Vase Life of New Cut Flower Cultivars

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SUMMARY. Each year a wide variety of new cultivars and species are evaluated in the National Cut Flower Trial Programs administered by North Carolina State University and the Association of Specialty Cut Flower Growers. Stems of promising and productive cultivars from the National Trial Program were pretreated with either a commercial hydrating solution or deionized (DI) water and placed in either a commercial holding solution or DI water. Over 8 years, the vase life of 121 cultivars representing 47 cut flower genera was determined. Although there was cultivar variation within each genus, patterns of postharvest responses have emerged. The largest category, with 53 cultivars, was one in which a holding preservative increased vase life of the following genera and species: acidanthera (*Gladiolus muriclae*), basil (*Ocimum basilicum*), bee balm (*Monarda* hybrid), black-eyed susan (*Rudbeckia* hybrids), campanula (*Campanula* species), celosia (*Celosia argentea*), common ninebark (*Physocarpus opulifolius*), coneflower (*Echinacea purpurea*), coral bells (*Heuchera* hybrids), feverfew (*Tanacetum parthenium*), foxglove (*Digitalis purpurea*), ladybells (*Adenophora* hybrid), lisianthus (*Eustoma grandiflorum*), lobelia (*Lobelia* hybrids), obedient plant (*Physostegia virginiana*), ornamental pepper (*Capsicum annuum*), pincushion flower (*Scabiosa atropurpurea*), pinkflower (*Indigofera amblyantha*), seven-sons flower (*Heptacodium miconioides*), shasta daisy (*Leucanthemum superbum*), sunflower (*Helianthus annuus*), snapdragon (*Antirrhinum majus*), sweet william (*Dianthus* hybrids), trachelium (*Trachelium caeruleum*), and zinnia (*Zinnia elegans*). Hydrating preservatives increased the vase life of four basil, coral bells, and sunflower cultivars. The combined use of hydrator and holding preservatives increased the vase life of three black-eyed susan, seven-sons flower, and sunflower cultivars. Holding preservatives reduced the vase life of 14 cultivars of the following genera and species: ageratum (*Ageratum houstonianum*), false queen anne's lace (*Ammi* species), knotweed (*Persicaria* hybrid), lisianthus, pineapple lily (*Eucomis comosa*), sneezeweed (*Helenium autumnale*), yarrow (*Achillea millefolium*), and zinnia. Hydrating preservatives reduced the vase life of 18 cultivars of the following genera and species: feverfew, lisianthus, ornamental pepper, pineapple lily, seven-sons flower, shasta daisy, sneezeweed, sweet william, sunflower, trachelium, yarrow, and zinnia. The combined use of hydrating and holding preservatives reduced the vase life of 12 cultivars in the following genera and species: false queen anne's lace, feverfew, pincushion flower, sneezeweed, sunflower, trachelium, yarrow, and zinnia. Data for the remaining 50 cultivars were not significant among the treatments; these genera and species included beautyberry (*Callicarpa americana*), black-eyed susan, blue mist (*Caryopteris clandonensis*), calendula (*Calendula officinalis*), campanula, cleome (*Cleome baserliana*), common ninebark, dahlia (*Dahlia* hybrids), delphinium (*Delphinium* hybrids), flowering peach (*Prunus persica* forma *versicolor*), heliopsis (*Heliopsis helianthoides*), hemp agrimony (*Eupatorium cannabinum*), himalayan honeysuckle (*Leycesteria formosa*), hydrangea (*Hydrangea paniculata*), larkspur (*Consolida* hybrids), lily of the Nile (*Agapanthus* hybrid), lisianthus, lobelia, ornamental pepper, pineapple lily, scented geranium (*Pelargonium* hybrid), sunflower, sweet william, and zinnia.

Commercially, cut stems are typically subjected to a hydrating solution and a holding solution. The purpose of a hydrator is to encourage water uptake. A commercial hydrator contains compounds to lower the pH, as water with a low pH is more easily taken up by stems when compared with water of high pH (Gast, 2000; Regan and Dole, 2010). Hydrators do not include sugar and are not designed to be used for extended periods of time longer than 24 h (Armitage and Laushman, 2003; Halevy and Mayak, 1981). However, a holding preservative is intended to be used for extended periods of time, 24 h or longer, typically during transport and storage. They regularly contain a carbohydrate source, an antimicrobial agent, and an acidifying agent (Dole and Wilkins, 2005; Halevy and Mayak, 1981). The carbohydrates support the cut stem, the antimicrobial agent deters the growth of stem-plugging microbes, and the acidifying agent helps slow microbial growth and encourages water uptake. Holding preservatives with a high percentage of carbohydrates aid in the opening of buds and in the development of flowers (Armitage and Laushman, 2003; Halevy and Mayak, 1981). In some cases, unamended water may be used in place of hydrator or holding solutions. The objective of this multi-year study was to identify patterns of postharvest responses to commercial hydrator and holding floral preservatives among 121 cultivars from 47 genera.

Materials and methods

Field-grown flowers were harvested between 7:00 AM and 10:00 AM at the optimum stage of development (Table 1). The lower half of the stem was stripped of its leaves and then placed into buckets filled with tap water within 5 min of being cut. Stems were then sorted into four similar groups based on stem length and diameter, flower bud number, flower size, as appropriate for the cultivar, and trimmed to a consistent length for each

Each year a wide variety of new cultivars and species are evaluated in the National Cut Flower Trial Programs administered by North Carolina State University and the Association of Specialty Cut Flower Growers. These new cultivars are tested at about 50 locations in the United States and Canada, providing valuable production and marketing information (Dole and Laushman, 2010; Dole et al., 2010). However,

postharvest life, a key component of a successful cut flower cultivar, is not included in the trial program.

Units

To convert U.S. to SI, multiply by	U.S. unit	SI unit	To convert SI to U.S., multiply by
10	%	mL·L ⁻¹	0.1
2.54	inch(es)	cm	0.3937
1	mmho/cm	dS·m ⁻¹	1
0.001	ppm	mL·L ⁻¹	1000
0.9464	qt	L	1.0567
(°F - 32) ÷ 1.8	°F	°C	(1.8 × °C) + 32

species, 30–45 cm. Two groups of stems were placed in hydrating solution or DI water for 4 h, after which one group from each solution was placed in a holding solution and the other in DI water. Experiments conducted from 2002 to 2005 used Chrysal Professional RVB Hydrating Solution (Pokon & Chrysal, Miami, FL) (hydrator) at 2 mL·L⁻¹ for 4 h and Chrysal Professional no. 2 Processing Solution (holding) at 10 mL·L⁻¹ until termination. Stems were placed in the hydration solution within 1 h after harvest. Experiments conducted from 2006 to 2009 used Floralife Hydraflor 100 (Floralife, Walterboro, SC) at 8 mL·L⁻¹ (hydrator) for 4 h and Floralife Professional at 10 mL·L⁻¹ (holding) for 44 h, then the stems were placed in DI water until termination. Each cultivar was tested only for 1 year; therefore, it was exposed to only one brand of hydrator and holding combination. Initial pH and electrical conductivity (EC) of the solutions were recorded (Table 2) when the first cultivars were tested each year and every month thereafter using a combination pH/EC meter (HI 9813 GroCheck meter; Hanna Instruments, Woonsocket, RI). During all years, each stem was placed in a quart-size Mason jar in a completely randomized design, by cultivar, in a postharvest environment held at 20 ± 2°C under 20–40 μmol·m⁻²·s⁻¹ light for 12 h·d⁻¹. For most species, 15 stems per treatment were tested, but occasionally 5–14 stems per treatment were used if sufficient stems were not available. Stems were terminated when “the average consumer” would discard them based on petal wilt, necrosis, discoloration or abscission, bent neck, leaf and stem discoloration, drying or general stem decline, depending on the species (Table 1). Vase-life data were collected and analyzed using analysis of variance (SAS 9.1; SAS Institute, Cary, NC). For genera with more than one cultivar,

data were combined if no significant differences occurred among cultivars. If differences among cultivars occurred, data were analyzed and presented separately for each cultivar. A separate analysis of sunflower and zinnia were conducted to determine the effect of changing brands of hydrator and holding preservatives.

Results and discussion

Many cultivars were unaffected by either hydrator or holding preservatives (Table 3). It is recommended that further testing be conducted, especially with the cultivars that included less than 10 replications. The variability in small number of stems can mask statistical significance that may be present, thus providing less than accurate results. For many species and cultivars discussed in this article, this is the first published report on vase life.

It is important to note that when the current results presented here conflict with previously published recommendations, each grower should assess his or her operation to determine the most practical use of hydrator and holding solutions for their unique situation. These differences could exist for several reasons, including differences in the specific cultivars tested, handling procedures (including timing, equipment, and weather), and postharvest environment. For the following genera, the vase life of one or more cultivars was significantly influenced by the treatments.

ACIDANTHERA. Holding preservatives slightly increased vase life to 10.3 from 9.3 d for stems in water. Armitage and Laushman (2003) and Scoggins (2002) support using holding solutions in their recommendations. Armitage and Laushman (2003) noted that the vase life should be 5–7 d with a preservative.

AGERATUM ‘HIGH TIDE WHITE’. The longest vase lives were obtained with water or a hydrator for the first 4 h, followed by holding in water. Stems placed in water alone, however, began to form roots, which greatly extended the vase life. In the commercial setting, a holding preservative is typically used, so that rooting would likely not occur. In the industry, it is recommended that a holding solution be used (Armitage and Laushman, 2003; Chain of Life Network, 2010; Scoggins, 2002). Even when held in

the holding solution, *ageratum* still had a long vase life, ranging from 20.3 to 20.8 d. In contrast, Armitage and Laushman (2003) indicated that the vase life would be from 7 to 10 d with preservative.

BASIL ‘CARDINAL’. The longest vase life was obtained when hydrator and holding solutions were used together. Individually, both hydrator and holding solutions increased vase life.

BEE BALM ‘RASPBERRY WINE’. The longest vase life was obtained when a holding solution was used after hydration with water. The Chain of Life Network (2010) recommended using a floral preservative, but warned that leaf discoloration or damage sometimes occurs.

CAMPANULA. Although ‘Heavenly Blue’ (*Campanula rapunculus*), ‘Champion Lavender Improved’, and ‘Champion White Improved’ (*C. medium*) were unaffected by the treatments, the longest vase lives for ‘Kent Belle’ (*C. takesimana*) were obtained when a holding preservative was used after being hydrated with water or hydrator. It is recommended that a holding solution is used with this genus. Armitage and Laushman (2003), Bosma and Dole (2002), the Chain of Life Network (2010), and Scoggins (2002) also recommended using a floral preservative for campanula.

CELOSIA ‘TOREADOR RED’. The longest vase lives were obtained when a holding solution was used after being treated with either hydrator or water. Without the holding preservative, vase life dropped by half to 17.5 or 13.5 d with hydrator or water, respectively. However, with a holding preservative, stems discolored slightly and desiccated rapidly, but did not exhibit bent neck or yellow foliage, prompting the longer vase life. To maintain color and texture most similar to freshly harvested flowers, it is recommended that only water or only a hydrator is used. Armitage and Laushman (2003), the Chain of Life Network (2010), and Scoggins (2002) support this recommendation. Holcomb et al. (1998) noted that vase life was 16 d in tap water; commercial holding preservatives produced variable results and could reduce vase life if the incorrect concentration is used.

COMMON NINEBARK. ‘Diabolo’ was unaffected by treatment, whereas the vase life of ‘Summer Wine’ was increased by a holding solution.

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Table 1. The stage at which cut stems of each of the cultivars were harvested and criteria by which the vase life of each cultivars was ended.

Species	Stage of harvest	Reasons for termination
Acidantha	33%–50% of flowers opened	50% of flowers wilted or turned brown
Adenophora ‘Amethyst’	33%–50% of flowers opened	50% of flowers wilted or turned brown
Ageratum ‘High Tide White’	Upper 33% of florets fully developed and fuzzy	50% of florets wilted or turned brown
Basil ‘Cardinal’	Upper leaves showing red color	50% of leaves wilted or stem bent
Beautyberry ‘Welsh’s Pink’	75% of fruit showing color	50% of fruit shriveled, turned brown or abscised
Bee balm ‘Raspberry Wine’	33% of upper florets opened	50% of upper florets abscised
Black-eyed susan, all cultivars	Outer ring of ray florets opened	Petals wilted, stem collapsed
Blue mist ‘First Choice’	33%–50% of florets opened	50% of florets wilted or turned brown
Calendula ‘Maayan’	Outer ring of ray florets opened	50% of florets wilted, turned brown, or stem bent
Campanula, all cultivars	33%–50% of flowers opened	50% of flowers wilted or turned brown
Celosia ‘Toreador Red’	Plume fully developed, no seeds yet	Bent neck, yellow foliage
Cleome, both cultivars	One row of flowers opened	50% of flowers wilted or turned brown
Common ninebark, both cultivars	Foliage fully colored	50% of leaves brown or discolored
Coneflower ‘Comet’	Petals colored and fully expanded	50% of petals wilted or turned brown
Coral bells ‘Florists Choice’	33%–50% of florets opened	50% of florets wilted or turned brown
Dahlia ‘Naomi’	Outer flower petals fully developed	Petals curled
Dahlia ‘Thalia’	Outer flower petals fully developed	Petals curled, bluing
Delphinium ‘Candle Violet Shades’	33%–50% of flowers opened	50% of flowers wilted or turned brown
False queen anne’s lace, both cultivars	50% of florets opened	50% of florets wilted or turned brown
Feverfew ‘Magic Lime Green’	Flowers fully opened	50% of petals wilted or turned brown
Flowering peach	33% of flowers opened	50% of flowers abscised
Foxglove, both cultivars	33%–50% of flowers opened	50% of flowers wilted or turned brown
Heliopsis ‘Summer Sun’	Flowers fully opened	50% of petals wilted or turned brown
Hemp agrimony	Inflorescence fully developed	Brown florets, wilting, abscission
Himalayan honeysuckle	50% of florets opened	50% of florets wilted, turned brown, or abscised
Hydrangea ‘Limelight’	50% of florets white, remaining florets immature and green	50% of florets wilted
Knotweed ‘Silver Dragon’	Foliage fully developed and stems long enough (>30 cm) for harvest	50% of leaves brown or discolored
Larkspur, both cultivars	33%–50% of flowers opened	50% of flowers wilted or abscised
Lily of the Nile ‘MidKnight Blue’	At least three flowers opened	50% of flowers wilted or turned brown
Lisianthus, all cultivars	One flower fully opened, second showing color	50% of flowers wilted or turned brown
Lobelia, all cultivars	At least three flowers opened	50% of flowers wilted or turned brown
Obedient plant ‘Summer Spires’	33%–50% of flowers opened	50% of flowers abscised
Ornamental pepper ‘Cappa Topfruit White/Red’	Fruit 75% colored	50% of fruit shriveled, peduncle wilted
Ornamental pepper ‘On Top Round Red’	Fruit 75% colored	50% of fruit shriveled
Pincushion flower ‘QIS Deep Red’	Florets fully opened	50% of florets abscised, bent neck
Pineapple lily ‘Sparkling Burgundy’ flowers	50%–75% of flowers opened	Stems collapsed
Pineapple lily ‘Sparkling Burgundy’ leaves	Leaves mature and well colored	Did not die after 35 d
Pinkflower	33% of florets open	50% of florets wilted or abscised
Scented geranium ‘Citrus Spice’	Stems long enough (>30 cm) to harvest	50% of leaves turned yellow or brown
Seven sons flower	33%–50% of bracts opened	50% of bracts turned brown or abscised
Shasta daisy ‘Polaris’	Flowers fully opened	Petals curled or turned brown
Snapdragon, both cultivars	At least three flowers opened	50% of flowers wilted or turned brown
Sneezeweed, both cultivars	33%–50% of florets opened	Brown florets, bent neck, yellow foliage
Sunflower ‘Stella Gold’	Petals perpendicular to stem axis	Brown and twisted petals, yellow foliage
Sunflower ‘Sunny’, ‘Terracotta’, ‘The Joker’	Outer ring of ray florets opened	Petals wilted, stem collapsed

(Continued on next page)

Table 1. (Continued) The stage at which cut stems of each of the cultivars were harvested and criteria by which the vase life of each cultivars was ended.

Species	Stage of harvest	Reasons for termination
Sunflower all other cultivars	Petals perpendicular to stem axis	50% of petals wilted or brown
Sunflower (<i>Helianthus salicifolia</i>) ‘First Light’	First outer ring of ray florets opened	Petal wilt, stem collapse
Sweet william, all cultivars	At least three flowers opened	50% of flowers wilted or turned brown
Trachelium, all cultivars	50%–75% of florets opened	50% of florets wilted or turned brown
Yarrow ‘Cassis’	Florets fully developed	50% of florets turned brown, bent neck, yellow foliage, wilting
Zinnia ‘Sun Cherry’	Outer petals fully expanded, one row of florets opened	Petals curled with bluish edges, undersides turned green
Zinnia, all other cultivars	Outer petals fully expanded, one row of florets opened	50% of petals wilted or turned brown

Table 2. pH and electrical conductivity (EC) of hydrator and holding solutions over 8 years of study.

Yr	Deionized water		Hydrator ^z		Holding ^z	
	pH range	EC range (dS·m ⁻¹) ^y	pH range	EC range (dS·m ⁻¹)	pH range	EC range (dS·m ⁻¹)
2002	4.5–4.6	0.00	3.2–3.5	0.46–0.54	2.5–2.9	0.44–0.53
2003	3.3–3.8	0.00	3.1–3.7	0.42–0.56	2.5–2.6	0.42–0.45
2004	3.1–4.2	0.00	— ^x	—	2.3–2.8	0.41–0.44
2005	3.6–7.0	0.00	3.1–3.6	0.33–0.61	2.1–2.8	0.25–0.46
2006	3.7	0.00	2.3	0.61	2.8	0.37
2007	2.9–3.8	0.00	2.3–2.7	0.59–0.66	3.0–3.4	0.35–0.41
2008	3.6–5.0	0.00	2.3–2.6	0.56–0.69	2.9–3.2	0.35–0.39
2009	3.6–4.6	0.00	2.5–2.8	0.79–0.93	3.1–3.5	0.38–0.45

^zFrom 2002 to 2005, Chrysal Professional RVB Hydrating Solution (hydrator; Pokon & Chrysal, Miami, FL) and Chrysal Professional no. 2 Processing Solution (holding; Pokon & Chrysal) were used; from 2006 to 2009, Floralife Hydraflor 100 (hydrator; Floralife, Walterboro, SC) and Floralife Professional (holding; Floralife) were used.

^y1 dS·m⁻¹ = 1 mmho/cm

^xData not collected

CONEFLOWER ‘COMET’. Holding preservatives increased vase life, and the longest vase life was obtained when a holding solution was used after hydration with water. Armitage and Laushman (2003) and Scoggins (2002) support the findings in these studies, whereas the Chain of Life Network (2010) warns against the use of holding solutions and recommends the use of only a hydrator. Armitage and Laushman (2003) indicated that vase life would be from 7 to 10 d with a preservative.

CORAL BELLS ‘FLORISTS CHOICE’. The longest vase life was obtained when hydrator and holding solutions were used together. Individually, both hydrator and holding solutions also increased vase life. Han (1998) also determined that using 0.5% sucrose as a pulse increased vase life of two *Heuchera* cultivars.

FALSE QUEEN ANNE’S LACE. ‘Casablanca’ (*Ammi visnaga*) and ‘Graceland’ (*A. majus*) differed in optimal postharvest procedures. Vase life of ‘Graceland’ was reduced with the

use of either a holding preservative alone or a hydrator and holding solution together. Except for the use of hydrator and holding solutions together, which reduced the vase life of ‘Casablanca’ slightly, all treatments had statistically similar vase lives. Floral preservatives would not be recommended for false queen anne’s lace. In contrast, Armitage and Laushman (2003), Scoggins (2002), and the Chain of Life Network (2010) recommended using floral preservatives. Armitage and Laushman (2003) noted that the vase life would be from 5 to 8 d in preservative.

FEVERFEW ‘MAGIC LIME GREEN’. The longest vase life was obtained by using a holding solution after hydration with water. The use of a hydrator decreased vase life and produced an even shorter vase life when used in conjunction with a holding preservative.

FOXGLOVE. For both cultivars, holding preservative slightly increased vase life when compared with water only and no significant differences occurred between cultivars. Therefore,

a holding solution should be used. The Chain of Life Network (2010) recommended using a floral preservative to get a vase life of 10–14 d.

LADYBELLS ‘AMETHYST’. Holding preservatives increased vase life, and the longest vase life was obtained with only a holding preservative.

LISIANTHUS. Cultivar interacted with treatment ($P \leq 0.0001$) such that 11 of the 16 cultivars tested were unaffected by holding treatment; holding preservatives increased the vase life of three and decreased the vase life of two. Of the three cultivars that responded well to a holding preservative, vase life increased to an additional 1.5–6.5 d. Vase life decreased from 0.5 to 2.3 d for the two cultivars that were negatively affected by the holding solution. When data from individual cultivars were analyzed, hydrator preservative decreased the vase life of ‘Twinkle Blue Blush’. Because of the variable response, individual cultivars should be tested. Regardless of the use of holding solution, a hydrator should not be used with

Table 3. Cultivars on which neither commercial hydrator nor holding solutions^z had an effect.

Genus	Cultivar	Minimum vase life (d) ^y	Avg vase life $\pm$ SD (d) ^x	Stems (no./treatment)
Beautyberry	Welsh's Pink	19	21.7 $\pm$ 2.6	15
Black-eyed susan	Prairie Sun	12	22.8 $\pm$ 6.7	11
Blue mist	First Choice	5	14.4 $\pm$ 3.4	15
Calendula	Maayan	3	4.8 $\pm$ 1.2	15
Campanula	Champion Lavender Improved	2	10.2 $\pm$ 4.6	15
	Champion White Improved	4	10.9 $\pm$ 3.2	15
	Heavenly Blue	2	14.3 $\pm$ 3.0	15
Cleome	Sparkler Lavender	1	5.9 $\pm$ 1.3	15
Common ninebark	Diabolo	12	19.6 $\pm$ 3.5	11
Dahlia	Naomi	4	5.7 $\pm$ 1.1	15
	Thalia	3	6.4 $\pm$ 1.1	10
Delphinium	Candle Violet Shades	4	9.0 $\pm$ 2.7	5
	Stiletto Indigo Blue	6	9.7 $\pm$ 2.0	15
Flowering peach	None	7	7.2 $\pm$ 0.5	15
Heliopsis	Summer Sun	2	12.0 $\pm$ 3.7	11
Hemp agrimony	None	5	22.7 $\pm$ 5.4	15
Himalayan honeysuckle	None	9	12.3 $\pm$ 2.7	6
Hydrangea	Limelight ^w	6	11.3 $\pm$ 3.4	15
Larkspur	Cannes Chrystal Pink	4	8.7 $\pm$ 2.4	7
	Cannes Purple Picotee	4	8.1 $\pm$ 2.2	7
Lily of the Nile	MidKnight Blue	7	10.7 $\pm$ 1.8	8
Lisianthus	ABC 02153 White	7	15.0 $\pm$ 3.6	6
	ABC 1-3 White	5	9.8 $\pm$ 1.7	15
	ABC Lavender	2	9.8 $\pm$ 3.1	13
	Advantage Cherry Sorbet	8	13.4 $\pm$ 2.6	5
	Arena White	11	15.7 $\pm$ 1.4	15
	Cadence Yellow	10	14.1 $\pm$ 2.1	11
	Fioretti Green	5	16.2 $\pm$ 5.4	13
	Malibu Purple	8	11.8 $\pm$ 2.8	7
	Ruffle Blue	4	11.3 $\pm$ 2.9	15
	Twinkle Pink Improved	7	11.4 $\pm$ 2.5	15
	Fan Blue	7	11.6 $\pm$ 2.2	15
	Hot Purple	20	24.4 $\pm$ 1.6	15
	Sparkler White	5	7.2 $\pm$ 1.9	15
	Sparkling Burgundy leaves	35 ^v	35.0 $\pm$ 0.0	15
	Citrus Spice	8	20.9 $\pm$ 8.1	15
Sunflower	565	8	10.9 $\pm$ 1.4	15
	Carmel	9	14.5 $\pm$ 1.5	15
	Lemon Éclair	7	8.1 $\pm$ 1.1	10
	Orange Queen	1	9.5 $\pm$ 4.5	14
	Pro Cut Bicolor	7	12.0 $\pm$ 1.4	10
	Pro Cut Orange	4	14.6 $\pm$ 3.2	10
	Sun4U Bicolor	7	10.6 $\pm$ 1.5	15
	Sun4U Orange	8	11.5 $\pm$ 1.4	15
	Tapuz	6	10.6 $\pm$ 1.9	15
	Bouquet Rose	9	11.4 $\pm$ 1.4	15
Sweet william	Fandango Crimson	3	9.4 $\pm$ 2.4	15
	Fandango Purple Picotee	8	11.8 $\pm$ 2.1	15
	Oklahoma Carmine	8	18.5 $\pm$ 4.5	15
Zinnia	Oklahoma Yellow	8	22.5 $\pm$ 6.4	15

^zFrom 2002 to 2005, Chrysal Professional RVB Hydrating Solution (hydrator) and Chrysal Professional no. 2 Processing Solution (holding) were used, and from 2006 to 2009, Floralife Hydraflor 100 (hydrator) and Floralife Professional (holding) were used.

^yShortest lived replication.

^xAverage overall four treatments $\pm$ SD.

^w*Hydrangea* 'Limelight' can be harvested at three different times: when florets are still green, all florets are bright white with maturity, or florets have turned pinkish-green later in their development. The first stage was tested in this study and typically results in the shortest vase life (B. Wollam, personal communication).

^zLeaves did not die even after 35 d in postharvest area.

lisianthus. Armitage and Laushman (2003), the Chain of Life Network (2010), Scoggins (2002), and Besemer (1985) all recommended the use of a holding preservative with lisianthus. Armitage and Laushman (2003) noted

that the vase life would be from 10 to 15 d and could be increased with the use of a preservative.

KNOTWEED ‘SILVER DRAGON’. The longest vase life was obtained when stems were placed in plain water after hydration in water. The use of a holding preservative shortened the vase life. Some ‘Silver Dragon’ stems developed roots, which contributed to the remarkably long vase life. Even the shortest lived stem had an outstanding vase life, 19 d.

LOBELIA. ‘Fan Blue’ was unaffected by treatment, while the vase life of ‘Compliment Mix’ was slightly increased by a holding solution.

OBEDIENT PLANT ‘SUMMER SPIRES’. Holding preservative increased the vase life to 5 d for stems held in water. Armitage and Laushman (2003), Scoggins (2002), and the Chain of Life Network (2010) strongly recommended the use of a holding preservative for obedient plant. As with our results, Armitage and Laushman (2003) noted that a vase life of 14 d could be obtained with the use of a holding solution.

ORNAMENTAL PEPPER. For all the three cultivars tested, the use of a commercial hydrator either reduced the vase life or had no effect, and so it should not be used. Cultivar interacted with treatment ($P = 0.0202$) such that the longest vase life for ‘Cappa Topfruit White/Red’ was obtained when a holding preservative was used without a hydrator, but the longest vase life for ‘On Top Round Red’ was obtained when hydrated with water, followed by either a holding preservative or water. Treatment had no effect on the vase life of ‘Hot Purple’. Foliage wilted readily, while the fruit was still presentable; consequently, as much of the foliage should be removed at harvest as practical.

PINCUSHION FLOWER ‘QIS DEEP RED’. The longest vase life was obtained using a holding preservative after hydration with water. Similarly, Armitage and Laushman (2003) indicated that the vase life would be 5–7 d in water and would increase to 7–10 d with a preservative. When a hydrator and holding solution were used together, vase life was shortest. Industry standards (Armitage and Laushman, 2003; Chain of Life Network, 2010; Scoggins, 2002) support the use of a holding preservative.

PINEAPPLE LILY ‘SPARKLING BURGUNDY’. Vase life for flowers was longest when stems were placed in plain water. Both hydrator and holding solutions reduced vase life, and if both

solutions were used, vase life dropped to a still acceptable 10.6 d. Although a holding preservative decreased the vase life, *Eucomis* could still be used in a bouquet and have a vase life competitive with other species in the vase. *Eucomis* ‘Sparkling Burgundy’ leaves were also exceptionally long lasting with an average and minimum vase life of 35 d. The leaves held in water rooted, preventing a final determination of vase life.

PINKFLOWER. The longest vase life was obtained when a holding solution was used after hydration with water.

SEVEN SONS FLOWER. The longest vase life was obtained when both hydrator and holding solutions were used. The use of a holding preservative alone also extended the vase life when compared with plain water. The bracts of this species were very brittle and tended to be abscised readily (personal observation).

SHASTA DAISY ‘POLARIS’. The longest vase life was obtained when a holding solution was used after hydration with water. Overall, the use of a holding preservative increased vase life, but the use of a hydrator decreased vase life.

SNAPDRAGON. Both snapdragon cultivars responded well in a holding preservative; the longest vase lives were obtained when a holding preservative was used, regardless of hydrator use. Industry recommendations (Armitage and Laushman, 2003; Chain of Life Network, 2010; Scoggins, 2002) support the use of a holding preservative. Armitage and Laushman (2003) noted that snapdragon typically has a vase life of 5–8 d in water.

SNEEZEWEED. For both cultivars, the combined use of hydrators and holding solutions reduced vase life; plain water was as effective as either a hydrator or a holding solution alone. No significant differences occurred between cultivars ($P \leq 0.05$). Therefore, sneezeweed should be placed in plain water after harvest and no commercial products used.

SUNFLOWER. Cultivar interacted with treatment ($P \leq 0.0001$) of the 26 cultivars tested; nine were unaffected by treatment, holding preservative increased the vase life of 16, hydration solutions increased the vase life of two, and the use of both hydrator and holding preservatives increased vase life of one cultivar. However, hydrator solutions reduced the vase life of

three cultivars and combining a hydrator with a holding solution decreased the vase life of two cultivars. It should be noted that some cultivars responded in more than one way to treatments (i.e., positively to a holding preservative but negatively to a hydrator). All cultivars either benefited or were unaffected by a holding preservative when used alone. An exception was that holding solutions for ‘Sunny’ stems caused slight petal tip browning (personal observation). ‘Terracotta’ petal color also deepened with age (personal observation), but that was not considered a positive or a negative change. Therefore, a holding preservative should be used with cut sunflowers. The Chain of Life Network (2010) supports the use of hydrators, holding preservatives, or plain water for post-harvest solutions of sunflowers, but states that the most benefit is gained from holding preservatives. Armitage and Laushman (2003) suggested that a floral preservative be used, which would result in a 7–10 d vase life.

SWEET WILLIAM. Cultivar interacted with treatment ($P \leq 0.0001$) such that the vase life of six of the nine cultivars tested, Amazon Neon Duo, Bouquet Purple, Sweet Coral, Sweet Red, Sweet Scarlet, and White with Ring, increased with the use of a holding solution; the other three were unaffected by the treatments. Hydrator had no effect, except for reducing vase life of ‘Sweet Red’. However, leaf browning of ‘Sweet Coral’ and ‘Sweet Red’ stems occurred when the holding solution was used in conjunction with a hydrator (personal observation). Thus, it is recommended that a holding preservative without a hydrator be used for sweet william. The Chain of Life Network (2010) supports this recommendation. Armitage and Laushman (2003) indicated that the vase life would be 7–10 d, but did not specify the solution.

TRACHELIUM. Vase life was the longest for all three cultivars when a holding solution was used without a hydrator. Cultivar interacted with treatment ($P = 0.0406$) such that a hydrator decreased the vase life of ‘Summer Purple’, regardless of holding solution, whereas the use of a hydrator shortened the vase life of ‘Summer White’ and ‘Lake Louise Purple’ when used in conjunction with a holding solution. Therefore, it is recommended that only a holding

Table 4. Influence of hydrator (hyd.) and holding (hold.) solutions on cut stems of new cut flower cultivars, in which one or more treatments had a significant effect on vase life.

Genus	Cultivar	Minimum vase life (d) ^y	Water		Hyd. ^z		Constant holding (yes/no)	Significance			Stems no./treatment
			Water (d)	Hold.(d) ^z	Water (d)	Hold.(d)		Hyd.	Hold.	Interaction	
Acidantha	None	3	9.1	10.1	9.4	10.5	Yes	NS	*	NS	15
Adenophora	Amethyst	3	10.9	14.0	11.2	12.2	Yes	NS	**	NS	15
Ageratum	High Tide White	12	26.9	20.3	25.1	20.8	Yes	NS	***	NS	15
Basil	Cardinal	3	4.7	10.6	8.9	14.0	No	**	***	NS	15
Bee balm	Raspberry Wine	5	7.9	9.6	8.4	9.1	No	NS	**	NS	15
Black-eyed susan	Autumn Colors	8	13.2	17.6	14.5	19.9	Yes	NS	**	NS	11
	Goldie Locks	4	16.0	21.0	23.7	17.9	Yes	NS	NS	*	15
Campanula	Kent Belle	7	11.8	15.3	11.9	14.6	Yes	NS	***	NS	15
Celosia	Toreador Red	5	13.5	33.2	17.5	33.8	Yes	NS	***	NS	11
Common ninebark	Summer Wine	9	13.5	14.4	11.3	16.1	Yes	NS	**	NS	15
Coneflower	Comet	8	17.1	20.7	16.4	18.1	No	NS	*	NS	15
Coral bells	Florists Choice	2	4.7	10.5	6.7	12.8	Yes	**	***	NS	15
False queen anne's lace	Casablanca	13	15.1	15.3	15.3	14.5	Yes	NS	NS	*	15
	Graceland	5	11.7	9.5	12.1	8.7	Yes	NS	***	*	15
Feverfew	Magic Lime Green	12	19.2	23.5	18.9	17.5	Yes	***	NS	**	15
Foxglove	Camelot Lavender	6	8.5	9.4	8.3	9.2	Yes	NS	**	NS	15
	and Camelot Rose										
Lisianthus	ABC Lavender	5	9.0	12.0	10.4	12.3	No	NS	*	NS	8
	Alice Pink	9	15.2	21.7	16.1	17.6	Yes	NS	**	NS	9
	Twinkle Blue Blush	13	16.5	18.9	15.3	15.4	Yes	***	NS	NS	8
	Twinkle Pink	8	13.8	17.4	14.0	15.8	Yes	NS	*	NS	8
	Vulcan Yellow	7	16.7	14.0	15.8	14.5	No	NS	**	NS	15
	Wonderous Purple	7	16.4	14.4	16.6	14.4	No	NS	**	NS	10
Lobelia	Compliment Mix	7	10.1	11.4	8.5	10.8	No	NS	*	NS	11
Obedient plant	Summer Spires	7	9.8	14.9	10.3	15.4	Yes	NS	***	NS	15
Ornamental pepper	Cappa Topfruit	4	14.6	18.4	13.9	14.7	No	*	*	NS	11
	White/Red										
Persicaria	On Top Round Red	10	15.9	16.3	14.3	15.3	No	**	NS	NS	15
Pincushion flower	Silver Dragon	19	34.0	26.2	33.5	30.5	Yes	NS	***	NS	15
Pineapple lily	QIS Deep Red	4	7.2	8.1	7.7	6.5	Yes	NS	NS	*	15
	Sparkling Burgundy flowers	6	42.2	28.9	17.1	10.6	No	***	**	NS	15
Pinkflower	None	5	6.6	8.7	7.5	8.7	No	NS	***	NS	15
Seven sons flower	None	10	11.1	11.5	10.5	11.6	No	NS	***	*	15
Shasta daisy	Polaris	2	10.3	12.5	9.4	10.6	Yes	*	**	NS	15
Snapdragon	Calima Deep Rose	4	7.2	7.7	6.3	8.3	No	NS	**	NS	15
	Chantilly Orange	3	5.1	7.6	4.4	7.6	No	NS	***	NS	9
Sneezeweed	Helena Gold and Helena Red Shades	2	14.2	13.9	13.2	8.8	Yes	***	***	**	15

(Continued on next page)

Table 4. (*Continued*) Influence of hydrator (hyd.) and holding (hold.) solutions on cut stems of new cut flower cultivars, in which one or more treatments had a significant effect on vase life.

Genus	Cultivar	Minimum vase life (d) ^y	Water		Hyd. ^z		Constant holding (yes/no)		Significance		Stems no./treatment
			Water (d)	Hold.(d) ^z	Water (d)	Hold.(d)			Hyd.	Interaction	
Sunflower	Arbel	7	9.8	12.4	10.7	10.8	No		NS	*	15
	First Light	3	12.0	17.9	7.0	16.9	Yes		**	NS	15
	Galilee Adami	3	11.1	11.6	7.5	9.5	No		***	*	15
	Lemon Summer	6	9.1	9.7	9.3	9.8	No		NS	NS	15
	Orange Glory	7	10.6	12.6	9.7	12.7	No		***	NS	10
	Premium Lemon	6	7.8	9.9	9.0	10.1	No		*	NS	15
	Pro Cut Red/Lemon	4	6.3	8.8	7.4	8.9	Yes		NS	NS	12
	Bicolor										
	Solara	7	8.9	10.1	9.0	12.2	No		*	***	14
	Stella Gold	3	6.7	7.9	6.3	5.1	Yes		***	**	15
Sweet william	Sun4U Lemon Yellow	7	10.1	12.5	10.2	12.3	No		NS	NS	15
	Sunny	11	14.7	17.2	14.5	15.3	Yes		NS	*	11
	Sunrich Orange	7	8.9	9.8	8.8	10.4	No		NS	**	13
	Tavor Joy	9	13.3	14.8	12.3	14.7	No		NS	***	15
	Terracotta	10	12.2	14.6	11.9	13.4	Yes		NS	***	12
	The Joker	1	6.8	9.8	7.1	6.8	Yes		**	***	14
	Tosca	5	9.3	11.5	9.6	11.0	No		NS	**	8
	Zohar	8	12.0	12.7	11.2	12.4	No		NS	*	15
	Amazon Neon Duo	12	14.0	15.4	13.8	15.5	Yes		NS	**	15
	Bouquet Purple	6	12.1	18.6	12.5	19.9	Yes		NS	***	15
Trachelium	Sweet Scarlet	11	15.3	21.7	15.7	20.1	Yes		NS	***	15
	Sweet Coral	12	15.3	18.8	15.5	16.0	Yes		NS	*	10
	Sweet Red	9	13.2	17.2	12.7	14.0	Yes		*	***	10
	White with Ring	8	11.3	15.5	12.1	17.1	Yes		NS	***	15
	Summer Purple	3	9.9	13.3	7.9	9.5	Yes		***	NS	15
	Summer White	2	9.2	12.5	9.1	6.6	Yes		**	NS	11
	Lake Louise Purple	5	12.3	14.6	12.7	11.2	Yes		*	NS	15
	Cassis	2	12.1	9.6	9.3	10.5	Yes		NS	NS	15
	Benary's Giant Lime	1	23.5	15.5	19.9	1.3	Yes		***	***	15
	Benary's Giant Wine	4	8.2	9.8	8.2	9.2	No		NS	*	15
Yarrow	Red Beauty	4	8.4	9.3	8.0	9.1	No		NS	*	15
	Sun Cherry	3	11.7	6.9	13.3	6.7	Yes		NS	***	15
	Sun Gold	3	11.1	9.3	12.0	7.8	Yes		NS	*	15
	Uproar Rose	9	22.5	16.2	25.3	14.7	Yes		NS	***	15
	Zowie! Yellow Flame	15	33.0	22.1	30.5	21.3	Yes		NS	***	15

Two groups of stems were placed in commercial hydrating solution or deionized (DI) water for 4 h, after which one group from each solution was placed in a holding solution and the other in DI water.

^yExperiments conducted from 2002 to 2005 used Chrysal Professional R/VB Hydrating Solution (hyd.) for 4 h and Chrysal Professional no. 2 Processing Solution (hold.) until termination. Experiments conducted from 2006 to 2009 used Floralife Hydrator 100 (hyd.) for 4 h and Floralife Professional (hold.) for 44 h, then placed in DI water until termination.^zShortest lived replicationNS, *, **, ***: Nonsignificant or significant at $P \leq 0.05$, 0.01, or 0.001, respectively

solution be used for trachelium. The Chain of Life Network (2010) and Dole et al. (2009) support this recommendation.

YARROW ‘CASSIS’. The longest vase life was obtained by placing stems in plain water (Table 4). Armitage and Laushman (2003) indicated that either water or holding preservative could be used to obtain a 3–4 d vase life and the Chain of Life Network (2010) recommended the use of floral preservatives.

ZINNIA. Cultivar interacted with treatment ($P \leq 0.0001$) such that the vase life for five of the nine cultivars was shorter with the use of a holding preservative, vase life of two cultivars increased by using a holding preservative, and two cultivars were unaffected by the treatments. The longest vase lives for ‘Sun Cherry’, ‘Sun Gold’, ‘Uproar Rose’, and ‘Zowie! Yellow Flame’ were obtained when plain water was used after hydration with either a hydrator or water. For ‘Benary’s Giant Lime’, the longest vase life was obtained when stems were placed in plain water after hydration with water. The use of a hydrator or a holding preservative decreased the vase life, but when used together, the vase life dropped by 3 weeks to 1.3 d. Petal margins browned and began to curl within 1 d when the hydrator and holding preservative were used (personal observation). The vase life of ‘Benary’s Giant Wine’ and ‘Red Beauty’ was longer with the use of a holding preservative. The Chain of Life Network (2010) states that zinnias are sensitive to the use of holding preservatives. The Chain of Life Network warns “...damage can result if the solution is made too strong (over 1%), too weak (0.5%), and/or if the wrong flower food brand is used.” Because of the unpredictability of a holding preservative on zinnias and the benefits of water, it is

recommended that each cultivar be tested.

Switching from Chrysal products and procedures (2002–2005) to Floralife products (2006–2009) had no effect as response patterns were similar among *Helianthus* and *Zinnia* cultivars (data not presented). In addition, there was no difference between leaving the stems in holding solution for 2 d or until termination, which suggests that the effect of solution uptake was not significantly greater after 2 d than over the course of the stems’ life. These results are not surprising as water uptake is highest immediately after harvest (Doi et al., 1999; Mayak et al., 1974) and at the commencement of rehydration.

Of the 121 taxa tested, 16 had a vase life longer than 21 d for at least one of the treatments, 38 had a vase life of 14–21 d and 39 had a vase life of 10–14 d, indicating that most of the taxa tested would be suitable for commercial production. However, these results represent optimal postharvest handling conditions without cold storage or shipping, which can reduce vase life. Commercial producers typically store cut flowers for many days and have to ship flowers either dry in boxes or wet in buckets of floral solution. Thus, the indicated vase life would likely be the maximum and commercial producers should expect shorter vase lives. This is supported by the fact that we generally reported a longer vase life for species that were also described in Armitage and Laushman (2003), which often relied on grower observations for determining vase life.

For the majority of taxa, either all treatments produced a similar vase life (Table 3) or treatment with a holding preservative produced the longest vase life (Table 5), indicating that holding preservatives can be used with most taxa. However, a universal

recommendation for use of a holding preservative cannot be made as it reduced the vase life of 14 cultivars in 8 genera. Interestingly, commercial hydrators had a less positive effect on vase life as they increased the vase life of only four cultivars in three genera and reduced the vase life of 18 cultivars in 12 genera. Thus, hydrator preservatives need not be used with most taxa. Of course, it is always best to conduct small scale, on-farm research as each operation has a unique situation, with variable processing procedures and commercial solutions used.

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Table 5. Number of genera and cultivars whose response to floral preservatives fits the indicated categories.

Category	Genera (no.)	Cultivars (no.)
Holding—positive effect	25	53
Holding—negative effect	8	14
Hydrator—positive effect	3	4
Hydrator—negative effect	12	18
Both hydrator and holding—positive	3	3
Both hydrator and holding—negative	8	12

Cultivars that had no response to any treatment are listed in Table 3. Cultivars can fit more than one category.

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