Production and Postharvest Evaluation of Selected Exotic Specialty Annual Cut Flower Species in Punjab, Pakistan

Ifthikhar Ahmad^{1,2,3}, Muhammad B. Rafiq¹, John M. Dole², Bilal Abdullah¹, and Kinza Habib¹

ADDITIONAL INDEX WORDS. cut flowers, cultivar evaluation, delphinium, snapdragon, stock

SUMMARY. Favorable agro-climatic conditions and comparatively cheaper and readily available human resources offer a promising business opportunity to cut flower production in Pakistan. Presently, growers are limited to traditional cut flower crops such as rose (*Rosa* hybrids), gladiolus (*Gladiolus* hybrids), marigold (*Tagetes erecta*), and tuberose (*Polianthes tuberosa*) because of unavailability of improved new species and cultivars. To diversify cut flower production in Pakistan, a study was conducted to evaluate the production and postharvest performance of different cultivars of delphinium (*Delphinium* hybrids), snapdragon (*Antirrhinum majus*), and stock (*Matthiola incana*) in Faisalabad, Punjab, Pakistan. ‘Guardian White’ delphinium had the shortest time to harvest first marketable stems (160 days) with comparatively shorter stems (87.7 cm). Whereas ‘Aurora White’ and ‘Aurora Blue’ were high-temperature tolerant and produced attractive racemes with longer stems; 112.0 and 99.7 cm, respectively. All cultivars lasted about 7 days in distilled water (DW). ‘Cheerful White’ stock had the shortest cropping time and produced highest quality double flowers with longest stems (51.8 cm) compared with other cultivars tested. Vase solution of 4% sucrose supplemented with 100 mg·L⁻¹ silver nitrate (AgNO₃) extended the vase life of ‘Cheerful White’ stock up to 11.8 days compared with 8.2 days in DW. Pulsing with 10% sucrose supplemented with 100 mg·L⁻¹ AgNO₃ extended the longevity of ‘Lucinda Dark Rose Double’ stock (10.2 days) similar to vase solution of 4% sucrose plus 100 mg·L⁻¹ AgNO₃; however, ‘Lucinda Dark Rose Double’ stock produced shorter stems than ‘Cheerful White’. ‘Appleblossom’ snapdragon produced >10 marketable stems per plant with highest quality attractive flowers, and stout stems, which lasted 10.8 days in 4% sucrose vase solution supplemented with 100 mg·L⁻¹ AgNO₃. Among tested species/cultivars, all exotic species/cultivars produced uniform high quality stems resulting in higher productivity as compared with local cultivars and were favorably appraised by flower growers/retailers and are best suited for diversification of local cut flower industry.

The floriculture industry is constantly looking for new cultivars and species of cut flowers to excite the consumers and diversify production (Regan and Dole, 2010). The specialty cut flower industry can take advantage of innovation by regularly introducing new cut flower species/cultivars, which will also reduce the risk of depending on a

limited number of species. Hundreds of new species and cultivars are released and evaluated every year for commercial cultivation (Clark et al., 2010).

Availability of production and postharvest handling protocols allows growers to select species and cultivars ideally suited for their climates. Pakistan is blessed with a wide diversity of

agro-climatic conditions, which are suitable for many specialty cut flower crops (Nasir and Rafiq, 1996). Presently, the Pakistani cut flower industry is dominated by traditional cut flower crops including rose, gladiolus, tuberose, and marigold, which are grown on small scale with traditional cropping patterns using outdated techniques and limited resources. Introduction of exotic specialty cut species is one of the best options for small-scale farming businesses, but producers are reluctant to grow new species because of the lack of sufficient information about their production and postharvest handling protocols (Ahmad et al., 2014; Regan and Dole, 2010).

Delphinium, snapdragon, and stock are well recognized in international markets as specialty cut flowers; however, they are grown only as bedding garden plants in some parts of Pakistan. Evaluation of these exotic specialty cut species in different regions can be one of the best options to diversify the local cut flower industry and to fulfill esthetic needs of the consumers. Among specialty cuts, annuals are popular, comparatively cheaper to produce, and have many available cultivars that are well suited for outdoor production (Ahmad et al., 2014; Dole et al., 2009; Starman et al., 1995). Most of these species may be grown outdoors during mild winters in central and southern plains of Pakistan. Delphinium, snapdragon, and stock offer an excellent opportunity to be introduced as specialty cuts in local markets because of their easy culture and magnificent flowers with acceptable longevity. Therefore, a study was conducted to evaluate exotic cultivars of delphinium, snapdragon, and stock in comparison with local cultivars of snapdragon and stock for their production and postharvest performance as cut flowers in the

The authors are grateful to American Takii Inc., Salinas, CA; Ball Horticultural Co., West Chicago, IL, and Sakata Seed America Inc., Morgan Hill, CA, for providing seeds of exotic cultivars for the study. We are also grateful to the Higher Education Commission, Islamabad, Pakistan, for partial funding of this study.

¹Institute of Horticultural Sciences, University of Agriculture, Faisalabad 38040, Pakistan

²Department of Horticultural Science, North Carolina State University, Raleigh, NC 27695

³Corresponding author. E-mail: ifthikharahmadhashmi@gmail.com or iahmad3@ncsu.edu.

doi: 10.21273/HORTTECH03814-17

Units

To convert U.S. to SI, multiply by	U.S. unit	SI unit	To convert SI to U.S., multiply by
0.4047	acre(s)	ha	2.4711
29.5735	fl oz	mL	0.0338
2.54	inch(es)	cm	0.3937
25.4	inch(es)	mm	0.0394
0.4536	lb	kg	2.2046
1	mmho/cm	dS·m ⁻¹	1
28.3495	oz	g	0.0353
1	ppm	mg·L ⁻¹	1
(°F - 32) ÷ 1.8	°F	°C	(°C × 1.8) + 32

agro-climatic conditions of Punjab, Pakistan.

Materials and methods

CULTIVAR PRODUCTION EVALUATION. Seeds of ‘Aurora Blue’ and ‘Aurora White’ delphinium (American Takii, Salinas, CA), ‘Guardian White’ delphinium, ‘Appleblossom’ snapdragon and ‘Lucinda Dark Rose Double’ and ‘Lucinda Dark Rose Single’ stock (Ball Horticultural Co., West Chicago, IL), and ‘Cheerful White’ stock (Sakata Seed America, Morgan Hill, CA) were imported, whereas seeds of local cultivars, Cheerio snapdragon and Desi stock were obtained from a local seed supplier (Chanan Din & Sons, Lahore, Pakistan). All seeds were sown in 128-cell plastic plug trays containing silt, leaf compost (produced on site in a windrow where leaves and grass clippings were kept for 3–4 months with every 3–4 weeks turnings until use), and coco coir (1:1:1 by volume) substrate during 20 Oct. 2014 to 24 Oct. 2014 and kept in a shade house at 22 to 27 °C day and 15 to 18 °C night temperature with 40% ± 10% relative humidity (RH). Seedlings were irrigated with tap water when required until two to three true leaf development stage. Seedlings were transplanted outdoors in a loamy soil [pH 8.1, electrical conductivity (EC) 1.9 dS·m⁻¹, and organic matter 0.66%] on thoroughly tilled and leveled flat planting beds with 15-cm plant-to-plant distance in 15-cm spaced rows. A compound fertilizer [20N–8.7P–16.6K; Engro Fertilizers, Karachi, Pakistan] at 100 kg/acre] was applied at transplanting, 6 weeks after transplanting, and at raceme emergence. The experiment was a randomized complete-block design with 20 plants in each replication for individual cultivars, and all treatments (cultivars) were replicated three times. All other cultural practices including irrigation, weeding, pest management, staking, etc. were similar for all treatments during entire period of the study.

MEASUREMENTS. Germination percentage of each cultivar was recorded. Data were recorded on stem length (centimeters), stem diameter (millimeters), time to harvest first marketable stem (days), number of marketable stems per plant, number of flowers per stem, raceme length (centimeters), flower quality (1 to 10

scale, with 10 as best), and fresh and dry weight of stem (grams).

POSTHARVEST EVALUATION. Cut stems of ‘Cheerful White’ and ‘Lucinda Dark Rose Double’ stock and ‘Appleblossom’ snapdragons were evaluated for their postharvest performance. Stems were harvested in the morning before 1000 HR at commercial maturity stage, when the lower two to three flowers were open. Leaves were trimmed from lower half of the stems, which were placed in buckets containing tap water and transported to Postharvest Floriculture Laboratory, Institute of Horticultural Sciences, University of Agriculture, Faisalabad, within 1 h of harvest. On arrival, stems were sorted on the basis of number of open flowers and stem caliper, recut to uniform lengths of 45 cm from stem base to tip, labeled and placed in respective treatments. Solutions were prepared using DW (pH 5.9, EC 0.32 dS·m⁻¹), and stems were placed in solutions within 2 h of arrival in the laboratory. For each species/cultivar, fresh solutions were prepared and used for treating cut stems.

Cut stems were either pulsed with 100 mg·L⁻¹ silver nitrate (AgNO₃) and 5% or 10% sucrose for 24 h before being placed in jars filled with DW or continuously placed in solutions containing 2% or 4% sucrose plus 100 mg·L⁻¹ AgNO₃ until termination. Control stems were placed in DW without any added compounds until termination. Stems were placed individually in glass jars containing 300 mL of vase solution. Stem ends of the flowers pulsed with sucrose solution were rinsed with tap water to remove excessive sugar attached with the stems to reduce microbial contamination, before placing in jars. Stems were kept in a vase life evaluation room at 22 ± 2 °C with 60% ± 10% RH and a 12 h photoperiod provided by cool-white fluorescent tubes. The tubes provided a photosynthetic photon flux density of 8–12 μmol·m⁻²·s⁻¹ at bench level (Ahmad et al., 2014). Experiments were arranged in completely randomized designs, conducted individually for each tested cultivar, and repeated once for confirmation of results. Each treatment had ten individual stem replicates with one stem per jar.

MEASUREMENTS. Stems were monitored daily for vase life (duration

from placement of flowering stems in jars in the postharvest evaluation room to the time when individual flowering stems were ended), water uptake (measured in milliliters from all vases when first stem/species was ended in each experiment) (Ahmad et al., 2014), and number of flowers opened at termination and termination symptoms. Termination symptoms, including petal wilting, petal necrosis, and stem bending, were recorded as present or not present. Stems were ended, if they developed one or more of the aforementioned symptoms on ≥50% of the racemes, leaves, or stem (Ahmad et al., 2013).

STATISTICAL ANALYSES. Data were subjected to analysis of variance procedures using General Linear Models procedures of Statistix (version 8.1; Analytical Software, Tallahassee, FL) and means were compared using Fisher’s least significant difference test at $P \leq 0.05$.

Results

DELPHINIUM. Among tested cultivars, Guardian White delphinium had highest germination percentage (85%, data not presented) and shortest production time (160 d) after sowing (Table 1). By contrast, ‘Aurora White’ and ‘Aurora Blue’ delphinium had 70% or 65% germination (data not presented), respectively, and produced flowers 17–20 d later than ‘Guardian White’ delphinium. Interestingly, Aurora cultivars performed better at warmer temperatures of early summer as they continued flowering until April when daily high temperatures reached above 30 °C (personal observation). ‘Aurora White’ delphinium produced tallest stems (112 cm) with the greatest diameter (11.3 mm) (Table 1). ‘Aurora White’ and ‘Aurora Blue’ delphinium had longer racemes (71.2 and 67.3 cm, respectively) with greater number of flowers per stem (56.9 and 53.8, respectively) compared with ‘Guardian White’ delphinium, which had 44.6 flowers (Table 2). Stems of ‘Aurora White’ delphinium had higher fresh weight (112.2 g) as compared with ‘Aurora Blue’ and ‘Guardian White’ delphinium with 80.6 and 44.6 g fresh weight, respectively. All tested exotic cultivars had similar quality racemes and stem dry weight (Table 2), as well as vase life, which was ≈7 d in the vases containing DW (data not presented).

Table 1. Time to harvest first marketable flower, stem length, and stem diameter of different cultivars of delphinium, snapdragon, and stock. All data represent means of 15 plants.

Treatment		Time to harvest first marketable flower (d) ^z	Stem length (cm) ^y	Stem diam (mm) ^x
Species	Cultivar			
Delphinium	Guardian White	160 c ^w	87.7 b	6.8 c
	Aurora Blue	177 b	99.7 ab	9.8 b
	Aurora White	180 a	112.0 a	11.3 a
Significance ^v		<0.0001	0.0474	0.0003
Snapdragon	Appleblossom	165	109.2 a	9.6 a
	Cheerio	165	57.1 b	7.0 b
Significance		NS	0.0046	0.0410
Stock	Cheerful White	129 c	51.8 a	7.3 a
	Lucinda Dark Rose Double	135 b	37.6 bc	7.2 a
	Lucinda Dark Rose Single	131 bc	36.3 c	6.8 a
	Desi	154 a	40.2 b	4.9 b
Significance		<0.0001	<0.0001	0.0008

^zDuration from sowing until harvest of first marketable stem.^y1 cm = 0.3937 inch.^xMeasured at harvest from just below raceme; 1 mm = 0.0394 inch.^wMean separation within species and columns by Fisher's least significant difference at $P \leq 0.05$.^vProbability values were obtained using General Linear Models procedures of Statistix (version 8.1; Analytical Software); NS = nonsignificant at $P > 0.05$.**Table 2. Flower number, raceme length, flower quality, and stem fresh and dry weight of different cultivars of delphinium, snapdragon and stock. All data represent means of 15 plants.**

Treatment		Flowers (no./raceme)	Raceme length (cm) ^z	Flower quality (1–10 scale) ^y	Stem fresh wt (g) ^x	Stem dry wt (g)
Species	Cultivar					
Delphinium	Guardian White	44.6 b ^w	53.3 b	9.1	44.6 c	10.2
	Aurora Blue	53.8 a	67.3 a	8.5	80.6 b	12.1
	Aurora White	56.9 a	71.2 a	9.2	112.2 a	11.1
Significance ^v		0.0259	0.0404	NS	0.0017	NS
Snapdragon	Appleblossom	16.2 a	15.1	10.0 a	52.1 a	7.1
	Cheerio	12.3 b	13.0	5.6 b	23.8 b	5.0
Significance		0.0054	NS	0.0229	0.0186	NS
Stock	Cheerful White	13.3 a	13.4	9.8 a	58.7 a	6.0 a
	Lucinda Dark Rose Double	13.9 a	10.7	10.0 a	40.9 b	5.3 ab
	Lucinda Dark Rose Single	12.9 a	11.1	5.5 b	27.4 c	4.4 b
	Desi	9.8 b	11.8	3.0 c	11.9 d	1.8 c
Significance		0.0093	NS	<0.0001	0.0005	0.0002

^zFlowering portion of the stem bearing flowers; 1 cm = 0.3937 inch.^y10 = best quality, 5 = average, 1 = poor quality.^x1 g = 0.0353 oz.^wMean separation within columns by Fisher's least significant difference at $P \leq 0.05$.^vProbability values were obtained using General Linear Models procedures of Statistix (version 8.1; Analytical Software); NS = nonsignificant at $P > 0.05$.

SNAPDRAGON. The local cultivar, Cheerio, snapdragon had higher germination percentage (99%) compared with exotic cultivar, Appleblossom snapdragon [70% (data not presented)] and both cultivars were ready to harvest at same time, 165 d after sowing the seeds (Table 1). However, 'Appleblossom' snapdragon produced three times more marketable stems per plant (data not presented) and two times taller stems (109.2 cm) as compared with 'Cheerio' snapdragon (57.1 cm) (Fig. 1). 'Appleblossom' snapdragon produced the greatest stem diameter (9.6 mm), flower number per stem (16.2), flower quality, and stem fresh

weight (52.1 g) as compared with 'Cheerio' snapdragon (Table 2). However, no differences were recorded between the cultivars for length of racemes and stem dry weight.

STOCK. Exotic cultivars of stock flowered earlier (129–135 d) with greater stem diameter (6.8–7.3 mm), higher number of flowers per stem (12.9–13.9), greater fresh and dry weight of stems (27.4–58.7 and 4.4–6.0 g, respectively), and better stem quality (5.5–10.0) with longer vase life (7.8–9.9 d) as compared with local cultivar Desi (Tables 1 and 2), but had similar germination percentage, which averaged 87% (data not presented).

Among exotic cultivars, Cheerful White stock produced stems with the greatest stem length (51.8 cm) and highest fresh and dry weight of a stem (58.7 and 6.0 g, respectively), and shorter time to harvest first marketable stems [129 d (Tables 1 and 2)] than 'Lucinda Dark Rose Double' and 'Lucinda Dark Rose Single' stock. 'Lucinda Dark Rose Double' stock also had attractive bicolor racemes with high quality sturdy stems (personal observation). 'Lucinda Dark Rose Single' and 'Desi' stock produced inferior quality stems and had shorter stems and vase life compared with 'Cheerful White' and 'Lucinda Dark Rose Double' stock.

Fig. 1. Comparison of stem length of exotic ‘Appleblossom’ (A) and local ‘Cheerio’ (B) snapdragon.

Raceme length did not differ among cultivars.

POSTHARVEST EVALUATION. Use of sucrose for short-term pulsing or continuous application as vase solution supplemented with $100 \text{ mg} \cdot \text{L}^{-1}$ AgNO_3 extended the longevity and increased water uptake of tested cultivars (Fig. 2). Stems of all tested cultivars of stock and snapdragon had the longest vase life when placed continuously in 4% sucrose supplemented with $100 \text{ mg} \cdot \text{L}^{-1}$ AgNO_3 (Fig. 2A–C). For ‘Cheerful White’ and ‘Lucinda Dark Rose Double’ stock, overnight pulsing with 10% sucrose plus $100 \text{ mg} \cdot \text{L}^{-1}$ AgNO_3 also extended vase life by 2.5 and 2.8 d, respectively, compared with stems placed in DW.

Snapdragon stems had similar water uptake irrespective of preservative solutions. For ‘Cheerful White’ and ‘Lucinda Dark Rose Double’ stock, stems placed in 2% or 4% sucrose vase solutions or pulsed overnight with 10% sucrose had higher water uptake than stems placed in DW (control) and 5% sucrose pulsing (Fig. 2D–E). All tested cultivars had

a similar number of opened flowers at termination, whereas petal wilt, petal necrosis, or both were major symptoms of termination along with stem bending of local ‘Cheerio’ snapdragon (data not presented).

Discussion

PRODUCTION EVALUATION. Demand for new cut flowers is rapidly increasing in today’s competitive floriculture industry. Every year, hundreds of new cultivars are being released and tested in different growing regions of the world. However, Pakistan’s cut flower industry is dominated by a few traditional cut flower crops. Therefore, growers as well as consumers have limited choices to fulfill their esthetic needs (Ahmad and Dole, 2014). This study demonstrated the response of potential exotic specialty cut species/cultivars viz. delphinium, snapdragon, and stock tested here in Faisalabad, Punjab, Pakistan, for diversification of local cut flower production. The results demonstrated that the tested cultivars can successfully be grown outdoors in Punjab, Pakistan, during winter and

are one of the best options for local small-scale flower businesses.

The exotic cultivars produced superior quality cut stems with longer stems over the local cultivars in the agro-climatic conditions of Faisalabad, Pakistan. ‘Appleblossom’ snapdragon and ‘Cheerful White’ stock had longer stems compared with local cultivars. Stem length is a major factor affecting cut flower quality and determining its price in the market. For highest prices, longer stems are preferred and should be $\geq 60 \text{ cm}$. ‘Appleblossom’ snapdragon stems had the greatest stem length, which was more than twice the length of local ‘Cheerio’ snapdragon and was tall enough to be considered a top-quality cut flower. Moreover, ‘Appleblossom’ snapdragon and ‘Cheerful White’ stock stems had greater stem diameters compared with local cultivars (Table 1). Stem diameter is an important quality factor because weak stems with smaller diameters may not be able to support heavy inflorescences and tend to break after harvest (Liang and Harbaugh, 2001). In addition, ‘Appleblossom’ snapdragon produced more than double the number of marketable stems compared with local ‘Cheerio’ snapdragon (data not presented). These results demonstrated better performance of exotic cultivars compared with local ones in terms of higher yields of the best quality cut stems. The tested cultivars produced longer sturdy stems with best quality flowers and had longer vase life than local cultivars tested. Moreover, exotic stock cultivars produced flowers in shorter time compared with local cultivars (personal observation). Similarly, on account of higher quality, stems of exotic cultivars had greater biomass than local ones, which make these cultivars highly desirable as cut flowers. Several factors such as production time, soil conditions, ability to produce high quality stems, and climatic conditions, particularly temperature and light intensity and duration during production, affect the successful production of a new species in a particular region (Dole and Greer, 2009).

POSTHARVEST EVALUATION. Short-term pulsing or continuous application of sucrose as vase solution extended the longevity and increased water uptake of stock cultivars (Fig. 2). ‘Cheerful White’ stock and ‘Appleblossom’ snapdragon stems

Fig. 2. Effect of pulse or vase preservative solutions on vase life (A–C) and water uptake (D–F) of different cultivars of stock and snapdragon. Data represent means of 10 stems placed individually in vases $\pm$ SE. Silver nitrate (AgNO_3) was used at $100 \text{ mg}\cdot\text{L}^{-1}$ (ppm) and sucrose (S) at either 5% or 10% in a 24 h pulse or 2% or 4% in the vase solution continuously; $1 \text{ mL} = 0.0338 \text{ fl oz}$.

had the longest vase life when placed continuously in 4% sucrose supplemented with $100 \text{ mg}\cdot\text{L}^{-1} \text{ AgNO}_3$ (Fig. 2A and C). Some species, such as delphinium, marigold, or snapdragon, require carbohydrates in the vase solution to continue their metabolic activities; therefore, cut stems should be kept continuously in a sucrose solution after harvest (Dole et al., 2013; Ichimura et al., 2000). Regan and Dole (2010) also noted that continuous use of 2% sucrose in vases extended the vase life of cut stock stems. A holding solution of sucrose with antimicrobial agents extended the vase life of snapdragon up to 3 d (Ahmad and Dole, 2014; Nowak and Rudnicki, 1990). Sucrose as a carbohydrate source encouraged

flower opening and increased the vase life.

Use of AgNO_3 , an antimicrobial agent, reduced bacterial population (personal observation) as compared with control and increased uptake water (Ahmad et al., 2013; Celikel and Reid, 2002; Dole and Wilkins, 2005). Stems of 'Cheerful White' stock placed in 4% sucrose vase solution supplemented with $100 \text{ mg}\cdot\text{L}^{-1} \text{ AgNO}_3$ had highest water uptake (121 mL), whereas those of 'Lucinda Dark Rose Double' stock had highest uptake when pulsed with 10% sucrose or continuously placed in 2% or 4% sucrose vase solutions supplemented with $100 \text{ mg}\cdot\text{L}^{-1} \text{ AgNO}_3$ (95, 91, or 86 mL, respectively) (Fig. 2D and E). These findings indicated the necessity

of using a biocide in preservative solutions to reduce microbial plugging or air embolisms at stem ends, which increased water uptake by the cut stems and extended vase life (Ahmad et al., 2014).

In summary, exotic 'Appleblossom' snapdragon and 'Cheerful White' and 'Lucinda Dark Rose Double' stock cultivars performed better than local cultivars. 'Guardian White' delphinium proved to be an early flowering cultivar, while 'Aurora Blue' and 'Aurora White' delphinium flowered later, but were quite tolerant to higher temperatures of above 30°C . The exotic cultivars produced the high-quality strong stems with a long vase life and were best suited for commercial production in Punjab, Pakistan, as specialty cuts. Moreover, postharvest pretreatment of cut stems with 10% sucrose supplemented with $100 \text{ mg}\cdot\text{L}^{-1} \text{ AgNO}_3$ for 24 h or vase solution of 4% sucrose supplemented with $100 \text{ mg}\cdot\text{L}^{-1} \text{ AgNO}_3$ extended the vase life and increased water uptake by cut stems.

Literature cited

- Ahmad, I. and J.M. Dole. 2014. Optimal postharvest handling protocols for *Celosia argentea* var. *cristata* L. 'Fire Chief' and *Antirrhinum majus* L. 'Chantilly Yellow'. *Scientia Hort.* 172:308–316.
- Ahmad, I., J.M. Dole, A.S. Carlson, and F.A. Blazich. 2013. Water quality effects on postharvest performance of cut calla, hydrangea, and snapdragon. *Scientia Hort.* 153:26–33.
- Ahmad, I., J.M. Dole, F. Schiappacasse, M. Saleem, and E. Manzano. 2014. Optimal postharvest handling protocols for cut 'Line Dance' and 'Tap Dance' *Eremurus* inflorescences. *Scientia Hort.* 179:212–220.
- Celikel, F.G. and M.S. Reid. 2002. Postharvest handling of stock (*Matthiola incana*). *HortScience* 37:144–147.
- Clark, E.M.R., J.M. Dole, A.S. Carlson, E.P. Moody, I.F. McCall, F.L. Fanelli, and W.C. Fonteno. 2010. Vase life of new cut flower cultivars. *HortTechnology* 20:1016–1025.
- Dole, J.M. and L. Greer. 2009. Production protocol development for greenhouse cut *Linaria*, *Lupinus* and *Papaver* flowers. *Scientia Hort.* 122:233–237.
- Dole, J.M. and H.F. Wilkins. 2005. *Floriculture: Principles and species*. 2nd ed. Prentice Hall, Upper Saddle River, NJ.

- Dole, J.M., V. Zenaida, F.L. Fanelli, and W.F. Fonteno. 2009. Postharvest evaluation of cut dahlia, linaria, lupine, poppy, rudbeckia, trachelium, and zinnia. *HortTechnology* 19:593–600.
- Dole, J.M., A.S. Carlson, B.D. Crawford, and I.F. McCall. 2013. Vase life of new cut flowers. *Acta Hort.* 1000:63–70.
- Ichimura, K., K. Kohata, and R. Goto. 2000. Soluble carbohydrates in delphinium and their influence on sepal abscission in cut flowers. *Physiol. Plant.* 108:307–313.
- Liang, R. and B. Harbaugh. 2001. Evaluation of trachelium cultivars as cut flowers. *HortTechnology* 11:316–318.
- Nasir, Y.J. and R.A. Rafiq. 1996. *Wild flowers of Pakistan*. Oxford Univ. Press, Karachi, Pakistan.
- Nowak, J. and R.M. Rudnicki. 1990. Postharvest handling and storage of cut flowers, florist greens, and potted plants. Timber Press, Portland, OR.
- Regan, E.M. and J.M. Dole. 2010. Postharvest handling procedures of *Matthiola incana* ‘Vivas Blue’. *Postharvest Biol. Technol.* 58:268–273.
- Starman, T.W., T.A. Cerny, and A.J. MacKenzie. 1995. Productivity and profitability of some field-grown specialty cut flowers. *HortScience* 30:1217–1220.