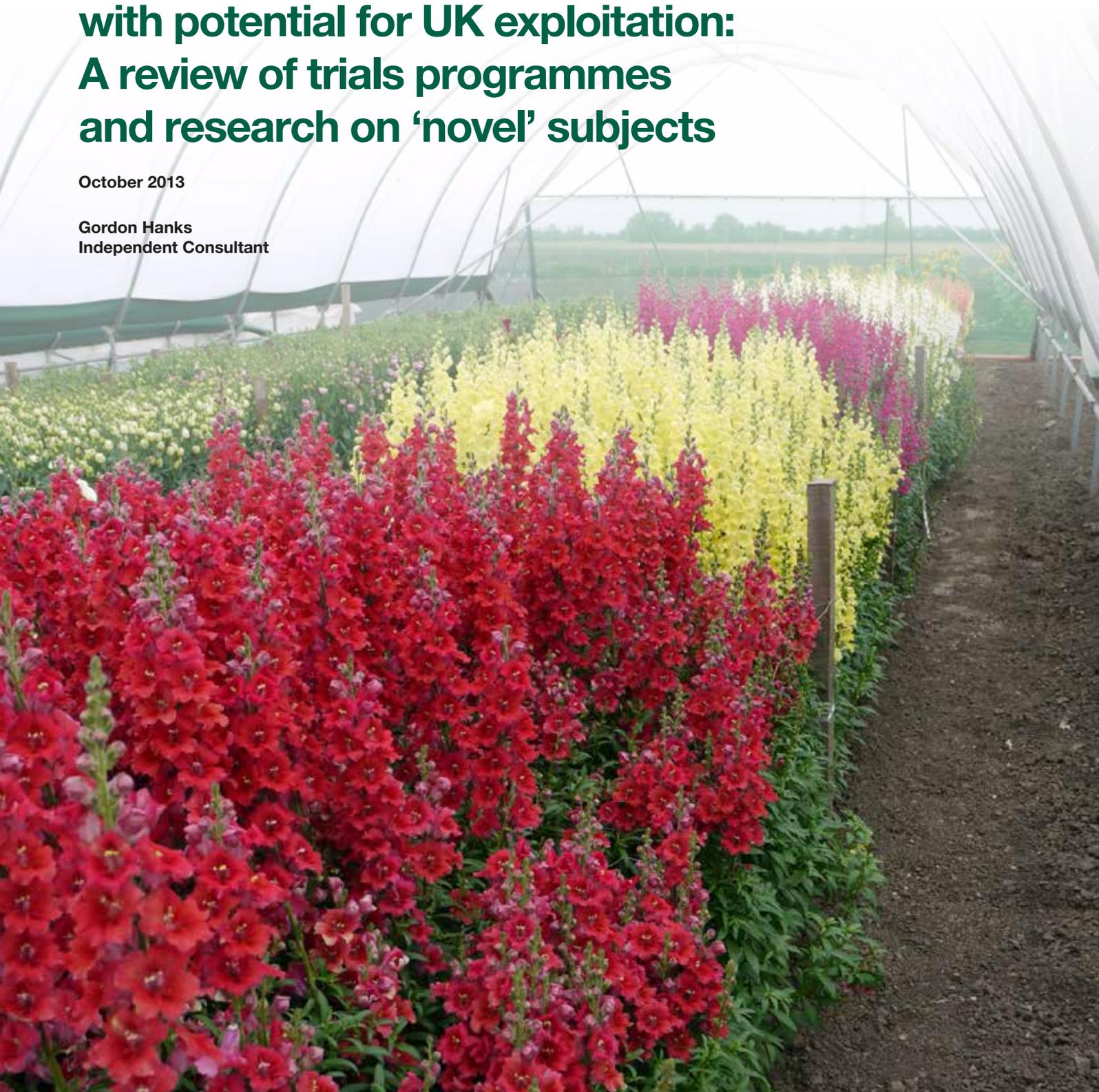




Field- and tunnel-grown cut-flowers with potential for UK exploitation: A review of trials programmes and research on 'novel' subjects

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Gordon Hanks
Independent Consultant



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Aims and scope of the review

Through carrying out a programme of information gathering, trials, demonstrations and technology transfer, the HDC-funded Cut-Flower Association (CFA; formerly operating as the National Cut-Flower Trials Centre, CFC) aims to encourage an appropriate expansion of cut-flower production in the UK.

One particular aim is to research 'novel' cut-flower subjects, novel in this context meaning flowers that are currently little known, or not grown, as cut-flowers in the UK. The project's remit primarily covers species suitable for growing outdoors in the field or in Spanish tunnels, though an extension into production under glass (to achieve continuity or extension of season) is not excluded. Annual, biennial and perennial species, bulbous plants, herbaceous and shrubby species, foliage and fillers, are all potentially included.

The current HDC-funded project runs from 2013 to 2017, and this review is part of the initial phase of information-gathering. The intention is to inform UK growers, technologists and researchers about new crop opportunities, and specifically to:

- Review worldwide research on novel cut-flower crops and how to optimise their commercialisation, and use this information to inform the CFA's programme of trials and demonstrations.
- Review trials programmes on cut-flowers and cultivars including novel subjects.
- Facilitate access to other sources of information on cut-flower production.
- Where possible, summarise data on production levels and trends in the cut-flower trade (this topic will be covered in a later update of the review).

The review uses both Internet sources and CABI's Horticultural abstracts database, and initially covers a period from about 2000 to date. It is a work in progress and will be extended and updated over the lifetime of the project. It is divided into four sections reviewing:

- Research on novel cut-flower crops.
- Cut-flower trials and programmes.
- Cultivar comparisons.
- Sources of information.

Research on novel cut-flower crops

Azalea

In studies in Germany it was found that azaleas are suitable for cultivation under glass as winter cut-flowers (Tiede, 2000). The article deals with flowering time, substrates and using gibberellins for the control of stem elongation.

New South Wales Christmas bush (*Ceratopetalum gummiferum*)

The Christmas bush is a native New South Wales shrub with attractive bright red fruiting calyces used in seasonal decorations. By the late-1990s some was being bush-picked and cultivated plants were of variable quality, but it was becoming sought after on international markets. At that time there was only one selected clone, 'Albery's Red', in cultivation, although there was also a selection with white calyces (Johnson and Ronowicz, 2000). In 1998 a project was set up in Queensland to identify the factors affecting its export potential (Zorin *et al.*, 2000). Two cultivar trials were set up using 'Albery's Red', 'Shiraz', 'Festival', 'True Blue' and 'Fairley's Coral Pink' at one site and 'White Christmas', 'Martin Place', 'KSCL 4', 'KSCL 6', 'True Blue', 'Wentworth Falls', 'Linden Late', 'KSCL 9', 'Bulli' and 'Fairley's Coral Pink' at another. These trials provided growers with recommendations on cultivars, crop management and growing conditions.

In later studies protected cropping was found to increase vase-life compared with field-grown materials, but the results were inconsistent between different locations (Ekman and Worrall, 2005). Larger stems had a significantly longer vase life than small ones. Differences in vase-life between the largest and smallest stems increased when the material was stored for 12 days at 5°C. Thick stems took up most water, but thin stems took up more water per unit weight.



Ceratopetalum gummiferum

Lily-of-the-valley (*Convallaria majalis*)

Convallaria was recently mentioned as a promising cut-flower by John Dole, following testing in the Association of Specialty Cut Flower Growers (ASCFG) National cut flower trials (Shaddick, 2012). This may seem a surprising finding, but was popular 50 years ago in the UK. No references to lily-of-the-valley as a cut-flower were found in a search of horticultural abstracts from 2000 to date (though many papers report on it as a source of pharmaceutical chemicals). Rather dated recommendations for its production as a cut-flower were given in some older ADAS literature (Ministry of Agriculture, Fisheries and Food, 1967). It can be grown outdoors or under protection, and can be forced for all-year-round (AYR) production.

Bleeding heart (*Dicentra spectabilis*)

Dicentra was recently noted as a promising cut-flower by John Dole, following testing in the ASCFG National cut flower trials (Shaddick, 2012). No references to *dicentra* as a cut-flower were found in a search of horticultural abstracts from 2000 to date, other than as a student exercise (Spaw *et al.*, 2008). Two papers dealt with the effect of cold and of gibberellic acid treatments (it had a cold requirement for flowering and gibberellic acid did not substitute for a cold treatment) (JeongSeob *et al.*, 2003) and clonal selection for naturalising in northern urban areas of Norway (Tuhkanen and Juhanaja, 2010).

Gentian (*Gentiana* species)

Cut-flower gentians have developed into a significant cut-flower crop in New Zealand and Japan. In New Zealand investigations have been undertaken to improve their post-harvest characteristics, establishing a baseline for selection of new cultivars with superior post-harvest performance. For *Gentiana triflora* the results suggested that sucrose and silver thiosulphate (STS) acted similarly on soluble sugar changes and ethylene production to inhibit flower senescence (Zemin and Leung, 2001). Using three *G. triflora* cultivars, 'Nasu No-Hakuryo' (white), 'Late Blue' (blue) and 'Ashiro No-Ake' (blue), it was shown that post-harvest quality was influenced by maturity at harvest, pulsing solutions, cultivar, fluoride and post-harvest storage. In particular, pulsing solutions containing sucrose or gibberellic acid extended vase-life of 'Late Blue' and enhanced the blue colour of buds of 'Ashiro No-Ake'; there was no improvement in the case of 'Nasu No-Hakuryo'. The effectiveness of these treatments was reduced when stems were not subjected to extended periods of post-harvest storage, or when stems were harvested at an advanced stage of development (Eason *et al.*, 2004).



Gentiana asclepiadea 'Knightschayes'

Also in New Zealand improvements have been sought to gentian cultivars to provide high-quality, resilient stems suitable for the export trade and with an expanded colour range. One aim is to produce inter-specific hybrids between *G. triflora* and *G. lutea* with the goal of producing yellow-flowered cultivars (Morgan, 2004; Morgan *et al.*, 2009). A new red cultivar, *G. triflora* 'Showtime Starlet', produced stems

longer than 50cm long, was not self-fertile (thereby reducing pollination-dependent flower senescence) and was relatively insensitive to ethylene (Eason *et al.*, 2007). Approaches to Plant and Food Research (New Zealand) for information have been unsuccessful.

In Japan gentians have been the subject of further relevant studies. To reduce post-harvest deterioration, methods (involving the UV spectral radiance of the corolla) have been researched to determine the optimum harvest time (Shono and Nishikawa, 2004; Shono *et al.*, 2009). Soil chemistry has also been studied with a view to improving production (Satoh *et al.*, 2004).



Gentiana species

The author has seen apparently Dutch-grown cut-flower gentians used by florists in the Spalding area (*Gentiana species* image). The tiered inflorescences were a spectacular blue with stems about 60 cm long, and vase-life was about 10 days.

Hellebores (*Helleborus* species)

Hellebores were recently mentioned as a promising cut-flower by John Dole, following testing in the ASCFG National cut flower trials (Shaddick, 2012). However, no specific references to cut-flower production were found in a search of horticultural abstracts from 2000 to date, though three papers incidentally mentioned its importance as a cut-flower; thus, "*Helleborus niger* ... is one of the most popular Christmas cut flowers cultivated in the South of France and exported at 95% to Germany, the Netherlands, Switzerland and Belgium. The intense production of this selected clone, which flowers just before Christmas, is limited by the low vegetative multiplication rate and by some specific diseases..." (Poupet *et al.*, 2006). In Italy "the plants are much in demand, especially as cut flowers in winter..." (Tallarico *et al.*, 2007). And, in Belgium "the increased horticultural interest in *Helleborus* requires the development of techniques for flowering control" (Christiaens *et al.*, 2012).

Ixodia achillaeoides subsp. *alata*

Ixodia is one of several genera of shrubby Australian everlasting daisies with uses in horticulture (Barker *et al.*, 2002). *Ixodia achillaeoides* subsp. *alata* was previously harvested for the dried flower trade, and is undergoing selection as a novel cut-flower. (Barth and Chinnock, 2000). It produces terminal flowering stems of white everlasting blooms of unique appearance and durability, and shows considerable variation in morphological and physiological characteristics which greatly influences floricultural potential. Field trials of selected varieties have provided standards against which new cultivars can be judged. Agronomic and post-harvest performance and floral descriptions are used for the selection of superior varieties for floriculture markets as cut-flowers and pot-plants. No further research papers on this species have been found, but *Ixodia* could be a genus to watch.



Ixodia achillaeoides

Lion's ear (*Leonotis leonurus*)

Leonotis is a South African plant being introduced into cultivation. It is aromatic, has attractive orange flowers, and is easy to grown in various regions. Field studies were conducted in Poland from 1997 to 2001, using seeds collected from Australia and Poland. Flowering took place from July to late-autumn. *Leonotis* species had a height of 120 to 300 cm and produced dense inflorescences consisting of 80 to 200 flowers at two to six levels on long, upright stems (Startek and Wraga, 2003).

Leonotis is one of numerous new floricultural crops being successfully introduced to Israel. However, its post-harvest life is limited due to abnormal flower opening, rapid senescence and abscission, and colour fading. Research to develop post-harvest treatments (sugars and ethylene inhibitors) for improving flower quality showed that the flowers respond positively and an optimal post-harvest treatment was developed (Meir *et al.*, 2009). An extended longevity of 12 days, with fully open flowers, was obtained after 48 hours of simulated air transport.

Other studies on cultivation have taken place in Italy (Frangi and Nicola, 2005; Roxas *et al.*, 2006). At the end of December rooted cuttings were pruned back and moved to an unheated plastic greenhouse; flowering started in April under protected cultivation and continued throughout the summer months, while plants kept outside flowered from June/July to late-October (Roxas *et al.*, 2006).



Leonotis leonurus

Lupins (*Lupinus havardii* and other lupin species)

Lupinus havardii (big bend bluebonnet) occurs along the Rio Grande River, Texas, and produces attractive tall blue flowers with potential as a new specialty cut-flower. *L. havardii* has been the centre of extensive research at Texas A&M and New Mexico State Universities. This species is very sensitive to ethylene, and several papers have been published on improving post-harvest life using sucrose, gibberellic acid and ethylene antagonists (Mackay *et al.*, 2000, 2005b, 2007; Sankhla *et al.*, 2005a, b; Valenzuela-Vázquez *et al.*, 2007), calcium and water regimes (Meir *et al.*, 2009; Picchioni *et al.*, 2001, 2002, 2007), and phenotypic selection (Mackay *et al.*, 2005a).

Two of these projects researched other potential lupins (lupines in the USA), such as *L. densiflorus*, which is less sensitive to ethylene than *L. havardii* (Mackay *et al.*, 2001; Sankhla *et al.*, 2005b). Another project involved using four advanced breeding lines (Sankhla *et al.*, 2005a, b). Several blue, white and pink selections have been produced with reduced ethylene sensitivity and extended vase-life. Based on test marketing and limited commercial production, 'Texas Sapphire' (blue) and 'Texas Ice' (white) have been released (Mackay *et al.*, 2007).



Lupinus havardii



Lupinus densiflorus

Saussurea pulchella

Saussurea is a biennial native to Japan, and some elite selfed lines have been selected. These flower in a year from seed and have deeper flower colour, more inflorescences and shorter peduncles compared with the wild forms (Yamasaki and Nishiuchi, 2000). When seeds were sown from February to May the plants flowered in the same year, although seeds sown from July to September produced rosettes the plants flowered the following year. Plants from seeds sown in March or April and pinched above the sixth node in August, flowered in October with a greater number of high-quality cut-flowers in the field. Bolting from rosette plants from seeds sown in October was enhanced under long day conditions in both heated and non-heated glasshouses, but flowering of the plants was delayed under long days.



Saussurea pulchella

Verticordia species

Despite reports of difficult cultivation, this may be a genus to watch. An Australian shrub of the myrtle family, it yields a profuse and striking display of intricate flowers which have been harvested for floristry. Verticordia is being researched in Israel with the aim of commercialisation (Ben-Jaacov *et al.*, 2000).

In Australia, 21 selections from 16 species of *Verticordia* were tested for vase-life and bud or flower drop (Seaton, 2006). Vase-life ranged from five days for *V. nitens* 'yellow form' to 19 days for *V. densiflora* var. *cespitosa*, with an average vase-life for all selections of 12 days. Nine selections had significant increases in floral organ drop following exposure to exogenous ethylene. Bud/flower drop ranged from 7% for *V. serrata* to 83% for *V. nitens* 'orange form'. Twelve selections, including *V. plumosa* var. *plumosa*, *V. densiflora* var. *cespitosa* and *V. monodelpha* var. *monodelpha*, were insensitive to exogenous ethylene. Two selections, *V. dichroma* var. *dichroma* and *V. grandis*, had over 9% floral organ drop irrespective of whether they were exposed to ethylene or not. These post-harvest responses were analysed according in their sub-genera, *Chrysoma*, *Eperephes* and *Verticordia*. All selections in the sub-genus *Chrysoma* (such as *V. nitens*) were sensitive to ethylene and had a short vase-life. 40% of selections in the sub-genus *Eperephes* were sensitive to ethylene and had a medium vase-life, and all selections in the sub-genus *Verticordia* were insensitive to ethylene and had a long vase-life.



Verticordia chrysostachys

Israeli introductions

The Israeli ornamentals industry has maintained a strong programme of introducing new species to commerce, derived especially from the native geophytes of the region, such as anemone, ranunculus, cyclamen, hyacinth, tazetta narcissus, *Lilium candidum* and tulip species, which were all relatively easy to commercialise. In addition there are several native plants still in the process of introduction, including the bulbous *Oncocycclus* irises, *Scilla hyacinthoides* and *Urginea maritima*, annuals such as *Centaurea crocodylleum* and *Lupinus pilosus*, and herbaceous perennials like *Eremostachys laciniata* and *Helichrysum sanguineum* (Halevy, 2000). This progress of this programme should be watched.

Review of cut-flower trials and programmes

Over time and across many countries there have been many 'cut-flower trials' which have been intentionally very practical and parochial in nature to inform producers in specific countries or regions. Such trials often seek to examine a wide range of cut-flower species, including novel ones, with the aim of discovering which crops are best suited for growing in the local area under current husbandry practices. A number of these with relevance to the UK are reviewed below.

The USA is the most evident source of such trials-based information on a comprehensive range of cut-flower crops, including new introductions. There are several trials programmes at (or co-ordinated through) universities, as a result of which many university extension services provide useful and freely accessible websites with leaflets and other downloadable documents. This may be a benefit of the 'Land-Grant University' system which provided sites and funding for universities that supported agricultural and other technical disciplines. Some projects have been relatively short-term, while others have been on-going and evolutionary, as the CFA's programme is intended to be.

Santa Rosa Specialty cut-flower trials

A wide-ranging cut-flower trial was carried out by the local Co-operative Extension Service from 1994 to 1997 in NW Florida, an area where horticultural skills were present but there was no history of field-grown cut-flower production (Mullins and Travis, 1997). An initial seminar showed strong interest among local growers in setting up a demonstration site to investigate which cut-flower crops would perform well and provide a means of diversification for local growers. In the Santa Rosa [County] Specialty cut-flower trials 56 species or cultivars were evaluated over three years, following simple but reproducible protocols (e.g. all crops were grown at one in-row spacing and on beds covered with a black mulch) with plot replication; the project could be seen as a 'model' cut-flower screen. The assessments involved growers and retail and wholesale customers. It was interesting to note that the local industry was surprised by the quality of the stems produced, as in the case of the CFA's trials.

The results identified the species and cultivars having the most potential for outdoor production in the area (Table 1). It was noted that the main determinant was the wholesaler's ideas on species and colour. The remaining, apparently less suitable crops, or perhaps those that would require more investigations before growing on a commercial scale, are listed in Table 2.

Of the 34 genera listed in Tables 1 and 2, 23 have been included in CFA trials (or the Defra-funded trials at Kirton that preceded them), including cosmos and zinnia which have been investigated (or re-investigated, in the case of zinnia) as a result of the current review of novel crops. Six of the genera would probably be considered already well known among UK field- or tunnel-raised flower growers – delphinium, dianthus, gladiolus, sunflower (helianthus), statice (limonium) and stock (matthiola) – although the CFA is still continuing trials on most of these, indicating the need for further research. However, of the genera trialled by the CFA, for most there was insufficient

interest by the cut-flower industry to justify further trials, the exceptions being snapdragons (antirrhinum), where interest has developed in the new 'trumpet' cultivars, and eustoma, where unexpectedly good crops have been obtained by growing in tunnels. Interest was also expressed in caryopteris, though the scent discouraged further trialling, and zinnia, for which the superb colour and flower shape were found very attractive but which were let down by poor stem strength and vase-life – this is now being continued using cultivars grown in the USA. Several genera tried in Santa Rosa have not yet been tested by the CFA: Asclepias, Calendula, Campanula, Centaurea, Liatris, Monarda, Penstemon, Platycodon, Triticum, Verbena and Veronica, and of these the reports on Verbena suggest that it too could also be trialled at the CFC.

The ASCFG National cut-flower trials programme

The ASCFG trials "are recognised as the only national cut flower evaluations in the country. Growers in all [climatic] zones test new annual, perennial and woody cut flower [sic] for hardiness, yield, stem length and marketability. Breeders and suppliers rely on these trials as an integral part of their cultivar development and evaluation process. Data are compiled by Dr John Dole at North Carolina State University (NCSU), where postharvest testing is also done," see: http://www.ascfg.org/index.php?option=com_content&task=view&id=116&Itemid=353

The cut-flowers are tested at about 50 locations across the USA and Canada, primarily at commercial cut-flower nurseries, but also at some universities and co-operative extension service providers. Full details of the scheme can be found on the NCSU website: <http://www.ncsu.edu/project/cutflowers/trials/index.htm>

Programmes were established for annuals in 1993, for perennials in 1998 and for woody subjects in 2004. The trials provide rankings based on a combined score incorporating (a) market appreciation, (b) the testers' willingness to grow the crop again, and (c) ease of cultivation. The plants are also assessed for yield, stem length and post-harvest life. Post-harvest information is collected by NCSU on a number of the crops each year, and eight years' work has been summarised for 121 cultivars covering 47 genera (Clark *et al.*, 2010); the data can also be accessed at: <http://www.ncsu.edu/project/cutflowers/postharvest/index.htm>.

Every year the results are published in winter issue of The Cut Flower Quarterly www.ascfg.org (also available via the NCSU website referenced above), while a summary is published in Greenhouse Product News (www.gpnmag.com) In addition each year the best five are nominated for the ASCFG "Cut Flower of the Year" award in fresh, woody and bulbous categories. Recent "Cut Flowers of the Year" are listed in Table 3 and further details can be found on the ASCFG website: http://www.ascfg.org/index.php?option=com_content&task=view&id=457&Itemid=458.

The NCSU website provides a list of species evaluated from 1993 to the latest year available, and the latest list (2011) has been reproduced in Table 4 for reference.

Table 1 Species and cultivars judged as having potential as field-grown cut-flower in Santa Rosa County, Florida. All were grown as transplanted plugs unless otherwise stated

Species and planting season	Cultivar (if given)	Comments
<i>Ageratum houstonianum</i> (spring)	'Blue Horizon'	Heavy production over two months, but at 30 cm the stems were shorter than desired.
<i>Ammi majus</i> (spring)	-	Vigorous and heavy-cropping, with 12 cm flower clusters on 81 cm stems.
<i>Antirrhinum majus</i> (autumn)	'Rocket Mixed'	Long flower spikes on 66 cm stems in spring.
<i>Asclepias tuberosa</i> (spring, direct-seeded)	-	Flowered on 50 cm stems. Heat-tolerant.
<i>Caryopteris incana</i> (spring)	'Blue Mist'	The most surprising flower in the trial. Flowered on 50 cm stems and the unusual flower design was attractive to florists.
<i>Celosia spicata</i> (spring)	'Flamingo Feather Pink' 'Flamingo Feather Purple'	Outstanding, flowered for three months with 91 cm stems. Small flower heads – a filler.
<i>Celosia plumosa</i> (spring)	'Century Mixed' 'Century Cream'	Flowered throughout summer, heat-tolerant. Large flower heads but stems only 40 cm.
<i>Delphinium</i> species (autumn)	'Pacific Giant Mix' 'Magic Fountain Mix'	Flowered well through April and May. 'Pacific Giant Mix' very prolific but stems considered too large for florists.
<i>Dianthus barbatus</i> (autumn)	'Tall Double Mix'	Initially productive, succumbed to heat early-May. Stem length 16 cm.
<i>Eustoma grandiflora</i> (spring)	'Echo Blue' 'Echo Mixed' 'Echo Yellow' 'Heidi Deep Blue' 'Heidi Pink Rim'	All cultivars performed well, 'Echo Blue' was preferred. Stems averaged 40 cm but 50 to 55 cm stems were required.
<i>Gladiolus</i> species (spring, corms)	'Mixed Colours'	Gave 76 cm stems and high-quality flowers. Browning of the calyx was noted, possibly heat-related.
<i>Gomphrena globosa</i> (spring)	'Strawberry Fields'	Very productive. Heat-tolerant. Used for fresh or dry sales.
<i>Helianthus annuus</i> (spring and summer, direct-seeding preferable)	'Schnittgold' 'Sonja' 'Sunbright' 'Valentine'	Most needed pinching to obtain multiple branching and smaller flowers required by florists. Sequential direct-seeding gave continuity.
<i>Helichrysum bracteatum</i> (spring)	'Monstrosum Mixed'	Profuse flowering but stems only 30 cm. Sales mainly limited to autumn. Consider late-spring or early-summer planting.
<i>Limonium sinuatum</i> (autumn)	'Fortress Mix'	Flowered heavily into July. 76 cm stems. One planting failed due to cold-injury.
<i>Matthiola incana</i> (autumn)	'Miracle White' 'Cheerful White'	Flowered for six weeks the next spring. 45 cm stems. Large flower heads.
<i>Monarda citriodora</i> (spring)	-	Tiered flower clusters on 66 cm stems. Provoked much interest.
<i>Monarda didyma</i> (spring)	'Panorama'	Colourful flowers but 35 cm stems.
<i>Verbena bonariensis</i> (spring)	-	Continuous flowering through spring and summer. Sturdy 91 cm stems.
<i>Zinnia elegans</i> (spring, direct-seeding preferable)	'Big Red' 'Enchantress Rose' 'Giant Blue Point Mix'	The most dependable flower in the trial. Continuous flowering on 45 cm stems. Cultivar selection is critical.

Table 2 Species and cultivars judged as currently less suitable in the Santa Rosa County cut-flower trials

Species	Cultivar
<i>Aster</i> species	'Early Pompon Supreme Mix' 'Giant Blue Point Mixed' 'Miss Nippon' 'Pommax Mix'
<i>Calendula officinalis</i>	'Prince Mix'
<i>Campanula calycanthema</i>	'Campanula Mixture'
<i>Centaurea americana</i>	-
<i>Cosmos bipinatus</i>	'Blush Pink'
<i>Craspedia globosa</i>	-
<i>Dahlia</i> species	-
<i>Echinops bannaticus</i>	'Blue Glow'
<i>Godetia amoena</i>	'Grace Mix'
<i>Liatris spicata</i>	-
<i>Nigella damascena</i>	'Persian Jewels'
<i>Penstemon barbatus coccineus</i>	'Husker Red'
<i>Platycodon grandiflorus</i>	'Fuji Mix'
<i>Rudbeckia hirta</i>	'Irish Eyes'
<i>Trachymene coerulea</i>	-
<i>Triticum durum</i>	'Black Tip'
<i>Veronica spicata</i>	'Sightseeing'

Table 3 Recent ASCFG "Cut Flowers of the Year"

Year	Species and cultivar
<i>Fresh category</i>	
2013	Stock 'Katz Cherry Blossom'
2012	<i>Zinnia</i> 'Queen Red Lime'
<i>Woody category</i>	
2013	<i>Symphoricarpos</i> 'Amethyst'
2012	<i>Viburnum</i> 'Wentworth'
<i>Bulbous category</i>	
2013	<i>Ranunculus</i> 'Super Green'
2012	Lily 'Royal Sunset'

Table 4 Plant species evaluated in the ASCFG National cut-flower trials programme (1993-2011)

Abelmoschus	Centranthus	Hydrangea	Physocarpus
<i>Achillea millifolium</i>	Chasmanthium	Hypericum	Physostegia
Aconitum	Chelone	<i>Iberis odorata</i>	Prunus
Adenophora	Chrysanthemum	Ilex	Pycnanthemum
Agastache	Cirsium	<i>Inula grandiflora</i>	Rhynchelytrum
Ageratum	Cleome	<i>Iris siberica</i>	<i>Rudbeckia hirta</i>
Agrostemma	Consolida	<i>Kniphofia thompsonii snowdenii</i>	Salvia
Allium	Coreopsis	Larkspur	Sambacus
<i>Amaranthus cruentus</i>	Cosmos	Lathyrus	<i>Scabiosa atropurpurea</i>
Armeria	Cotinus	Lavetra	Schizachyrium
Ammi	Crocoshmia	Lepidium	Sedum
Ammobium	Delphinium	Leucanthemum	Sidalcea
Anaphalis	Dianthus	Liatris	Silene
Andropogon	Didiscus	Lilium	Snapdragon
Anemone	Digitalis	Limonium	Solidago
Annual aster	Doronicum	Linaria	Solidaster
Antirrhinum	Echinacea	Lisianthus	<i>Spiranthes cerna</i>

Table 4 Plant species evaluated in the ASCFG National cut-flower trials programme (1993-2011) continued

Aquilegia	Echinops	Lobelia	Statice
Aronia	Eragrostis	<i>Lupinus morello</i>	Stipa
Artemisia	Eryngium	Lysimachia	Stock
Asclepias	Eupatorium	Matricaria	Sunflower
Aster	Euphorbia	Matthiola	Sweet pea
Astilbe	Eustoma	Meilca	Sweet william
Astrantia	Flowering kale	<i>Melinis nerviglumis</i>	Sunflower
Baptisia	Gaillardia	Mentha	Syringia
Brassica	<i>Gentiana makinoi</i>	Millet	<i>Tanacetum parthenium</i>
Buddleia	Geum	Miscanthus	Thalictrum
Calamagrostis	Godetia	Monarda	Thermopsis
Calendula	Gomphrena	<i>Nepeta subsessilis</i>	Trachelium
Callicarpa	Gypsophila	Nigella	Trycirtus
Callistephus	Hedychium	Organum	Verbascum
Campanula	Helenium	Panicum	Vernonia
Capsicum	Helianthus	Papaver	Veronica
Carthamus	<i>Helichrysum bracteatum</i>	Patrinia	Veronicastrum
Caryopteris	<i>Heliopsis helianthoides</i>	Pennisetum	Viburnum
Catanache	Helipterum	<i>Penstemon digitalis</i>	Viscaria
Celosia	Helleborus	Pepper	Weigelia
Centaurea	Heptacodium	Persicaria	Zantedeschia
Centaureidum	Heuchera	<i>Phlox paniculata</i>	Zinnia

To give a flavour of the trials carried out, here are the highlights from the latest two reports available – 2010 (Dole *et al.*, 2011) and 2011 (Dole and Laushman, 2012).

2010 highlights

Celosia

‘Red Flame’ (Genesis) achieved the best score, with deep red flowers, leaves and stems and many small to medium heads on side-shoots. It averaged 7 stems per plant 43 cm long. ‘Celway Terracotta’ and ‘Celway Purple’ (Kieft-Pro-Seeds) gave many but smaller flower-heads, averaging eight stems per plant 55 cm long.

Dianthus

Of five cultivars tested, ‘Purple Picotee’, ‘Crimson’ and ‘Crimson Picotee’ (Goldsmith) were prolific, with 12 stems per plant but average stem lengths of 30 cm (though up to 45 cm stems with some growers, good for bouquets).

Lisianthus

Fourteen cultivars were tested, and top-rated this year was ‘Excalibur Yellow’ (Sakata), with an average of three stems per plant and tall stems averaging 60 cm. ‘Vulcan II Deep Purple’ (Takii) was also well-rated.

Marigold

Many of the species trialled in this programme are native North American plants that have become major cut-flowers, such as liatris, lisianthus, sunflower and zinnia. But marigold is the exception, presumably because of its fragrance - or odour, depending on one’s point of view. Despite this, the report authors thought it was time to reconsider the potential of marigolds, which can be highly productive over a long period. The first (and sometimes the second) wave of flowers should be sacrificed to allow the side-shoots to grow long enough to harvest. The top of the stem is hollow, meaning that careful handling is needed. Marigolds work well filling-out bouquets and arrangements. The vase-life is eight to 14 days, depending on the cultivar and flower food used. Some cultivars have stems that are too short, but, of the five cultivars tested (all from Gloeckner), ‘Narai Yellow’ produced 76 cm long stems.

Scabiosa

Scabiosa species are used as cut-flowers, but are relatively unimportant because of the short stems (*Scabiosa caucasica* and *S. stellata*) or small flower-heads (*S. atropurpurea*). ‘Fama Deep Blue Improved’ scored highest of the four cultivars tested (all from Benary), with large blue flowers, long stems and flower production in the first year - though it was reported as little different to ‘Fama Deep Blue’ itself. ‘Fama White’ and ‘Perfecta’ were similar and also collected high scores.

Snapdragon

Two conventional forms – ‘Calima Pure White’ and ‘Calima Yellow’ (Sakata) were among the top-rated cultivars, with averages of five stems per plant 43 cm long, much shorter than glasshouse snapdragons. Of the ‘open-face’ snapdragons, the bright yellow ‘Chantilly Yellow’ (Takii) did well, with eight stems per plant 43 cm long (though some growers attained stems up to 76 cm long).

Stocks

Three cultivars (Ball) performed well, but ‘Katz Bright Rose’ was best with many double flowers and fragrance.

Sunflower

Only one sunflower cultivar was tested, ‘Summer Breeze’ (Takii), a typical tall, large-flowered, non-branching type.

Zinnia

‘Queen Red Lime’ (Benary) created most discussion, with its unusual colour and doubleness, but the flowers were smaller than ‘Giant’ and ‘Uproar Rose’. ‘Benary’s Giant Lime’ also scored highly with its double flowers, although the flowers were smaller than others in the series.

Other species

Also included but less well-rated were amaranthus, aster, campanula, carthamus, iberis, ornamental kale, larkspur, molucella, sea oats and *Setaria*. The reasons for failure included lack of length, poor growth, pests or disease, poor germination, inconsistency, producing foul-smelling vase-water and stems drooping in the vase.

The ‘top-five’

Using a combined score derived from market appreciation, the growers’ willingness to grow the crop again, and ease of cultivation, the top-five plants were the three snapdragon cultivars mentioned above, sunflower ‘Summer Breeze’ and zinnia ‘Benary’s Giant Lime’.

2011 highlights

Ageratum

Among ageratums trialled for summer bouquets, ‘Everest’ (Ball/Kieft), a classic ageratum blue, ranked highly.

Annual asters

Asters featured heavily in the trial with 19 large-flowered cultivars covering a range of colours. Asters were once one of the most important cut-flowers in the USA, but cultivation became difficult in some areas because of Aster Yellow Virus and the requirement for a 12 to 14 hour day for flower initiation. They were grown in the open, in tunnels or in glasshouses. Those of the ‘Bonitas’ series (Sakata/Gloeckner) scored highest, with rich colours similar to the ‘Matsumoto’ series and a tighter centre. The best rated cultivars were ‘Bonitas Pink’ and the bicolor ‘Rose Shanghai Rose-White’ (Gloeckner).

Basil

Basil has become popular as fragrant fillers for bouquets, and ‘Aromato’ (Genesis) was the cultivar of choice. Whether it

was too fragrant or not fragrant enough was a highly personal judgement.

Celosia

Celosias were described as “a variable group of plants ranging from large crested types to those with large plumes, and the search continues for the perfect cultivar”. Good examples were the small-crested ‘Orange Peach’ and ‘Tornado Red’ (Genesis) and the plumed ‘Sunday Dark Pink’ and ‘Sunday Wine Red’ (Ball/Kieft). They were productive and probably amenable to pinching in some cases. ‘Wine Red’ has attractive reddish foliage.

Peppers

For an autumn crop, peppers were highly rated, particularly ‘Orange Globe’ (Genesis) with its large clusters of orange fruit.

Sunflower

Many sunflower cultivars were trialled and some of the most favoured were bicolors: ‘ProCut Amber Glow’, ‘ProCut Bicolor Plus’ and ‘ProCut Lemon Bicolor’ (SeedSense) and ‘Musicbox’ and ‘Ring of Fire’ (Benary). ‘Giant Sungold’ (Benary) with a ‘teddy bear face’ was very tall and thick-stemmed and would probably benefit from pinching to produce multiple heads. Among classic sunflower colours were ‘ProCut Brilliance’ (ruffled orange-gold petals and dark centre), ‘ProCut Gold’ (similar to ‘Brilliance’ but with a green centre; both SeedSense). Some cultivars – such as ‘Valentine’ (Benary), with profuse branching and small heads – were loved or hated depending whether required for bouquets or farmers’ markets.

Other species

Also tested this year but less well-rated were ammi, campanula, craspedia, delphinium, larkspur, lisianthus, rudbeckia, scabiosa and snapdragon.

The ‘top-five’

The top-five plants were the sunflowers ‘Bicolor Plus’, ‘Brilliance’, ‘Gold’ and ‘Red Lemon Bicolor’, and the pepper ‘Orange Globe’.

At a presentation to the Cut-Flower Centre in April 2012, John Dole emphasised the increasing demand of USA consumers for novelty. This was something that US growers were prepared to consider (and are increasing with provision from Spanish tunnels rather than glasshouses), but which Columbian growers were apparently not (Shaddick, 2012). The following specialty cut-flowers received special mention for their success or potential:

- Dicentra.
- Hellebore.
- Lily.
- Lily-of-the-Valley.

For the 2013 cut-flower trials it was planned to include the following:

- *Amaranthus* ‘Elephant Head’ (Genesis).
- *Celosia* ‘Red Flame’ (Genesis) and “Bombay Series” (Kieft-Pro).
- *Dianthus* ‘Sweet Black Cherry’ (PanAmerican).
- “Eggplant pumpkin on a stick” (Genesis).

- *Iberis* 'Yael' (Genesis).
- Larkspur 'Cannes White', 'Arena II Blue Flash', 'Arena II Light Pink' and 'Arena III Baby Pink' (American Takii).
- Snapdragon 'Chantilly Velvet' (American Takii) and 'Purple Twist' and 'Trumpet Pink' (PanAmerican).

The ASCFG National perennial and woody plants trials programme

These results appear to be reported separately from the cut-flowers, and the following are the main points from the 2005 report (the latest report found so far). See http://www.ncsu.edu/project/cutflowers/trials/2005/report_perennial_woody.htm

Callicarpa

'Early Amethyst' was very productive, even in its first year, and gave 47 stems per plant in the second year between 58 and 106 cm long. However, it is necessary to remove the leaves before sale so a cultivar that drops its leaves earlier is needed.

Echinacea

Several interesting cultivars are available and others are on the way. 'Ruby Star' was the best of those trialled and was nominated for best cut-flower from this section.

Eryngium

'Blaukappe' can be used fresh or dry and was highly rated.

Geum

'Fireball' was rated well with large orange flowers, nine stems per plant averaging 63 cm in length.

Heuchera

'Florists Choice' [sic] and 'Magic Wand' averaged 15 stems per plant (up to 35 with some growers) with small heads but stems of 45 to 66 cm.

Hydrangea

'Limelight' was productive with heavy heads, even in the first year, but in the second year gave 91 cm long, strong, straight stems and an average of 26 stems per plant.

Physocarpus

'Diabolo' produced good bronze cut-foliage though yield varied from two to 30 stems per plant in the second year, with stem lengths about 73 cm long.

Zantedeschia

'Edge of Night' was stunning but produced only one to three stems per plant with stem lengths of 35 to 45 cm; despite this, high process could still be realised.

The 'top-five'

These were *Heucheras* 'Florists Choice' and 'Magic Wand', *Zantedeschia* 'Edge of Night', *Geum* 'Fireball' and *Hydrangea* 'Limelight'.

Cornell University cut-flower trials programme

Cut-flower trials are run by Professor HC (Chris) Wien at Cornell University, Ithaca, New York. Unlike the variety testing programme of the ASCFG, here the concentration is on developing production techniques, with a strong element of understanding the physiological processes underlying growth and development. Trials are carried out both in the field and in tunnels, with an emphasis on growing cut-flowers (and other horticultural crops) in 'high tunnels' (what in the UK would be called 'Spanish' tunnels), adding to the relevance of this work to the UK. Detailed reports of trials from 2004 to the present are accessible on the Cornell University website <http://hort.cals.cornell.edu/cals/hort/research/wienresearch.cfm>. This is an impressive programme, despite the report noting that from 2011 the volume of trials had been reduced due to staffing considerations! As an example, the main points from the 2011 cut-flower trials are given below.

Amaranthus topping trial

Three tall amaranthus varieties were grown in a tunnel and either topped in the seedling stage or not. Neither yield nor stem length were affected by the treatment, although topping tended to delay flowering. In this species topping may not be beneficial.

Larkspur topping trial

Two varieties tested in the trial reacted differently to topping: the later, taller 'Sublime White' showed a yield increase, whereas 'Galilee Blue' had a lower yield. Harvest was not delayed by tip removal.

Sunflower pinching and spacing experiment

Two branching cultivars and one single-stem cultivar were grown at 15 x 15, 22 x 22 and 30 x 30 cm spacing and either pinched at the six leaf stage or left untreated. Pinching increased stem numbers by three- or four-fold at all spacings. The increase in planting density reduced flower size to an unmarketable below 3 cm diameter. The highest marketable yields were of 'ProCut' series cultivars 'Amber Glow' and 'Goldrush' pinched and grown at 22 x 22 cm spacing, and of 'Starburst Lemon Éclair' at 15 x 15 cm spacing, not pinched.

Sunflower photoperiod experiment

Thirteen varieties were screened for day-length response by growing them for the first three weeks in short (12 hour) or long (16 hour) days in a glasshouse and then transplanting them to the field. Two showed a short-day response, 'Goldrush' and the standard cultivar 'Sunrich Orange'. All the 'ProCut' lines were insensitive to day-length, increasing their potential to be grown at other times or in places not providing a long summer day-length.

Sunflower pollination experiment

In a preliminary trial sunflowers were either pollinated or not, and the force required to remove petals from the flower head was measured. With the three varieties tested, pollination did not appear to affect the tendency of petals to be lost, but this will be checked again in 2012.

Varietal differences in sunflower petal-detachment force

The time-course of petal retention was measured on four versions of 'ProCut Bicolor' and two standard lines using a

detachment-force meter. Detachment force decreased with time after harvest and varied between the varieties tested. Petals of 'ProCut Lemon' and 'ProCut Bicolor V.2' were significantly harder to detach, indicating their longer vase-life, a finding that confirms similar tests run in 2010.

Influence of angle of pull on detachment force values in sunflower petal detachment

Petal detachment was done more easily when the petal was pulled backwards toward the stem, than if pulled forward in the direction of petal insertion on the head. Preliminary measurements indicated similar varietal differences as when the previously standard technique was used, i.e. pulling out the petals parallel to the surface of the disc. The ease of petal loss when flower heads were brushed against an obstruction was probably similar to the backward pull method used here.

***Ammi majus* variety trial**

Ammi 'Pink' was compared with the carrot variety 'Black Prince'. Fewer than half the ammi plants flowered, and in those the flower colour was closer to white than pink. 'Black Prince' was more prolific, but the umbel colour tended to grey rather than black.

Aster (*Callistephus*) variety trial

Nineteen varieties of aster were grown in the field, either under a canopy of 'Typar' (to protect against aster yellows infection) or in the open. Contrary to expectation there was little aster yellows and little Fusarium root rot, so good yields were achieved. Most promising were the 'Shanghai' series, especially 'Rose-White', 'White' and 'Crimson', and the 'Bonita' series, both of which deserve to be tested again and more widely grown.

Basil

Of the four lines tested, 'Aramato' stood out as having excellent stem length, productivity and attractive foliage. Hydration of the cut stems was a problem with all varieties, and would probably have been improved by using a hydration solution.

Celosia

Seven varieties were compared in tunnel and field and good growth and productivity was obtained in both. 'Sunday Wine Red', 'Ruby Parfait Wheat' and 'China Town' were the most attractive and promising cultivars.

Chrysanthemum

Six lines were received as cuttings and grown in a tunnel. Flowering was relatively late, but the late frost in autumn only negatively affected the latest-flowering lines, 'Yoko Ono' and 'Judith Baker'. Most promising were 'Whirl-away', an early spray-type spoon with purple flowers, and 'Maryll', a later and larger flowered spoon with red flowers.

Cosmos

In a spring field planting, three 'Double Click' lines were compared with 'Sensation Mix'. The 'Double Click' lines were productive, but there were problems keeping them hydrated after harvest. 'Sensation Mix' is a short-day plant that began flowering in late-summer on large plants.

Craspedia

Three lines were grown in tunnels as well as in the field. There were few differences among the varieties tested, but the drier tunnel environment allowed more vigorous growth than in the field, doubling the stem yield and improving stem length. All varieties exhibited outstanding vase-life, fresh and dried.

Grasses

Two annual grains were sown directly in the field, and two Pennisetum lines were sown in the glasshouse and transplanted. Pennisetum 'White Lancer' was most productive, with long, thin inflorescences. Of the cereal grains, *Triticale* 'Silver Tip' was taller and more attractive than *Triticum* 'Black Tip'.

Lisianthus

Five lines were tested in both tunnel and field. 'ABC 2-4 Yellow Improved' was vigorous and productive, whereas 'ABC 2-3 Misty Blue' was too late for the conditions at Ithaca, in contrast to 'ABC 1-3 Misty Blue' which was productive and had attractive flowers on somewhat short stems.

Peppers

The new ornamental pepper 'Orange Globe' has small, round fruit borne at the end of branches turning from green to yellow, but the yellow colour faded quickly and the fruit became wrinkled and unattractive. In contrast 'Cappa Conic' was attractive even when dried.

The trial gardens at the University of Georgia, Athens

"The trial gardens at the University of Georgia (UGA) are less than half a hectare in size but serve as a research facility for most of the world's flower breeders. Data is gathered on crop entries and placed on line for breeders, retailers and growers to evaluate. Marketing and promotion of the garden as a research and crop introduction facility has grown in importance over the last five years and is accomplished through open houses, on-line award programmes and continuous communication with the breeders and partner companies. New crop introductions have been a part of the gardens for many years. Crops are presently introduced from scientists at UGA and private breeders. Crops are distributed via Athens Select©, a national brand supported by selected propagators throughout the United States. The royalties from the sale of Athens Select crops are administered through the University to help fund the trial gardens and additional new crop research. The creation of a distribution and marketing network between an academic institute and the horticulture industry is uncommon" (Armitage, 2012).

As the UGA trial gardens cover annual and perennial ornamentals of all types – not specifically cut-flowers – details will not be included in this review; nevertheless the data may be a useful source of information on a wide range of species used (or potentially used) as cut-flowers. Information (from 2009 to date) may be accessed at <http://ugatrial.hort.uga.edu/> and includes extensive listings and photographs of species and cultivars, selections of the 'Best of the Best' and links to the National Plant Trials programme of which the UGA trial gardens was a founding member when the scheme was launched in 2012 (see www.PlantTrials.org).

University of Natural Resources and Applied Life Sciences, Vienna

Trials were conducted in Vienna with selected field-grown cut-flowers (Balas *et al.*, 2005). The aims were to collect information on the potential of extensive and organic growing systems, to safeguard marketable quality, and enhance knowledge of growing techniques (such as floral preservatives) for maintaining vase-life during the whole post-harvest period. Cultivars of selected annual species were investigated:

- *Ammobium alata* 'Bikini' (sown and grown under protection and planted in the field at the beginning of May).
- *Dahlia variabilis* 'Primaner' and 'Red Cap' (derived from cuttings and planted in intercropping systems in the field with ornamental maize, rye or *Scabiosa atropurpurea*).
- *Delphinium consolida* 'Prachmischung' (sown and grown under protection and planted in the field at the beginning of May).
- *Helianthus annuus* 'Floristan' and 'Holiday' (direct-drilled).

The intercropping systems involved using maize to protect dahlia from high temperature and irradiation, scabiosa as a second crop to use the growing area more intensively as cover, and rye for covering soil surface. Sunflower 'Holiday' was grown in a trial comparing conventional integrated production, several organic trials and a no input system without chemical plant protection and fertilizer application. (Further details can be obtained later.)

Agricultural Research Institute, Cyprus

With a view to satisfying the demand of European and world markets for new products, several species were cultivated over the period 1995 to 1998 in an unheated glasshouse and in the open at Zyghi Experimental Station, Cyprus (Chimonidou-Pavlidou, 2000). The species were evaluated for productivity/m², stem length and fresh weight. All were suitable for use as fresh and dry flowers:

- *Achillea millefolium*.
- *Craspedia globosa*.
- *Delphinium consolida*.
- *Helichrysum bracteatum*.
- *Helipterum roseum*.
- *Helipterum manglesii*.
- *Limonium otolepis*.
- *Limonium perezii*.
- *Limonium sinuatum*.
- *Limonium suworowii*.

Review of cultivar comparisons

Helianthus annuus

Trials were conducted in 1999 in San Remo, Italy, with sunflowers 'Elite Sun' and 'Sun King' (for summer production) and the pollen-free 'Yellow F1' (for autumn production) (Scordo and Paterniani, 2001). Topping of 'Elite Sun' above either the second or fifth node, five to six weeks after transplanting, resulted in shorter stems, and smaller but more numerous flower-heads, up to five per plant (compared with a single flower if not topped).

Thirteen single-stem and 16 branching pollen-free sunflower cultivars were evaluated in field trials at the North Mississippi Research and Extension Center, Verona, Mississippi State, for cut-flower production (Sloan and Harkness, 2006). Stem length and diameter and flower-head diameter were assessed across six planting dates during the summer growing season. All the single-stem cultivars produced stem diameters in excess of 1.4 cm and were too large for general florist usage. The stems and flower-heads of the branching cultivars were smaller and better sized for floral arrangements. The yield of stems from the branching cultivars ranged from three to 13 stems per plant over the planting dates. In the branching group the dark-flowered cultivars produced the greatest numbers and the longest stems in the trial. Yellow/gold-flowered branching sunflowers in this trial did not produce as many stems as, and stem lengths were shorter than, the dark-flowered sunflowers.

Lisianthus

Long popular in European and Asian markets, Lisianthus was developing as an important crop in the USA in the late 1990s and more cultivars were becoming available there. In work

at the University of Florida, 47 cultivars (from PanAmerican, Sakata and Takii) were grown in the field and comprehensively evaluated (Harbaugh *et al.*, 2000). Previously published cultivar comparisons had been less comprehensive. A number of seedling, flower stem and post-harvest attributes were assessed and a 'total rank sum of all attributes' (TRS) was used to assign the best performing cultivar in each flower-colour group for small- and large, double- and single-flowered cultivars, these being 'Malibu Purple' (large, single, blue/purple flowers), 'Malibu Blue Blush' (large, single, picotee/blush), 'Alice Purple' (small, single, blue/purple), 'Balboa Blue' (double blue/purple), 'Avila Blue Rim' (double, picotee/blush), 'Mellow Pink' (large, single, pink), 'Flamenco Wine Red' (large, single, red), 'Flamenco Rose Rim' (large, single, pink/picotee), 'Alice Pink' (small, single, pink), 'Avila Rose' and 'Echo Pink' (double, pink), 'Alice White' (small, single, white) and 'Mariachi White' (double, white).

In Japan, 96 cultivars of Lisianthus were screened for their suitability for autumn shipment over the period 2000 to 2002 (Fukushima *et al.*, 2003). Thirty-five cultivars had good flower production, stem lengths of over 70 cm and stem weights of over 40 g. Sixteen cultivars with eight florets or more per stem were identified as highly suitable, and a further 19 (producing less than eight florets per stem) were identified as suitable under certain conditions.

Ranunculus asiaticus

Ranunculus is a relatively little known cut-flower and the post-harvest performance of ten cultivars was tested at the University of Turin (Scariot *et al.*, 2009). Cultivars 'Auriga', 'Bianco2', 'Dido', 'Green', 'Juno', 'Ken', 'Lulù', 'Pluto',

'Saigon' and 'Shangai' were treated with silver thiosulphate (STS), amino-oxyacetic acid (AOA), 1-methylcyclopropene (1-MCP, Ethylbloc) or exogenous ethylene. The evaluation of post-harvest performance was based on the symptoms of senescence, stem fresh weight, petal colour, ethylene production and chlorophyll content. Senescence was usually reached after about 13 days, with 'Green' the longest-lived (16 days) and 'Lulù' the shortest (11 days). AOA extended the longevity in four cultivars ('Lulù', 'Pluto', 'Bianco2' and 'Green') and STS in two ('Pluto' and 'Bianco2'). Exogenous ethylene application had no adverse effect on any of these cultivars, so they are ethylene-insensitive and precautions against exposure to ethylene are not needed.

Trachelium caeruleum

A few cultivars of *Trachelium* were becoming available in the USA in the late-1990s and 11 cultivars were assessed at the University of Florida (RongNa and Harbaugh, 2001). The plants, from PanAmerican and Sakata, were grown in an "open sided, fibreglass-covered, sawtooth greenhouse" in which the temperature ranged from 6 to 37°C over the course of the whole trial. The 'TRS' method of assessment was used

as previously described. All but 'White Umbrella' reached the required stem length of 76 cm. Inflorescence diameter varied from 10 cm ('Summer Lake') to 15 cm ('Lake Powell'). 'White Umbrella' was the earliest to flower and 'Lake Powell' the last, but production times varied only from 160 to 169 days from sowing. 'Summer Lake' had a vase-life of seven days, while 'White Umbrella' was 11 days. The highest rankings were gained by 'Lake Powell' (white), 'Summer Blue Wonder' (blue) and 'Lake Superior' (purple).

Zinnia elegans

In trials in Mississippi 13 cultivars of zinnia were evaluated for cut-flower production, planting in May, June and July (Sloan and Harkness, 2008). The data recorded included the number of days to harvest, duration of harvest period, number of stems per plant, and stem length and diameter. Within each of three planting dates there were no significant differences in the number of stems per plant for 10 of the cultivars. Stem and bloom size increased from the May to July planting, while median number of stems produced from the May, June and July plantings were 22, 11 and 14 per plant, respectively.

Sources of information on cut-flower crops

In addition to the trials programmes referred to above, many universities in the USA offer useful web-pages or downloadable leaflets for cut-flower growers. As with the trials programmes, caution needs to be exercised in interpolating from these sources for UK use, since they derive from trials and experience over the USA's wide climatic range but, with selection, there

is much useful guidance here. Unless otherwise stated, this information refers to field-grown cut-flowers, but whether grown outside or under glass will depend on the climatic zone. These and other North American information sources are summarised in Table 5 overleaf.

Table 5 Other sources of information on field-grown cut-flowers

University and web addresses for cut-flower information	Species and topics covered
British Columbia MAFF http://www.agf.gov.bc.ca/ornamentals/floriculture/fieldcut.pdf	Cut-flowers generally
California (Davis) http://sfp.ucdavis.edu/pubs/brochures/specialtyflo	Cut-flowers generally
Florida http://smallfarms.ifas.ufl.edu/crops/flowers_and_foliage/cut_flowers.html	Zinnia Many ornamentals topics
Kansas State http://www.ksre.ksu.edu/bookstore/pubs/MF1034.pdf http://www.ksre.ksu.edu/bookstore/pubs/MF1034.pdf http://www.ksre.ksu.edu/bookstore/pubs/MF2436.pdf http://www.ksre.ksu.edu/bookstore/pubs/MF1174.pdf http://www.ksre.ksu.edu/bookstore/pubs/MF2261.pdf	Fertilisation Comprehensive growers' guide Water quality and cut-flowers Cold storage Post-harvest
Kentucky http://www.uky.edu/Ag/NewCrops/introsheets/cutflowers.pdf	Cut-flowers generally

University and web addresses for cut-flower information	Species and topics covered
<p>Massachusetts</p> <p>http://extension.umass.edu/floriculture/fact-sheets/field-grown-annuals-cut-flowers</p> <p>http://extension.umass.edu/floriculture/fact-sheets/cut-flowers-insects-and-mites-commercial-production-field-grown-cut-flowers</p> <p>http://extension.umass.edu/floriculture/fact-sheets/weed-management-outdoor-cut-flowers</p> <p>http://extension.umass.edu/floriculture/fact-sheets/postharvest-handling-six-more-field-grown-cut-flowers%E2%80%94gladiolus-helianthus</p> <p>http://extension.umass.edu/floriculture/fact-sheets/sugar-and-acidity-preservative-solutions-field-grown-cut-flowers</p>	<p>Cut-flowers</p> <p>Pests</p> <p>Weeds</p> <p>Post-harvest</p> <p>Preservatives</p>
<p>North Carolina State</p> <p>http://www.ces.ncsu.edu/depts/hort/floriculture/cfr/index.htm [general index]</p> <p>http://ipm.ncsu.edu/AG136/ncstate.html [pests]</p> <p>http://www.ces.ncsu.edu/depts/hort/floriculture/manuals/se_cut_flwr.pdf [south-east outdoor cut flowers]</p> <p>http://www.ncsu.edu/project/cutflowers/postharvest/index.htm [post-harvest]</p>	<p>Cut-flowers generally</p> <p>Asters, hydrangea (forced), ornamental cabbage/kale and other ornamental vegetables</p> <p>Also leaflets on specific topics: height control, plant growth regulators, ethylene, trace elements, weeds, etc.</p>
<p>North Dakota State</p> <p>http://library.ndsu.edu/tools/dspace/load/?file=/repository/bitstream/handle/10365/8053/AA13_1993.pdf?sequence=1</p> <p>http://www.ag.ndsu.edu/pubs/plantsci/landscap/h1200.pdf</p>	<p>Dried and fresh cut-flowers</p> <p>Growing for market</p>
<p>Oklahoma State</p> <p>http://pods.dasnr.okstate.edu/docushare/dsweb/Get/Document-1115/HLA-6426web.pdf</p>	<p>Cut-flowers generally</p>
<p>Purdue</p> <p>https://sharepoint.agriculture.purdue.edu/agriculture/flowers/cutflowerguides.aspx#annual [main listing]</p> <p>http://www.hort.purdue.edu/newcrop/proceedings1990/v1-457.html [gerbera]</p> <p>The site lists factsheets contributed by Maryland, Kansas State, Massachusetts, Vermont, North Dakota State and Oklahoma State Universities, University of California at Davis and ATTRA</p>	<p>Cut-flowers generally</p> <p>Perennials generally</p> <p>Field or tunnel crops: achillea, allium, anemone, aster yellows, celosia, coneflower, gerbera, larkspur, liatris, lisianthus, paeony, statice, sunflower and zinnia</p> <p>Glasshouse crops: astroemeria, anemone, anthurium, celosia, carnation, chrysanthemum, coralbells, freesia, gladiolus, larkspur, lisianthus, snapdragon</p> <p>Also leaflets on specific topics: production, P&D, storage, handling, post-harvest, etc.</p>
<p>Vermont</p> <p>http://pss.uvm.edu/ppp/percuts.html</p> <p>http://pss.uvm.edu/ppp/coh29ph.htm</p>	<p>Perennials</p> <p>Post-harvest</p>

University and web addresses for cut-flower information	Species and topics covered
Virginia State/Virginia Tech http://smallfarms.ifas.ufl.edu/crops/flowers_and_foliage/cut_flowers.html http://pubs.ext.vt.edu/category/crops.html	Cut-flowers generally Bulbs (summer flowering) Dahlia Lisianthus

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**Horticultural
Development
Company**

Stoneleigh Park
Kenilworth
Warwickshire
CV8 2TL

T: 024 7669 2051
E: hdc@hdc.org.uk
Twitter: @HDCtweets

www.hdc.org.uk