mm)	Stems/ bulb (no.)
Coral	53.2 b	12.7 b	1.20 a
Cream	53.4 b	15.4 a	1.01 a
Lavender	40.9 c	10.2 c	0.61 b
Sparkling Burgundy	61.7 a	15.3 a	0.57 b
Significance (P≤0.05)	<0.0001	<0.0001	<0.0001

[a, b, c] Means followed by the same letter are not significantly different according to the LSD procedure at α = 0.05.

Table 9. The effect of production location and planting density on the stem length and caliper of *Eucomis* hybrid, 'Coral' and 'Cream.' Means are an average of 10 replications. Year 1.

		Length (cm)		Caliper (mm)	
Location	Density (bulbs/ crate)	Coral	Cream	Coral	Cream
Field	6	46.5 c	36.7 c	12.13 c	13.79 c
	12	49.8 b	39.2 b	11.81 c	13.05 c
Greenhouse	6	58.8 a	53.8 a	14.02 a	16.48 a
	12	56.9 a	53.2 a	12.99 b	14.81 b
Significance					
Location (L)		<0.0001	<0.0001	<0.0001	<0.0001
Density (D)		NS	NS	<0.0001	<0.0001
L*D		0.0004	0.0213	0.0213	0.0386

[a, b, c] Means followed by the same letter are not significantly different according to the LSD procedure at α = 0.05.

[NS] Nonsignificant at P≤0.05.

Table 10. Effect of temperature and storage treatment on the shoot height and emergence of *Eucomis* ‘Coral,’ ‘Cream,’ ‘Lavender,’ and ‘Sparkling Burgundy.’ Once flower production ceased bulbs were no longer watered and foliage was removed from all bulbs and then stored in one of several treatments. Shoot emergence and height were recorded on 1 and 16 Mar. 2010.

		Storage Treatment			1 Mar.		16 Mar.			
Night temperature (°C)	Cultivar	Removed	Days	Location	Shoot Height (mm)	Shoots emerged (no.)	Shoot Height (mm)	Shoots emerged (no.)	Change in height (mm)	Change in shoots emerged (no.)
2	Coral	yes	96	Cooler[X]	14	4	25	9	11	5
			80		15	5	26	6	11	1
			54		0	0	14	1	14	1
			47		0	0	12	4	12	4
		no		GH[Y]	NA	NA	NA	NA	NA	NA
				cooler	0	0	20	5	20	5
				outside[Z]	25	20	55	23	30	3
	Cream	yes	96	cooler	3	1	3	1	0	0
			80		0	0	0	0	0	0
			54		0	0	0	0	0	0
			47		0	0	0	0	0	0
		no		GH	NA	NA	NA	NA	NA	NA
				cooler	0	0	0	0	0	0
				outside	30	1	30	1	0	0
	Lavender	yes	96	cooler	0	0	11	3	11	3
			80		0	0	5	1	5	1
			54		0	0	0	0	0	0
			47		0	0	10	0	10	0
		no		GH	0	0	12.5	1	12.5	1
				cooler	NA	NA	NA	NA	NA	NA

				outside	NA	NA	NA	NA	NA	NA
10	Coral	yes	96	cooler	41	6	50	7	9	1
			80		26	7	40	10	14	3
			54		16	2	22	6	6	4
			47		5	0	14	5	9	5
		no		GH	22	4	40	10	18	6
				cooler	26	17	69	29	43	12
				outside	NA	NA	NA	NA	NA	NA
	Cream	yes	96	cooler	0	0	0	0	0	0
			80		0	0	0	0	0	0
			54		0	0	0	0	0	0
			47		0	0	15	1	15	1
		no		GH	12	1	15	1	3	0
				cooler	NA	NA	NA	NA	NA	NA
				outside	NA	NA	NA	NA	NA	NA
	Lavender	yes	96	cooler	0	0	55	1	55	1
			80		23	2	45	6	22	4
			54		0	0	15	1	15	1
			47		0	0	15	2	15	2
		no		GH	NA	NA	NA	NA	NA	NA
				cooler	28	4	53	8	25	4
				outside	38	5	68	7	30	2
18	Coral	yes	96	cooler	139	13	185	13	46	0
			80		81	16	144	16	63	0
			54		58	12	122	12	64	0
			47		34	7	78	14	44	7
		no		GH	143	31	198	31	55	0
				cooler	NA	NA	NA	NA	NA	NA

			outside	199	19	259	19	60	0
Cream	yes	96	cooler	0	0	14	3	14	3
		80		25	3	71	7	46	4
		54		0	0	18	3	18	3
		47		0	0	0	0	0	0
	no		GH	0	0	0	0	0	0
			cooler	40	1	53	7	13	6
			outside	NA	NA	NA	NA	NA	NA
Lavender	yes	96	cooler	107	7	128	7	21	0
		80		112	7	153	7	41	0
		54		43	3	136	4	93	1
		47		49	7	96	11	47	4
	no		GH	NA	NA	NA	NA	NA	NA
			cooler	118	15	153	18	35	3
			outside	61	8	125	10	64	2

[X] cooler temperature, 13°C

[Y] unheated double layer polyethylene covered greenhouse

[Z] average night temperature for Raleigh, NC from Oct. 28, 2009 to Dec 14, 2009, 5°C

Table 11. The effect of preservatives on the vase life of *Eucomis* ‘Coral,’ Cream,’ ‘Lavender,’ and ‘Sparkling Burgundy’. Stems were placed into Floralife Hydraflor 100 or DI water for four hours followed by either Floralife Professional or DI water for two days. Stems were then placed into vases of DI water until termination. Stage 1.

		Vase life (d)			
Hydrator	Holding	Coral [Z]	Cream	Lavender	Sparkling Burgundy
Water	Water	17.9 a	35.4 a	23.2 a	48.5 ab
	Professional	9.8 b	23.4 b	21.5 a	50.3 a
Hydraflor 100	Water	9.4 b	22.7 b	21.6 a	43.0 ab
	Professional	6.3 b	17.1 b	15.9 a	29.9 b
Significance					
Hydrator (Y)		0.0071	0.0001	NS	0.0155
Holding (O)		0.0032	<0.0001	NS	NS
Y*O		NS	0.0438	NS	NS

[a, b] Means for one cultivar followed by the same letter are not significantly different according to the LSD procedure at $\alpha = 0.05$.

[Z] Cultivars are significantly different from one another, $P \leq 0.0001$

[NS] Nonsignificant at $P \leq 0.05$.

Table 12. The effect of production location on vase life of *Eucomis* ‘Coral,’ Cream,’ ‘Lavender,’ and ‘Sparkling Burgundy’. Stems were placed into Floralife Hydraflor 100 or DI water for four hours followed by either Floralife Professional or DI water for two days. Stems were then placed into vases of DI water until termination. Stage 1.

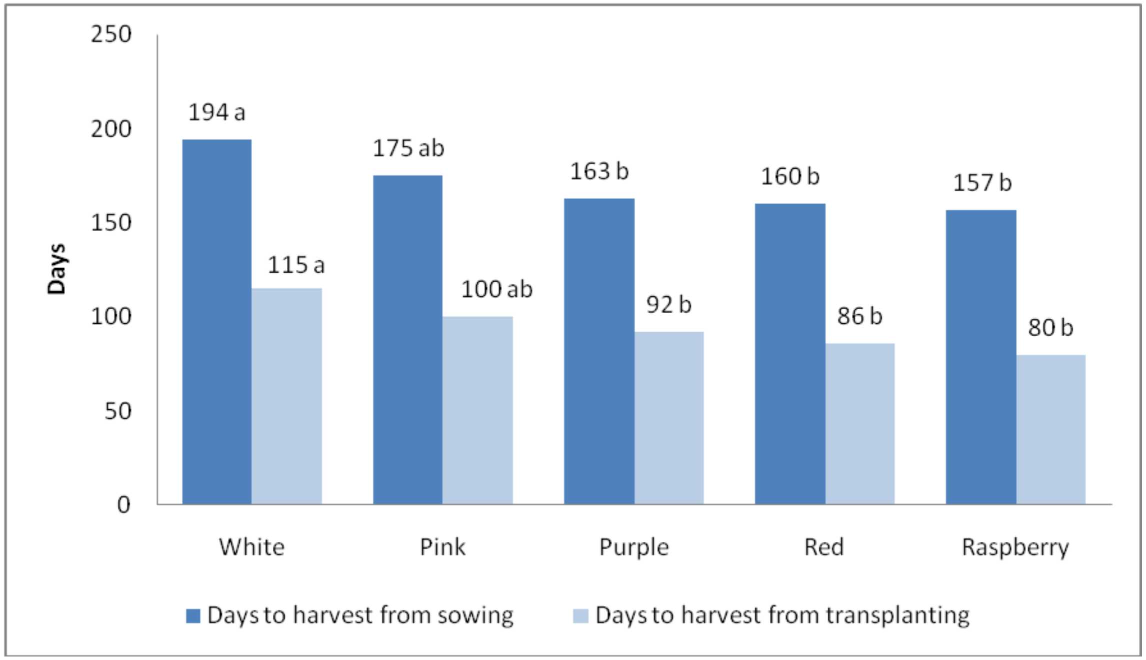
	Vase life (d)			
Location	Coral [Z]	Cream	Lavender	Sparkling Burgundy
Field	12.7	22.9	37.6	37.6
Greenhouse	9.6	28.2	15.0	48.2
Significance	NS	NS	<0.0001	0.0443

[a, b] Means for one cultivar followed by the same letter are not significantly different according to the LSD procedure at $\alpha = 0.05$.

[Z] Cultivars are significantly different from one another, $P \leq 0.0001$

[NS] Nonsignificant at $P \leq 0.05$.

Figure 1: Effect of flower color on days to harvest from transplanting and sowing on *Penstemon grandiflorus* 'Esprit' mix.



[a, b] Values above each column in a series followed by the same letter are not significantly different according to the HSD procedure at $\alpha = 0.05$.