Project title:	The National Cut-flower Trials Centre Programme for 2013 - 2017
Project number:	PO/BOF 002a
Project leader:	Lyndon Mason (Director, The Cut Flower Centre Ltd)
Report:	Fourth Annual Report (2016)
Previous report:	First Annual Report (2013) Second Annual Report (2014) Third Annual Report (2015)
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Date project commenced:	01 January 2013
Date project completed (or expected completion date):	31 December 2017

The results and conclusions in this report are based on investigations conducted over a one-year period. The conditions under which the experiments were carried out and the results have been reported in detail and with accuracy. However, because of the biological nature of the work it must be borne in mind that different circumstances and conditions could produce different results. Therefore, care must be taken with interpretation of the results, especially if they are used as the basis for commercial product recommendations.

AUTHENTICATION

We declare that this work was done under our supervision according to the procedures described herein and that the report represents a true and accurate record of the results obtained.

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Grower Summary

Headline

- Scabious showed great promise for cut-flower production in the UK when grown in both tunnels and outdoor. The 'Scoop' series has an attractive range of colours, high yields, good vase-life and potential for use in mixed bouquets.
- Craspedia is an unusual product with high yields of yellow, globe-shaped flowers on long, strong stems. 'Paintball Globe' and 'Ellisse' showed good potential for sales as fresh or dried flowers and as a filler in bouquets.
- Gomphrena is prolific, with red, pink and white flower spikes and the possibility of 'once-over' cropping. It showed good potential as a filler.
- A range of ornamental grasses generated much interest for use in fashionable mixed bouquets. *Panicum elegans* 'Sprinkles' and *Stipa capillata* 'Lace Veil' particularly elicited positive comments.

Background

For a long time the UK has had a relatively low *per capita* consumption of cut-flowers compared with other western European countries, but between the late-1980s and early-2000s the UK's annual imports of cut-flowers rose from some £125m to around £550m. Over the same period the value of UK-grown cut-flowers remained static at around £50m *per annum.* This shortage of enterprise was attributed to (1) a lack of 'know-how' and (2) a reluctance to compete against the Dutch flower export market. The National Cut Flower Centre (CFC) project was set up in 2007, largely with funding from the HDC (now AHDB Horticulture), and is currently funded by AHDB Horticulture until the end of 2017. The immediate aim of the project is to provide information on producing a wider range of cut flowers outdoors and, taking advantage of the increased availability of low-cost Spanish tunnels, under protection (*'crop information'*). The longer-term aim is to stimulate the UK grower's interest in developing and commercialising novel cut flowers (*'crop introduction'*) while continuing to improve the quality of the more traditional products (*'crop improvement'*). In the context of the project the term 'novel cut flowers' is interpreted widely: it could include a species completely new to production horticulture, or might simply indicate a crop or cultivar with which UK growers or customers are unfamiliar at the present time.

Summary of the project and main conclusions

The Centre continues to develop its role as an information hub and cohesive voice for the UK cut flower industry, as demonstrated by the high turnouts at the Open Days. The CFC has been successful in developing the core strategic theme of the project by facilitating and hosting AHDB Horticulture-funded herbicide trials, undertaking trials looking at alternative growing media for boxed lilies (partially funded by Bulrush Horticulture), developing a standalone AHDB Horticulture-funded trial to investigate the hydroponic production of cut flowers and carrying out a review and industry survey of flower spotting issues in cut sunflowers.

Several crops trialled at the Centre have attracted enough attention for commercial production to commence, including antirrhinum, bupleurum, lisianthus, sedum and woody foliage. Many subjects from the most recent trials are generating market interest too: these include 'alternative' varieties of ornamental brassicas, craspedia, direct-seeded herbaceous fillers, gomphrena, ornamental grasses, scabious, seasonal alstroemeria and trachleium.

Crop information

Trials are underpinned by the reports produced by the CFC including:

- Database of firms supplying seeds and planting material for cut flower production (updated in 2015);
- Report on research on new cut-flower crops and cut flower trials programmes worldwide (updated in 2015 and 2016 and on-going);
- Report on the statistics of production and trends in the cut flower trade worldwide (published in 2015, updating on-going).

This information would also be of value to growers planning their own new product development and documents are available from the AHDB Horticulture and CFC websites.

Crop improvement

Alstroemeria – garden cultivars (Alstromeria cultivars)

Commercial alstroemeria cut flower production involves contemporary, high-quality and expensive cultivars grown as glasshouse crops. The availability of Spanish tunnels, however, raises the possibility of growing an inexpensive, seasonal crop of the older, garden cultivars, to which no royalties are attached. A feasibility trial was set

up over 2014–2016 with a selection of cultivars (‘Apollo’, ‘Avanti’, ‘Bonanza’, ‘Candy’, ‘Dana’, ‘Flaming Star’, ‘Friendship’, ‘Golden Delight’, ‘Nina’, ‘Orange Supreme’, ‘Pink Sensation’ and ‘Tanya’) grown in a Spanish tunnel or outdoor beds.

Marketable flowers were produced in the tunnel starting week 31 (2014), week 23 (2015) and week 22 (2016), and picking continued until weeks 41–44, when all recording was brought to an end to allow the tunnels to be de-skinned for winter. Under protection the plants were very vigorous, producing strong stems that some growers considered better than those from a typical glasshouse crop. The outdoor crop, over the three years, produced marketable stems from weeks 33, 26 and 26, respectively, but were less vigorous with fewer flowers compared with the protected crop. In the year of planting there was a slow build-up in flower production, with most picking in the second half of the season, while in the second and third years there was a shift to earlier picking with a rapid build-up to the main picking period. With this combination of twelve cultivars and tunnel and outdoor plots the supply of flowers was reasonably consistent and occurred over a long, five month period, though few or no flowers were available in some weeks each year. The consistency of supply might be improved by growing new plantings alongside older ones, or by making a small number of sequential plantings.

Overall, yields in the tunnel were more than double those for outdoor plots, and annual production increased over the three years of the trial. In round terms, tunnel-grown crops produced about twice the yield of outdoor beds in 2014 and about three-times the yield in 2015, falling back to less than double in 2016. The overall yields of individual cultivars varied markedly. In the tunnel or outdoors, the productivity of half of the cultivars increased annually, while most of the rest peaked in the second year. Overall, ‘Nina’ was the highest yielder, consistent in the tunnel and outdoors and across the three years. ‘Dana’, ‘Flaming Star’, ‘Friendship’ and ‘Tanya’ were among the higher producers too, with ‘Dana’ doing particularly well as a first-year crop and in outdoor beds and ‘Friendship’ doing well in the tunnel. Overall, ‘Apollo’, ‘Bonanza’, ‘Golden Delight’ and ‘Orange Supreme’ were poorer performers.

A selection of cultivars was sampled for vase-life (VL) testing, giving a satisfactory average VL of 12 days[1]. It appeared important to allow the flowers to show good colour before picking as this made the product more attractive and did not appear to detract from its VL. Growing non-PBR cultivars in tunnels appeared to have strong potential.

[1] All vase-lives in this report refer to the length of the consumer (vase) phase itself, which follows the simulated storage, transport and retail phases that total a further 3–4 days.

And, despite their lower quality and yields, growing alstroemeria in the open may still have a place for small growers.

Brassica, ornamental (Brassica oleracea cultivars)

Consumer and grower interest in ornamental brassicas continues to be high, despite uncertainties about some aspects of their husbandry and which cultivars to grow. Trials in 2015 and 2016 addressed the choice of cultivars for the high-quality tunnel crop, growing some newer cultivars alongside the more familiar 'Crane' series. In 2015 the cultivars grown were 'Agathana', 'Anthonia', 'Bogdana', 'Bright Wine', 'Condor Early White', 'Condor Pure White', 'Crane Bicolour', 'Crane Queen', 'Crane Pink', 'Crane Red', 'Crane Rose', 'Crane White', 'First Lady', 'Galina', 'Katya', 'Ksenia', 'Kysia', 'Olga', 'Svetlana', 'Varvara' and 'Vera'. Only 'Kysia' failed to colour-up. Compared with the trial averages, 'Bright Wine' and 'Olga' produced heavier stems, 'Bogdana', 'Crane Queen' and 'Katya' lighter stems, 'Anthonia' larger heads and 'Agathana', 'Crane White', 'Olga' and 'Varvara' smaller heads. With high–quality heads and VL of 10–17 days, a number of the less familiar cultivars showed real promise and generated market interest exceeding that of the more familiar 'Crane' series.

There was an impression that many growers and pack-houses would prefer to stay with the well-tried 'Crane' series until more experience has been obtained with alternative cultivars. To this end plots of 'Crane' cultivars ('Crane King', 'Crane Pink', 'Crane Queen' and 'Crane White') and others ('Agathana', 'Anthonia', 'Bogdana', 'Condor Pure White', 'First Lady', 'Ksenia', 'Kysia', 'Olga' and 'Vera' were trialled in tunnels in 2016. 'Kysia' again failed to colour-up. All cultivars produced heads of high quality, though some (especially those with dissected leaves) failed to give the high marketable yields of others. In vase-life testing all cultivars reached at least the guaranteed life of 5 days.

China aster (Callistephus chinensis cultivars)

In the last decade china asters (annual asters) have become an important seasonal outdoor summer cut flower in the UK, dominated by the 'Matsumoto' spray type grown in quantities of about 9 million stems annually. Work at CFC up to 2013 opened up a new market for the alternative large headed, 'bloom'-type, culminating in the 'Krallen' series with their vibrantly coloured flowers. Generating distinct interest from growers, there appeared to be potential for commercialising 'Krallen' in the UK. However, post-harvest quality became an issue when petal-spotting and browning of the flower-tip

became apparent. Since no cause or remedy was found, CFC trials looked towards finding alternative cultivars. Between 2010 and 2015 trials were conducted with the 'Beautiful Day', 'Benary Princess', 'Harlequin', 'Matador', 'Jewel', 'Lady Coral' 'Matador', 'Meteor' and 'Standby' series. Many of the cultivars tested had stem and flower attributes with promise for growing in the UK, but none was considered likely to become an alternative for 'Krallen'.

In 2016 the Centre carried out a demonstration of a further series of spray-asters, 'Julie', and two coded bloom-type asters. Recently becoming available from Miyoshi, these have a different colour range and a claim for earliness. The demonstration was used as a source of material for showing to packers and supermarkets and it was reported that samples were well received by one supermarket, but that they were similar in timing and quality to some other cultivars being grown in the industry. In favour of the 'Julie' series, some different colours and fresh seed stocks were appreciated. Grown under tunnels the plants were larger but paler than outdoor-grown plants.

Column stocks (Matthiola incana cultivars)

Column stocks are a mainstay of UK protected cut flower production. Variety trials carried out at the Centre in 2012 and 2013 added to the industry's interest in the 'Katz' series as a late-summer crop. Although their stem quality was poorer in 2013 than in 2012, possibly due to higher than usual summer temperatures in the second year, it still excelled that of comparable plants grown in a commercial glasshouse trial. Growing the crops in both steamed and non-steamed soil showed a strongly beneficial effect of steaming on stem weight (but not on stem length). In the commercial glasshouse trial the plants were also used to evaluate susceptibility to fusarium wilt (the glasshouse had a history of the disease). Resilient and productive cultivars included 'Avalanche White', 'Fantasy Red', 'Fantasy Red Imp', 'Phantom Cream Imp', 'Phantom Red', cultivars of the 'Anytime' and 'Katz' series and 'Figaro Lavender'; these properties were not shared by cultivars in the 'Opera' series.

At the same time there were increasing concerns about the poor establishment, growth and flower uniformity in column stocks. This did not appear to be due to any single factor, but to a combination of issues such as the poor performance of some varieties on un-steamed soil and the presence of *Pythium* or *Fusarium*. Separate HDC projects were carried out in 2013 to survey cultural practices, investigate the role of *Pythium* and *Fusarium*, and consider the possibly of remedial effects from soil amendments

(projects PO 005 and 005a). In 2014 the control by fungicides of fusarium wilt was investigated at CFC: Cercobin WG, Octave and Signum were options for control, while Plover and Switch appeared successful initially, but most plants subsequently died.

In 2016 a new demonstration of column stocks was set up to show the commercial varieties currently available from the only two suppliers to the UK, Florensis and Noordam (subsequently Noordam decided to withdraw from this market after 2016), and to investigate the effects of steam-sterilisation. Cultivars from the 'Aida', 'Anytime', 'Centum', 'Figaro', 'Jordyn', 'Mathilda', 'Milla' and 'Opera' series were included. Replicate plots were planted in steam-sterilised and untreated areas of the tunnel. The plugs established well but were stressed by hot weather in mid-July. As was known to be the case with late-planted commercial crops this year, the trial suffered from uneven flowering, the 'Mila' cultivars being the worse of all: only 'Mila Apricot' produced a reasonable number of marketable stems ('Mila White' produced a late flush at the end of August). Downy mildew, diamond-backed moth and sclerotinia were further problems, necessitating rouging of the crop and an intensive spray programme. As expected, performance in the non-steamed soil was poorer than in the steamed area, but the difference was less marked than had been seen in previous trials. With the weather-related problems that occurred in 2016, no formal records of the trial were taken, but it gave growers an opportunity to view the recent new introductions, such as 'Mathilda' and 'Mila', side-by-side with the older, longer established varieties.

Lily (Lilium cultivars)

Lilies remain hugely popular with UK customers and UK production of cut flowers from imported bulbs has been very successful. To avoid the soil-borne pathogens common in glasshouse soil, lilies are generally grown in crates of growing media. For many years peat has been used as the sole or basic growing medium, so there is obviously interest from growers to discover suitable alternatives or diluents for peat, and trials of alternative substrates have been carried out by the CFC since 2013. In the first trial a selection of newer cultivars was assessed for the suitability of a green-waste substrate in two separate trials. Bulbs were grown in 100% grower's peat-based medium, 100% green-waste or a 50:50 v/v mixture. Stems were longest when grown in the grower's peat-based medium, shorter in the mixture and shortest in the green-waste, though the tallest and shortest average length for a cultivar varied by only 20 to 25cm. There were no differences in bud count between growing media. Apart from the shortness of affected stems, quality was superb in all three media, and subsequently the work was scaled-up on a commercial site.

In 2014, in the first of two trials using cultivar ‘Dynamite’, bulbs were planted in 100% grower’s peat-based medium, 100% coir, 100% ‘Forest Gold’ (a wood-derived ‘potting substrate’) or mixtures of grower’s peat-based medium with coir (50:50 v/v), with anaerobic digestate (80:20 and 60:40 v/v) or with re-cycled green-waste (50:50 v/v). There were insignificant differences in stem length and weight between the growing media. Growing in grower’s peat-based medium + anaerobic digestate mixes gave better leaf colour than growing in grower’s peat-based medium alone, while growing in grower’s peat-based medium + green-waste delayed picking by a week and gave some stunted stems with chlorotic leaves, slightly reducing the yield of marketable stems. In the second trial, 100% ‘green-compost’ was for substituted for ‘Forest Gold’ and the range of grower’s peat-based medium + anaerobic digestate mixes expanded (80:20, 60:40 and 40:60 v/v). As in the first trial the differences between growing media in average stem length and weight were insignificant, there were no between-media differences in cropping date, and no visual differences between plants grown in different media.

In 2015 trials were conducted with cultivars ‘Alma Ata’ and ‘Capistrano’ planted in 100% grower’s peat-based medium, 100% coir, 100% anaerobic digestate and the mixes grower’s peat-based medium + anaerobic digestate (60:40, 40:60 and 20:80 v/v) and coir + anaerobic digestate (33:67 v/v). Plants grown in 100% anaerobic digestate were stunted, chlorotic and distorted, and those from grower’s peat-based medium + anaerobic digestate (20:80 v/v) only marginally better. Lilies grown in anaerobic digestate + coir, despite making a good height, had chlorotic, mottled foliage. Plants grown in 100% grower’s peat-based medium, 100% coir or the ‘weaker’ mixes of grower’s peat-based medium + anaerobic digestate (40:60 and 60:40 v/v) were all normal and marketable. Stems were tallest grown in grower’s peat-based medium, significantly shorter in 100% anaerobic digestate and slightly shorter in the anaerobic digestate mixes. Stems were heaviest grown in grower’s peat-based medium + anaerobic digestate (40 and 60% anaerobic digestate) and lightest in 100% anaerobic digestate. There were some points of difference in the chemical analysis of the anaerobic digestate used each year. The nitrogen concentration of the 2014 sample was higher than in 2015, perhaps accounting for the better foliage colour in lilies grown in anaerobic digestate in 2014. The poorer performance of lilies in anaerobic digestate or anaerobic digestate-rich mixes may have been attributable to the high conductivities and pH of anaerobic digestate. Hence green-waste or green-compost may have a role in lily growing, but would need to be of a more consistent quality. Anaerobic digestate appears suitable to use mixed with grower’s peat-based

medium at up to 60% anaerobic digestate. Lilies also performed well when grown in 100% coir, which should also be considered as a peat alternative or diluent. Before growers adopt green-waste/green-compost or anaerobic digestate as materials for growing lilies, more needs to be known of their analysis and standardisation.

In 2016 the emphasis of lily trials changed to the assessment of growing in peat + wood fibre and peat + cocopeat mixtures, in comparison with grower's peat-based medium or coir. The mixtures comprised peat with 10, 20 or 30% wood fibre or cocopeat. Lily 'Dynamite' was used throughout. Lilies grown in 100% coir were stunted, but otherwise there were no indications of visual differences between plants in any treatment, and all treatments were picked within a few days. Growing in 100% coir produced stunted stems that were significantly shorter (70cm) than stems grown in the other eight growing media, in which stem lengths hardly varied (averages between 77 and 80cm). Stem weight was light in 100% coir (99g) with all other growing media yielding significantly heavier stems (averages between 126 and 151g). Growing in grower's peat-based medium gave stems averaging 126g, slightly lighter than for the peat + wood fibre mixes and significantly lighter than those growing in peat mix or the peat + cocopeat mixes. The results suggested that all trial mixes were worthy of further investigation as growing media for lilies in crates, but particularly the peat + cocopeat mixes. These had no adverse effects on growth, appearance and cropping, with the potential to reduce peat usage by 30%, possibly more.

General topic: herbicide trials

The loss of key active ingredients, such as chlorthal-dimethyl, propachlor and oxadiazon continues to be a major concern for growers of outdoor cut flowers. In 2015 parts of an AHDB Horticulture-funded project examining alternative herbicide treatments (HNS PO 192a) was carried out at the CFC site, using drilled china asters, larkspur, sweet william and wallflowers. 'Stomp Aqua' + 'Gamit 36 CS', applied post-drilling, pre-emergence, was safe and effective for use on drilled china aster, and this treatment could be followed up with a post-emergence application of 'Shark' if required. Tank-mix 'Stomp Aqua' + 'Goltix 70 CS' provided the best weed control and was the safest option in sweet william trials. In the drilled wallflower trial 'Butisan S', 'Gamit 36 CS' and 'Wing-P' (low rate) appeared safe when applied at drilling. 'Wing-P' (low rate) + 'Gamit 36 CS' also appeared to be safe on wallflowers as a tank-mix. 'Benfluralin' was safe as a pre-drilling incorporated treatment on wallflower and could be combined with some of the post-drilling treatments. The drilled larkspur trial proved challenging, partly because of phytotoxic effects from the herbicides used; nevertheless the trial

gave some pointers to investigate in later trials. This work was followed up in 2016 as part of the CFC project, using transplanted china aster and drilled sweet william.

For china aster the aim was to follow-up the current recommendation for pre-planting 'Stomp Aqua' + 'Gamit 36 CS' (2.0 + 0.25L/ha). There were two alternatives to pre-planting 'Stomp Aqua' + 'Gamit 36 CS', 'Nirvana' (3.0L/ha) and 'Wing-P' (2.5L/ha), and each of these applications was followed up, three weeks post-planting, with 'Butisan S' (1.0L/ha), 'Venzar Flo' + 'Flexidor 500' (0.75 + 0.125L/ha) or 'Successor' (2.0L/ha), or had no further applications. There were large numbers of weeds on the untreated plots, and of the pre-planting treatments 'Wing-P' and 'Nirvana' were most effective in reducing weed numbers, while the tank-mix of 'Stomp Aqua' + 'Gamit 36 CS' was much less effective. Applied at this stage, however, 'Wing-P' and 'Nirvana' each resulted in some stunting of the crop, more seriously so in the case of 'Nirvana'. Using 'Stomp Aqua' + 'Gamit 36 CS' resulted in very slight stunting only.

Considering the post-planting treatments, 'Butisan S' was the most effective, with 'Venzar Flo' + 'Flexidor 500' and 'Successor' being less effective. Treatment with 'Butisan S' or 'Successor' resulted in very slight marginal leaf scorch to the youngest leaves at the time of spraying, though this was rapidly outgrown; there was no scorch when 'Venzar Flo' + 'Flexidor 500' had been used. Overall, the combination of 'Stomp Aqua' + 'Gamit 36 CS' followed by 'Butisan S' was probably the best compromise between weed control and crop safety. On some sites 'Wing-P', either alone or followed by 'Venzar Flo' + 'Flexidor 500', might be an option.

For drilled sweet william the current recommendation is for 'Stomp Aqua' + 'Goltix 70 SC' (0.75 + 1.0L/ha) at drilling, followed-up at the four true-leaf stage by 'Shark' (0.4L/ha), and the aim of this trial was to see if this treatment could be bettered. Tank-mix 'Stomp Aqua' + 'Goltix 70 SC' at drilling was followed by either 'Butisan S' (1.5L/ha), 'Butisan S' + 'Shark' (1.5 + 0.4L/ha), 'Springbok' (1.6L/ha), 'Springbok' + 'Shark' (1.6 + 0.4L/ha), 'Successor' (2.0L/ha), 'Successor' + 'Shark' (2.0 + 0.4L/ha), 'Venzar Flo' + 'Flexidor 500' (0.75 + 0.125L/ha) or 'Venzar Flo' + 'Flexidor 500' + 'Shark' (0.75 + 0.125 + 0.4L/ha). In addition there was a treatment of 'Goltix 70 SC' (1.5L/ha) at drilling, followed by 'Shark' (0.4L/ha) and an untreated control.

In the untreated control, weed cover was complete, while in the 'Goltix 70 SC' - 'Shark' programme weed cover reached 47%. For the other programmes, all based on an initial application of 'Stomp Aqua' + 'Goltix 70 SC', weed growth varied widely. The most effective programme for weed control was follow-up Venzar Flo' + 'Flexidor 500'

+ ‘Shark’ (5% weed cover), followed by ‘Springbok’, ‘Springbok’ + ‘Shark’, or ‘Venzar Flo’ + ‘Flexidor 500’ (18–22%); the remaining programmes resulted in weed cover of 33% or more. In the early stages slight to mild stunting occurred in all treatments except the control, and the four treatments giving good (≤22%) weed control gave relatively more stunting. However, the stunting effect was transient and the plants recovered. As a result of the trial the recommended herbicide programme would be the one giving the best weed control: ‘Stomp Aqua’ + ‘Goltix 70 SC’ at drilling followed by ‘Venzar Flo’ + ‘Flexidor 500’ + ‘Shark’ post-emergence.

Crop introduction (1) Crops first trialled in 2016

Cleome (Cleome hassleriana and cultivars)

Cleome hassleriana is a sturdy, attractive garden annual with unusual flowers - a possible candidate as ‘something different‘ in cut flowers. In 2016 cultivars ‘Cherry Queen’, ‘Colour Fountain Mix’, ‘Rose Queen’ and ‘Violet Queen’ were sown into plugs and planted into beds in a tunnel. Establishment was satisfactory. There were no obvious differences in growth or development of the plants grown at two spacings (25 and 65 plants/m^2). They were grown in two batches, transplanted in weeks 13 and 25; the later planting started flowering four weeks after the first and both were still flowering in October. Apart from their colours, there were no obvious difference between the cultivars. Cleome proved a very prolific crop that kept producing constant flushes of flowers over a long period, the flowers being large, showy and distinctive.

Samples were subjected to standard VL testing. Cleome wilted very quickly after harvesting but recovered when re-hydrated in the chilled cabinet. Flowers, leaves and stems remained in acceptable condition on VL day 7. However, there was some abscission of flowers and shedding of the fine, black pollen (which was less when ‘RVB Clear’ rather than ‘CVBN’ had been used as the post-harvest treatment). The stems were somewhat difficult to handle because of their spines, and the plants and cut flowers have a distinctive aroma that some may find unpleasant. Despite their attractive and unusual flowers and adequate VL, further trials may not be appropriate because some consider the cleome’s spines and aroma render them unsuitable for supermarket sales, and they may also be difficult to handle and hence unsuitable for use on a processing line. They may be suitable for supplying to florists for use in specialised situations where the flowers will not be handled by customers.

Craspedia (Craspedia globosa and cultivars)

With its slender unbranched stems and ball-shaped clusters of yellow flowers, craspedia is another example of a cut flower produced abroad but unfamiliar as a UK-grown crop. It is useful as a filler and may also be used as a dried flower. In 2016 cultivars three cultivars were grown in demonstration plots in 2016: 'Ellisse' and 'Paintball Globe' were obtained as rooted cuttings, potted-on and transplanted to beds in a tunnel in week 21, while 'Sun Ball' was obtained as seed, sown into plugs and transplanted to the tunnel in week 18. 'Ellisse' and 'Paintball Globe' gave large flushes of very strong, tall flowers but were very similar in shape to each other. Seed-raised 'Sun Ball' produced weaker plants with smaller flower-heads with shorter, kinked stems and fewer stems per m^2.

Samples of 'Ellisse' and 'Paintball Globe' were subjected to standard VL testing. All stems remained in acceptable condition on VL day 7, with no obvious differences between stems that received post-harvest treatment with 'RVB Clear' or 'CVBN'. Further samples showed that craspedia also dried well, the flowers retaining their colour. Craspedia is an unusual product with potential for sales as fresh or dried flowers.

Eremurus (Eremurus stenophyllus and other species and cultivars)

Eremurus stenophyllus is a rhizomatous plant producing tufts of linear leaves at ground level and bearing upright stalks (up to 1.5m-high) with dense racemes of yellow flowers. Interspecific hybridization has produced a wider range of colours including whites and pinks. As a demonstration, rhizomes of cultivars 'Cleopatra', 'Moneymaker' and 'Tapdance' were planted in beds in a polythene tunnel in week 45, 2015. In 2016 there was a low yield of the tall, elegant flowers, while all plants showed conspicuous leaf senescence, even during flowering. The crop was left in place and as of January 2017 many shoots were emerging.

Gomphrena (Gomphrena globosa and G. haageana cultivars)

Gomphrena is another example of a cut flower produced abroad but unfamiliar to UK customers. An annual herbaceous plant bearing white, pink, purple or red solitary flower spikes at the stem tips, gomphrena can be used fresh-cut or dried. Nine cultivars, including 'Fireworks', four *G. globosa* cultivars and four *G. haageana* cultivars, were grown in a tunnel as demonstration plots in 2016. Apart from cultivar 'Fireworks', which was obtained as plug-plants and transplanted to the tunnel in week

25, they were obtained as seeds, sown into plugs in weeks 13 and 20, and transplanted to the tunnel in week 19 and 25. They started flowering around week 29, and initially the stems were very short and looked unlikely to suit as a cut flower. After three to four weeks, however, much longer stems, with real cut flower potential, were being produced. Samples were subjected to standard VL testing, and although the stems wilted rapidly after picking, they recovered once they were placed in a post-harvest treatment and cooled. The stems, flowers and foliage remained in acceptable condition on VL day 7. Gomphrena is very prolific and may have potential as a filler, though the soft foliage might make it difficult to handle in a commercial situation. Further trials will be carried out in 2017 with a view to forming an economic assessment.

Grasses, ornamental

Growers and customers are showing interest in a wide range of ornamental grasses as bouquet fillers. Several species and cultivars were demonstrated in 2016: *Bromus macrostachys*, *B. secalinus, Eragrostis elegans*, *Panicum elegans* 'Sprinkles', *P. miliaceum violaceum, Setaria italica* 'Mix', *Setaria pumila glauca, Sorghum nigrum*, *Stipa capillata* 'Lace Veil' and *Uniola paniculata* (sea oats). All were grown from seed which was either sown into plugs (week 12) and transplanted into beds in a polythene tunnel or outdoors (week 16 or 17), or direct-drilled to tunnels (week 18 or 28) or outdoors (week 18).

In tunnels all species had good germination and vigorous growth. Within species the only substantial difference was that the plugs took slightly longer than the direct-drilled crops to mature. Later planted crops flowered later, and this may be the way to achieve continuity and will be investigated in 2017. Powdery mildew was severe on *Bromus secalinus* in both tunnels and outdoors and with both planting dates. The outdoor plots were not a success, probably because of the weather, as the plants were frosted soon after planting, severely affected some species. There was a partial recovery but then they were held back by the wet weather in June. Outdoor cropping will be examined again in 2017.

Samples of *Bromus macrostachys*, *Eragrostis elegans*, *Panicum elegans* 'Sprinkles', *P. miliaceum violaceum*, *Setaria italica* 'Mix', *Sorghum nigrum* and *Stipa capillata* 'Lace Veil' were subjected to standard VL testing. All samples remained in an acceptable condition on VL day 7; at this point some leaves of *Bromus macrostachys*, *Panicum miliaceum violaceum* and *Setaria italica* 'Mix' were showing some yellowing or dehydration, but probably not to an extent that would have resulted in the failure of a

mixed bouquet since leaves of the other grasses were unaffected. Little or no shedding of anthers or pollen was seen.

Of all of the trials in 2016, the ornamental grasses generated the most interest amongst growers and others. There was a great variety in head form amongst the species grown, with *Panicum elegans* 'Sprinkles' and *Stipa capillata* 'Lace Veil' in particular elicited positive comments. All species tested have potential for use in mixed bouquets with a 7-day guaranteed VL. They appeared relatively easy to grow and there was a lot of interest from packers and supermarkets. They showed real promise for greater production in the UK. Trials should continue in 2017 and might also include regular cereals such as wheat.

Scabious (Scabiosa caucasica and S. atropurpurea cultivars)

The genus *Scabiosa* comprises annual and perennial herbs up to 0.6m-tall that, with their attractive flowers in a wide range of colours, and high yields, are often grown outdoors as cut flowers, though not in the UK. A large demonstration was set up in 2016, using cutting-raised plants of a new series: 'Blackberry Scoop', 'Cherry Vanilla Scoop', 'Cotton Candy Scoop', 'Lavender Scoop', 'Marshmallow Scoop', 'Raspberry Scoop' and 'Vanilla Scoop'. Plugs were transplanted into beds in a tunnel in week 18 and to outdoor beds in weeks 18 and 20. Slow to establish at first, they grew vigorously after pinching three weeks after transplanting. In the tunnel flowering started in week 26, with a heavy flush from week 29 onwards, and flowering was still continuing in October when the trial was terminated. Flowering was prolific, though the percentage of stems >45cm in length varied through the season and between cultivars. The outdoor plantings also cropped well, considering the prevailing conditions (frost a week after planting, water-logging in June, drought and high temperatures in August). It was only possible to obtain 'Cherry Vanilla Scoop' and 'Vanilla Scoop' in time for planting outdoors, and 'Cherry Vanilla' was prone to leaf chlorosis while 'Vanilla' performed poorly (they will be further investigated in 2017). Samples were subjected to standard VL testing and all remained in acceptable condition on VL day 7. Although care has to be taken when harvesting, they were relatively robust and easy to handle and did not appear to have complicated post-harvest requirements.

Scabious appeared to have great potential for cut flower production in the UK, both under plastic and outdoors. These new cultivars, with their attractive range of flower colours, high yields and good VL, have been well received by the industry. They have good potential for use by retailers in mixed bouquets. The only problem is the lack of

stem length, which would limit how they could be utilised, which will also be investigated in 2017.

Solanum, ornamental (Solanum aethiopicum cultivars)

'Pumpkin-on-a-stick' is an unusual novelty that really caught the imagination of trial participants in the USA. The bright red 'pumpkins', actually resembling small (but toxic) tomatoes, are related to the winter cherry (*S. pseudocapsicum*) sold as a brightly fruiting house-plant. 'Pumpkin-on-a-stick' and 'Golden Eggs' were grown to assess the UK trade's response. Sown in plugs, they were transplanted into beds in a tunnel in week 18 or 19 at two planting densities.

'Pumpkin-on-a-stick' was an incredibly vigorous plant that started flowered in July, with fruits seen developing soon after. As expected the lower density produced sturdier stems than the higher density. The plants have vicious spines on stems and leaves, and removing these (as in the USA) would add costs and make it a specialty crop rather than a mainstream one. 'Golden Eggs' was interesting but very slow to mature and was not fully ripe before the covers had to be removed for the winter.

The industry did not appear to be enthusiastic about either of these novelties, although they may have a place with some of the smaller 'artisan' growers.

Crop introduction (2) crops with trials on-going

Basil (Ocimum basilicum)

There has been interest in growing basil as a fragrant filler for mixed bunches and bouquets, and in 2014 cultivars 'Dark Red Opal', 'Floral Spires Lavender', 'Floral Spires White' and 'Sweet Dani Lemon' were tunnel-grown as demonstration plots. They made good growth, with some cultivars having attractive foliage with potential for the suggested use. But the VL of these cultivars was poor (<5d) and further trials were postponed until better cultivars were available. 'Aromato' and 'Cardinal' are basil cultivars that were well received in ASCFG trials and in 2016 they were grown in demonstration plots. Plugs were transplanted to beds in a tunnel, growing well and producing good stems in August. Unfortunately post-harvest testing showed that the stems failed to take up water, confirming their poor VL.

Caryopteris (blue spiraea) (Caryopteris clandonensis cultivars)

Caryopteris is a popular garden shrub up to 1.5m-tall and bearing usually bright blue flowers in clusters near the branch ends. It had been included in trials in 2008, but concerns had been expressed then about the unacceptable smell sometimes associated with the crop. Although individual opinions varied and there appeared to be differences between cultivars, sufficient concerns had been raised to discourage further trialling at that point. In 2016 a new range of caryopteris bred specifically for cut flower production – the 'Pagoda' series. Three cultivars were grown in demonstration plots: plug-plants were transplanted into beds in a tunnel in week 21. 'Pagoda Lagoon' showed real promise because of its rich colour, but 'Pagoda Blush' was disappointing because of its rather insipid colour and short stems. The crop has been left *in situ* and its performance will be assessed in 2017.

Delphinium (*Delphinium elatum* cultivars)

Delphinium cultivars have previously been trialled extensively, but growers and others continue to debate whether more of their potential might be realised, say by the arrival of new cultivars. In 2014 'Sea Waltz', 'Sky Waltz' and 'Tango Dark Blue' became available and were trialled, proving to be productive, with attractive flower spikes, and producing two or three flushes a year. Examples of a further new series, 'Trick', became available in 2016 and were also trialled. Plugs of three 'Trick' cultivars were transplanted into beds in a tunnel in week 19. They produced a good flush of flowers in mid- to late-July and a second heavy flush in early-September. The spikes were elegant, upright and well-liked by growers. In VL tests, all stems treated with 'AVB' lasted >8d in the vase, 'RVB Clear' being less effective. The 'Trick' series were considered to have good potential as straight bunches or for use in bouquets. There is scope for further post-harvest work and improvements through cultivar selection. Further assessments will be made in 2017.

Fillers, seed-raised

Recent years have seen an increase in growers' interest in producing cheap, seed-raised fillers, either in tunnels or outdoors. A range of fillers was demonstrated in 2014 and 2015, and there were follow-up trials with *Ammi visnage*, *A. majus* and *Daucus carota* (ornamental carrot) in 2016.

The earlier trials with ammi had shown that *Ammi visnage* had the potential to produce big flower-heads for use in the larger, more expensive bouquets, alternatively smaller flower-heads could be produced by using higher planting densities or growing outdoors

to reduce the vigour associated with protected cropping. *A. majus* was slow to mature but produced marketable stems from later sowings both in tunnels and outdoors. Stems of both species achieved a long VL. There was marked enthusiasm from customers and growers for further comparative trials of ammi in 2016, and a range of cultivars was investigated: *Ammi majus* 'Bishop's Flower', 'Queen of Africa' and 'Snowflake', and *A. visnaga*, 'Green Mist', 'Mystique', 'Queen Anne's Lace' and 'White Spray'. Seed were direct-drilled in three rows along beds in a tunnel (week 18) and outdoors (week 20). The main picking period for *A. majus* cultivars was week 28 onwards and for *A. visnage* cultivars from week 30 or 31 onwards. In general, growth in a tunnel was still rather too vigorous, but this has to be balanced against the protection afforded by growing in a tunnel.

Ornamental carrot 'Dana' was grown in the same way as ammi, but only in the tunnel. It produced flowers from week 25 onwards, generating great interest among growers. A further trial will be carried out in 2017.

Gypsophila (*Gypsophila paniculata* cultivars)

In 2014–2015 two new gypsophila cultivars with improved stem and flower qualities, 'Zinzi Discovery' and 'Zinzi Tyree', were grown in demonstration plots, but, probably due to late delivery and planting, the results were disappointing. Further cultivars were demonstrated in 2016: 'Andromeda', 'Beauty Bride', 'Dynamic Love', 'My Pink', 'Orstar', 'Paniculata', 'White Victoria' and 'Xlence'. Plugs were transplanted into beds in a tunnel in week 21. All varieties produced some marketable stems in 2016 but their full potential will be assessed in 2017 once the plants have become established.

Solidago (*Solidago media* cultivars)

Solidago is often used as a filler with flowers such as freesia, requiring small stems (weighing about 15g) which can be supplied cheaply from imports. Solidago had previously been included in CFC demonstrations in 2008, when stems from tunnel plantings averaged 124cm in length and 274g in weight and those from outdoor plots 106cm and 222g. Solidago stems of this size would be suitable only for bunch sales, for which there is unlikely to be a demand. To examine the crop further, three cultivars were grown in demonstration plots in 2016. Plugs were transplanted into beds in a tunnel in week 21. They produced a heavy crop of high quality stems in mid- to late-August but did not achieve a second flush. The plants were left *in situ* for their potential to be assessed in 2017.

Trachelium (Trachelium caeruleum)

Trachelium is not well known in the UK, although it is widely grown in the Netherlands and has been trialled and grown in the USA. It seemed a good subject to include in trials. After the initial trial of 2013 failed due to seed germination issues, replacement plugs of 'Corine Purple' were transplanted in week 23 at 64/m^2 into beds in a tunnel. They produced an attractive display with flowering starting in late-August. A further trial in 2014 using plug-plants of 'Corine Purple' and examples from the 'Lake Michigan' series, were transplanted into beds in a tunnel in week 22 at 64/m^2. Initial growth appeared weak and budding-up occurred early but the stems lengthened and strengthened as the plants matured and each plant produced at least one heavy lead stem and a number of marketable side-shoots. Flower colours were impressive. The total yield of marketable stems ranged from 86/m^2 for 'Corine Purple' to 158/m^2 for 'Lake Michigan Blue'. For the lead stems, average lengths varied between 57 and 66cm and average weights (trimmed to 55cm) from 23g ('Lake Michigan White') to 32g ('Corinne Purple'). A later (week 27) planting of 'Lake Michigan Purple' was too late to achieve natural season flowering and the stems obtained were short.

A further trial was set up in 2015 to investigate transplanting dates (weeks 18, 22 and 25) and compare pinched and non-pinched (single-stemmed) crops, with the planting density kept at 64/m^2 for the non-pinched plants but reduced to 25/m^2 in the plots destined for pinching. Yields and stem length were satisfactory, though with large varietal differences, 'Lake Forrest White' and 'Lake Michigan Red' producing the tallest stems (70cm) and 'Lake Forrest Blue' and 'Lake Forrest Purple' the shortest (64cm), while trimmed stem weight varied little between treatments. The non-pinched plants grew vigorously and produced at least one or two side-shoots. The mean numbers of marketable stems ranged from 133/m^2, equivalent to 5.3 stems/plant (for pinched 'Lake Forrest Blue') to 273, equivalent to 4.3 stems/plant (for non-pinched 'Lake Michigan White'). Non-pinched plants cropped around 10 days earlier than pinched plants. VL testing showed a range of cultivar averages from 14 to 17days.

The greater number of stems/plant from pinched crops was of great interest for the economics of the crop and was further investigated with 'Lake Forrest Blue' and 'Lake Michigan White' in 2016. Plugs were transplanted in week 21 into beds in a tunnel at the same planting rates as in the previous experiment, and pinching took place two weeks after transplanting. The plants produced a superb crop with long, strong healthy stems. Pinched plants produced an average of just over 5 stems per plant, while non-pinched plants gave about 3.5 stems per plant.

There appears to be good potential for growing tunnel-raised tracheliums in the UK. In the past, tracheliums have had a poor reputation because of browning and the low weight of imported stems: the UK product seems much better – greener, taller and heavier. At present the high cost of plants is deterring growers from trying trachelium, but it may be possible to reduce costs by manipulating the number of marketable stems produced by pinching, varying planting density and testing other cultivars.

Veronica (Veronica longifolia cultivars)

Cultivars of *Veronica longifolia* are the most suitable veronica for cut flower production, having sufficient height and a good range of colours including blues. Veronicas had previously been demonstrated at the CFC in 2008, when four colours from the 'Spark' series had been grown in tunnels and outdoors. Across the cultivars, stems from tunnel plantings averaged 63cm in length and 29g in weight, and those from outdoor plots 44cm and 18g. At the time it was concluded that, for a number of reasons, not least a small production window, veronica cut flowers were unlikely to be economic in the UK. However, following revived interest, a further tunnel demonstration was suggested in 2016 and plots of three cultivars of the 'Skylark' series were grown. Plugs were transplanted to beds in a tunnel in week 19 at a density of 20/m^2. They produced a good crop of flowers during August and were prolific, with straight stems and well coloured spikes. A programme against powdery mildew is necessary. Veronicas show real potential as a cut flower in the UK and should be trialled further in 2017.

Zinnia (Zinnia elegans cultivars)

Zinnias have been grown previously at the CFC, in 2007 and 2008, when the industry was enthusiastic about their wide range of cheerful, vibrant colours. However, after picking, the hollow stems can collapse and bend just below the flower-head, making them unusable. Trials with zinnia were put on hold until varieties with improved stem strength became available. Trials started in 2013, using mainly the 'Benary's Giant' series but also the 'Oklahoma' series, which were considered superior to the other cultivars previous trialled, with better overall vigour, attractive flowers in a wide range of colours, and long stems. Overall, however, the VL results have given a rather unclear picture.

Early concerns about stem bending, due to the hollow stem, were not seen until late in vase-life, though VL was barely acceptable at a maximum of 7 days (2013 trials). In 2014 VL samples failed to survive until the end of the retail store phase; this may have

related to earlier infection with bacterial blight, although it was also suggested that zinnias may be sensitive to cool-chain conditions. In tests in 2015 they performed reasonably well, most stems lasting beyond the guarantee day, day 5, but between vase-days 5 and 10 they failed quickly, and on average <50% survived beyond vase-day 10. Stems failed for a variety of reasons, including botrytis in the bud and bending of the neck, but mainly for discolouration around the edges of the petals. Interestingly, stems harvested at the early stage with apparently weak necks, appeared to become firmer in the neck rather than bending, as had been expected, but VL was not obviously shorter for the most advanced stems than for those cropped at an earlier stage. It was suggested that neck bending may occur only when stems are picked at an over-mature stage, and that otherwise the developmental stage at picking is of little importance. There appeared to be large differences in performance between cultivars, with extremes of 10 days and 6 days. There were only minor differences in flower quality scores between conditioner treatments ('CVBN' treatments and 'RVB'). Finally, in 2016, the petal browning seen earlier did not arise until later in VL, and seemed a part of natural aging; very few instances of stem bending were observed; and the first stem deaths occurred on VL day 6 and the last on vase day 10, with an average VL of 8.5 days. Although further post-harvest work is ideally needed, at the present time it seems zinnias have an acceptable VL, and with the colour range available their presence in a bouquet should ensure they are of interest to retailers.

Financial benefits

Anecdotal and firm evidence has indicated that a number of crops has been trialled and grown commercially as a direct result of the CFC trials programme. Examples known to have been grown on a small-scale include the annual dianthus from Hilverda, *Aster ericoides*, carnation 'Solomio', dahlia 'Karma', phlox, seasonal Alstroemeria, scented pinks, and zinnia. Others have been grown on a more commercial scale, the main ones being antirrhinum, a spot-crop of bupleurum, lisianthus, trachelium, and various hardy perennials including hypericum, salix, sedum, spiraea and *Symphoricarpos* (snowberries). The following is an estimate of the area grown and farm-gate value of some of these products, the hardy perennials being included as single category:

- Antirrhinum: amount extra grown in 2016 approximately 1.0ha with an annual farm-gate value of £115,000.
- Hardy perennials: amount extra grown in 2016 approximately 10ha with a farm-gate value of £35,000 per ha which is based on hypericum with an average yield

figure which takes into account that some of these are relatively new plantings and have not yet reached their maximum yield. This represents an annual farm gate vale of approximately £350,000

- Lisianthus: amount extra grown in 2016 approximately 0.75ha with an annual farm-gate value of about £114,000 on an 80% cut percentage.
- 'Others' are a category that is not easy to give an accurate estimate of area to but when taking into account outdoor bupleurum, trachelium and the various crops planted by the large number of small artisan flower growers, this could represent between another 2 and 5 ha of additional plantings which could be an additional annual farm gate value of between £50,000 and £200,000.

To enable growers to undertake a basic assessment of the commercial potential of some of the most promising subjects, the following section includes some basic yields, planting density data and plant costs of the three subjects listed above, as well as of trachelium which showed great promise in the 2014 trials.

- Antirrhinum: planting density around 64 plants/m^2 of bed, with 80 to 95% of stems being harvested (one stem produced per plant); the plant cost is approximately €46 per 1,000 plus delivery.
- Hardy perennials, using hypericum as an example: planting density around 2.4 plants per/m^2, yield of around 20 stems per plant from year three onwards; the plant cost of hardy perennials varies with the subject, the cheapest being sedum at less than €1 per plant, then hypericum at about €1.60 per plant and snowberries at about €2 per plant. The expected life of these crops would be between 10 and 20 years.
- Lisianthus: planting density between 64 and 80 plants/m^2 of bed with 80 to 95% of stems being harvested (one stem produced per plant); the plant cost is approximately €95 per 1,000 (dependent on variety) plus delivery.
- Trachelium: planting density around 64 plants/m^2 of bed with at least one lead-stem harvested per plant and with some varieties in 2016 also producing one or two additional side-shoots; the plant cost is approximately €75 per 1,000 plus delivery. The economics of a pinched crop should also be considered by growers to reduce the cost of plant material.
- Scabious: planting density between 6 and 8 plants/m^2 of bed with the propagator estimating a yield of around 100 stems/m^2 being harvested (although initial trials have indicated that this could be and underestimate); the plant cost is approximately €0.85 each.

- Veronica: planting density around 20 plants/m^2 of bed with the propagator estimating a yield of around 80 stems/m^2 per flush (early trials indicate one flush in the first year and two in the second); the plant cost is approximately €0.70 each.
- Alstroemeria: planting density around 5 plants/m^2 of bed with yields of between 200 and 400 stems/m^2 being harvested (depending on the year and variety); the plant cost is approximately £3.50 or £4.50 each depending upon pot size.

In addition to the new crops being grown by commercial cut flower growers a wide range of new products are also been grown on a small scale by a large number of artisan growers. A number of UK mail order companies have also taken on board products such as annual dianthus, dahlia and zinnia. And while these growers are unlikely to be paying an AHDB levy, any increase in the production of UK cut flowers can only be good for the industry as a whole.

Action points

The 2016 trials highlighted the following new product opportunities that could be considered by UK growers who are interested in expanding the range of cut flowers they produce and offer:

- Craspedia, gomphrena, scabious and a range of ornamental grasses, which provide novelty in flower form and colours, and grow well in tunnels and have shown promise outdoors. Some of these (especially scabious and craspedia) have also been successfully trialled in glasshouses on grower holdings in 2016.
- *Ammi majus* and *Ammi visnaga*, which are economic, direct-drilled fillers growing well in tunnels and outdoor beds.
- Trachelium, which has promise as a new UK crop grown in tunnels to complement production in glasshouses.
- Non-protected cultivars of alstroemeria, which grow well as a natural-season tunnel crop, eliminating the high plant costs associated with protected varieties, while still producing a large yield of high quality stems.
- Lily growers looking to take advantage of peat reduction could consider growing them in crates of peat + wood fibre or peat + cocopeat mixtures, which give yields and quality as good as or better than standard peat-based growing media.
- Trials on herbicide programmes showed that the following treatments gave the best compromise between weed control and crop safety:
- For transplanted china aster, apply ‘Stomp Aqua’ + ‘Gamit 36 CS’ pre-planting followed by post-planting ‘Butisan S’.

- For drilled sweet william, apply ‘Stomp Aqua’ + ‘Goltix 70 SC’ at drilling followed by ‘Venzar Flo’ + ‘Flexidor 500’ + ‘Shark’ post-emergence.

Science Section

Introduction

As described in detail in previous reports [2] the cut flower trials programme was set up partly in response to increasing *per capita* purchases of cut flowers in the UK which might have been expected to stimulate production by UK growers, but had instead resulted in greatly increased imports, while UK production remained more or less static. The CFC has tried to redress this import issue by stimulating the market for UK produced flowers.

The practical aim of the programme is to provide (a) improvements in the growing of established cut flower crops, and (b) information to encourage the introduction and production of new or alternative cut flower products, primarily grown in Spanish tunnels or outdoors but with potential for glasshouse production. The underlying aim is to stimulate UK cut flower growers to develop and commercialise new and alternative cut flowers for the benefit of consumers and producers. In the project the term ‘new crops’ is interpreted very widely – it could include a species completely new to production horticulture, or may simply indicate a crop with which UK growers are currently unfamiliar or for which improvements to husbandry or quality are needed. The types of trial carried out are varied and depend on the present understanding of a particular crop, and include (a) simple demonstration plots, (b) cultivar trials, (c) trials to develop a production protocol, (d) trouble-shooting experiments, (e) larger-scale commercial evaluations and (f) collaborative R&D on themes identified by industry/AHDB Horticulture. As well as carrying out practical trials, the programme includes information gathering and technology transfer roles and a remit to identify gaps in knowledge and encourage the submission of concept notes to address them.

This report describes the work carried out in 2016. It gives a brief review of the information gathering work (fully described elsewhere), detailed reports of the 2016 trials, summaries of the earlier trials in the project, and an inventory of technology

[2] The cut-flower trials project was proposed by industry representatives and funded by the HDC (now AHDB Horticulture) starting in 2007. The initial project (PC/BOF 268, 2007-2008) was jointly funded by the HDC and the Lincolnshire Fenlands LEADER+ programme. This was followed by projects PC/BOF 268a (2009), PC BOF 002 (2010-2012) and, currently, PC BOF 002a (2013-2017). Copies of earlier project reports are available from both the CFC and the AHDB Horticulture websites.

transfer activities. An index to the cut flowers trialled since 2007 is included as Appendix 1. The Project Leader and Management Group (MG) would welcome comments and suggestions from growers and the industry at large for future projects.

Crop information

Gathering information about cut flower crops made use of both internet sources and CABI's '*Horticultural Abstracts*' ('*HA*') database, a compilation of all significant research on horticultural crops worldwide. The information was summarised into the databases and reviews listed below, which are available from the AHDB Horticulture and CFC websites.

Database of seed and planting material suppliers

A database of companies supplying seeds and planting material for cut flower production was compiled in 2013 using internet and other resources. It was up-dated in 2015.

Review of new cut flower crops and cut flower trials programmes

R&D on new cut flower crops was largely reviewed through the world scientific literature using '*HA*' (see above), and this is where information on species genuinely new to the cut flower trade is to be found. Also included are reviews of overseas cut flower trials, and internet sources of information for growers. The initial (2013) review was updated in 2015 and 2016.

Production levels and trends in the cut flower trade

International statistics on the world production and trade in cut flowers was reviewed in 2015. The main source of information used is the annual *International Statistics, Plants and Flowers* from AIPH.

Materials and methods

Demonstrations, trials, experiments and commercial evaluations

As in previous years, the 2016 experimental programme was developed by the Management Group (MG), taking into account the views received from growers and others, and information from the review of new crops and cut flower trials (see previous section). Depending on the present state of understanding of a crop, different species might require a simple demonstration plot, a comprehensive cultivar trial, the development of a production protocol or a trouble-shooting experiment (e.g. to develop

seasonal extension or test pesticide effects), or a larger-scale evaluation at a commercial nursery. The programme includes the investigation of several new crops each year, assessing their potential for UK production, and deciding whether or not to take them forward for further testing. The experimental programme consisted of many individual demonstrations, trials, experiments and evaluations on numerous species and cultivars, and the individual trial methods are given under the 'Results' section, with only the more general methods being described in this section.

Protocols and facilities at the Centre

By arrangement with David Robinson (Managing Director, R Robinson & Son Ltd), the trials programme is hosted at Rookery Farm, Holbeach St John, Spalding, Lincolnshire. The National Cut-Flower Trials Centre ('the Centre') is constituted as The Cut Flower Centre Ltd with project leader Lyndon Mason as Director; it is managed by a Management Group (MG) comprising representatives of growers, packers, retailers and AHDB Horticulture. The programme is formulated each year by the MG, taking into account comments received from growers and others through the year.

Protocols were agreed between David Robinson of Rookery Farm and the Centre's MG with the aim of achieving a good standard of commercial husbandry, adapted as necessary to suit small trial plots that might require frequent or detailed records to be kept and individual pesticide, irrigation, fertiliser and other treatments to be made.

The facility at Rookery Farm, Holbeach St John, Spalding, Lincolnshire comprises a single-span 'Haygrove' tunnel[3] (7.9m wide × 38.1m long), a triple-span 'Pro-Tech' tunnel[4] (overall 22.7m wide × 38.0m long) and an adjacent area of outdoor beds of 600m^2. The growing area is provided with anti-rabbit fencing. Since it is an exposed site, wind-breaks of 2.5m-high polypropylene netting are provided at each end of the 'Pro-Tech' tunnel. The polythene covers are removed for the winter in late-October in order to protect the structures; in some cases this will have brought crops to a forced end. Typical of the area, the soil is deep alluvium drained by ditches and pumps.[5]

Site preparation

The growing areas were sterilised as required by the year's trials programme. For the 2016 season the south half of the 'Haygrove' tunnel was steam-sterilised on 15 April

[3] http://www.Haygrove.co.uk/
[4] http://www.Pro-Tech-marketing.co.uk/
[5] *Soils of England and Wales*, Soil Survey of England and Wales

2016, leaving the north half un-treated as required for the column stock trial being planted there. The unplanted north end of 'Pro-Tech' tunnel bay 1 and all of 'Pro-Tech' tunnel bays 2 and 3 were also steam sterilised at the same time.

Each year in April soil samples were taken across the trials site for standard glasshouse soil analysis. As it is not possible to give a base fertiliser recommendation for all minor cut flower crops, the aim was to bring base fertiliser levels up to about those required for column stocks or chrysanthemums, that is indices of 2 for N, 5+ for P, and 4 each for K and Mg. In April 2016 the 'Haygrove' tunnel received 15g/m^2 'Nitram' (ammonium nitrate) and 50g/m^2 sulphate of potash, 'Pro-Tech' bay 1 received 15g/m^2 'Nitram' only, bay 2, 50g/m^2 sulphate of potash only, bay 3, 15g/m^2 'Nitram', 50g/m^2 triple superphosphate and 50g/m^2 sulphate of potash, and the outdoor area 15g/m^2 'Nitram', 110g/m^2 triple superphosphate and 50g/m^2 sulphate of potash.

Plant material

Most plants were obtained as plug-plants or seeds, some as rooted or un-rooted cuttings, liners or bulbs. Seeds were either germinated in plugs and transplanted, or direct-drilled. Details, and any special treatments, are described under the 'Results' section.

Crop husbandry – planting

Most plants were transplanted into labelled plots along the 1m-wide beds at the specified density. Individual plot lengths were dependent on the trial, and wherever practical 0.5m-long unplanted 'guard areas' were left between plots and at the ends of the beds, to guard against shading and 'end effects'. Up to and including 2014, the beds were generally covered with 1.2m-wide, 120-gauge, micro-perforated black polythene film and planting was through the film, otherwise planting was directly into the border soil. In 2015 and later planting was made directly into the border soil, little advantage being seen in using a film mulch in this context. Crops were watered with a hand-lance immediately after planting and then to ensure establishment. More details and any exceptions are given under the 'Results' section.

Crop husbandry – post-planting

Once plants were established most water was applied as needed through the lay-flat irrigation lines, although if required a hand-lance would also be used. Once in growth, plants received a weekly liquid feed, with applications increased as required to twice

per week on vigorous crops later in the growing season. The liquid fertiliser used was 'Universol® Green' (23:6:10:2.7 N:P:K:MgO with trace elements; Everris International). Beds were provided with one or more layers of support netting if required by the crop, the netting being raised with the growth of the crop. Sometimes plants were stopped (pinched) or other treatments applied, and details are given under the 'Results' section.

Pesticide applications

The pesticides applied in 2016 were as detailed below.

- For powdery mildew, sulphur (as 'Thiovit Jet') to asters, delphiniums and solidago,, weeks 18.
- For powdery mildew, myclobutanil (as 'Systhane 20EW') to asters, delphiniums and solidago, weeks 23 and 26.
- For powdery mildew, cyflufenamid (as 'Takumi 5C') to asters, delphiniums and solidago, week 30.
- For botrytis and leaf spotting, iprodione (as Rovral) and azoxystrobin (as Amistar) on lilies and ornamental brassica, weeks 36 and 43.
- For aphid, pymetrozine (as 'Chess WG') to all asters and delphiniums, week 24.
- For thrips, spinosad (as 'Tracer') to all crops in, week 24.
- For aphid, pymetrozine (as 'Chess WG') to all lilies and ornamental brassicas, week 40.
- For pests, cypermethrin (as 'Toppel 100 EC') to all ornamental brassicas week 34.
- For pests, spirotetramat (as 'Movento') to all indoor and outdoor crops, week 34.
- For foliar diseases, azoxystrobin (as 'Amistar)' to all ornamental brassicas, week 41.
- For pests and foliar diseases, acetamiprid (as Gazelle SG and pyraclostrobin (as Signum) to all lilies and ornamental brassicas, week 38.

Crop assessments

Stems were picked at the appropriate commercial stage for each crop, wherever practicable taking samples close to the peak cropping date. Usually the number of marketable stems picked was recorded (and converted to numbers of stems per m^2), along with (for an appropriate random sample of each plot) picking dates, lengths and weights of stems (either overall figures or after trimming to a specified length) and other measurements as appropriate (such as spike length or flower-head diameter). Other than as required by trimming, the stem lengths and weights quoted always refer to the total weights and lengths of the whole stem (including buds, flowers or inflorescences).

Less formally, the plots were also assessed at intervals by the MG and others as appropriate, and in the case of preliminary demonstrations emphasis was placed on photographs and grower comments. As appropriate to the practical nature of the project, demonstration plots were not usually replicated; where replicated, randomised trials were undertaken and as appropriate the data were subjected to analysis of variance. In the analysis of variance tables the value of P (probability) indicates the statistical significance of the source of variation (say, growing medium or herbicide treatment). (In the tables *, ** and *** indicate significance at the 0.05, 0.01 and 0.001 levels of probability, i.e. that the result obtained could be expected to have occurred by chance in one in 20, one in 100 or 1 in 1000 instances, respectively, while NS indicates not significant (i.e. P>0.05)).

Protocols for trials at commercial nurseries

Some evaluations have been carried out at appropriate commercial nurseries, either because conditions at the Centre were unsuitable or in order to assess crops on a larger scale or on a more 'commercial' basis than would be practical at the Centre. No CFC trials was conducted at commercial nurseries in 2016.

Vase-life testing

Vase-life (VL) testing is an essential component of any cut flower trials programme. As there is a shortage of test facilities and the CFC has been unable to use a single, dedicated VL room throughout, the facilities and protocols used have varied over time. Typically, VL testing includes some simulation of the treatment and storage of the cut-stems in the production, transport, storage and retail phase, ending with the actual VL tests under simulated home conditions. The VLs quoted refers to the number of days in the vase only, not including the preparatory stages. Assessment involves determining not only the longevity of the product in an acceptable state, but also flower and leaf quality throughout VL, the clarity of vase water, and the 'throw-out' criteria. The conditions for the VL test have generally become standardised at 20°C and 60% RH under lighting of 1,000 lux for 12h/day; many other factors are also important, including how the stems are cut/re-cut, the cleanliness of the vases, and water quality.

In 2016 VL tests on cleome, craspedia, delphinium, gomphrena, ornamental brassicas (batch 2), ornamental grasses, scabious and zinnia were carried out by Claire Strait (Chrysal UK) using new facilities at the University of Lincoln's Holbeach Campus. Stems at the appropriate picking stage were harvested at CFC (or a commercial nursery in the case of brassica), placed in clean buckets containing 4L water (3L water

in the case of brassica) incorporating one of two alternative post-harvest treatments appropriate for the species being tested. With the exception of brassica the post-harvest treatments were drawn from 'RVB Clear' (4ml product/4L water), 'CVBN' (two tablets/4L water), 'AVB' (8ml product/4L water) or 'Professional 2 T-bag' (two bags/4L water); for brassica several post-harvest treatments were tested (see text for details). The samples were transported in these buckets to the VL facility where they were placed in a cold display unit (2°C) (in the case of brassica and delphinium initial storage, for two days in the case of brassica and over-night in the case of delphinium, was in the growers' cold store (2–4°C) before transferring to the cold display unit). After two days in the cold display unit the stems were removed from the post-harvest treatments and de-sleeved, the basal 2cm of stems were removed, and they were placed in water incorporating a 'Professional 2 T-bag' (two bag per 4L water) in the VL room (standard conditions as above), simulating retail-store conditions (in the case of brassica the removal of the basal 2cm of stems was instead carried out when the VL test was set-up, and was omitted in some treatments, see text). After a further two or three days the VL test itself was started when the stems were removed to vases (usually ten stems per vase) containing 1L of water incorporating 'Chrysal Universal Liquid Food' (one 'liquid stick' per 1L water) and kept at the same conditions as before. The VL test continued for seven to 10 days, depending upon longevity of the subject.

In addition, further VL testing of ornamental brassicas (batch 1) and of woody foliage was carried out by Butters Group in 2016. Stems were picked into plain water and stored for two days in the growers' cold store (2–4°C). After transfer to the VL testing facility, the stems were re-cut, placed in water with added 'CVBN' (two tablets/2L water), placed in a cold store (5°C) for five days and then moved to the VL room (conditions as above) for an additional five days. Finally, the stems were removed to vases containing 1L of water incorporating a universal flower food and kept at the same conditions as before. The VL observations continued for up to eight days.

Results

In describing the results, the trials involving *Crop Improvement* – 'new ways with old crops' - are described first, followed by those involving *Crop Introduction* – 'novel crops for the UK'.

Crop improvement

In 2016 the previous trials on alstroemeria, brassica (ornamental), china aster and

column stock (all primarily cultivar selection) and lily (alternative growing media) were extended. Herbicide trials were extended to china aster and sweet william.

Alstroemeria – garden cultivars (Alstroemeria cultivars)

Alstroemeria, more familiar as a glasshouse crop using modern, high-quality and expensive cultivars, had not been included in the earlier projects at the CFC. However, the ready availability of Spanish tunnels raised the possibility of growing a seasonal crop of older cultivars that are free of Plant Breeder's Rights (PBR) and therefore cheaper to source. A feasibility trial using twelve non-PBR cultivars was set up in 2014 and will be grown until 2017 (Table 1). For photographs of the cultivars used, see the project annual report for 2015.

Table 1. Details of 2014–2016 alstroemeria cultivars feasibility study

Site	Rookery Farm
Varieties	'Apollo', 'Avanti', 'Bonanza', 'Candy', 'Dana', 'Flaming Star', 'Friendship', 'Golden Delight', 'Nina', 'Orange Supreme', 'Pink Sensation' and 'Tanya'
Format(s) and supplier(s)	7 and 9cm plug-plants (Parigo)
Propagation and pre-planting treatment(s)	None
Planting or sowing date(s)	Transplanted week 22, 2014 (tunnel) Transplanted week 23, 2014 (outdoor)
Plant spacing(s)	5/m^2
Planting site(s)	2m-long plots in beds in 'Pro-Tech' tunnel bay 1 1m-long plots in beds outdoor
Layout	Un-replicated demonstration plots
Post-planting treatment(s)	One layer of support netting in 2014, increased to three layers in 2015 and 2016 Weak and short stems removed at the start of each season to encourage stronger growth Removed flower-heads in the early stages until stems started to reach specification Mulch applied to outdoor plots over first winter
Pests, diseases and disorders	Minor caterpillar and aphid damage noted in 2016
Picking stage(s) and market specification(s)	Buds just starting to show colour Stem length 60cm
Picking and recording date(s)	2014: from week 30 to week 44 (in tunnel) or week 45 (outdoors) 2015: in tunnel from week 23 to week 44 when they were still cropping but the tunnel was de-skinned; outdoors, from week 26 to week 41 2016: in tunnel from week 22 to week 41 when they were still cropping but the tunnel was de-skinned; outdoors, week 26 to week 41 Picking half-weekly, weekly or fortnightly according to the state of the crop

Records taken	Picked to a minimum specification of 60cm, recording picking dates and number of stems picked each date
VL testing	Sampled for testing week 29, 2014 (tested by Butters Group)

Plant establishment in 2014 was considered very good. As expected for new alstroemeria plantings, the earlier stems were short and weak and were cut-out and discarded. Marketable flowers were produced from week 31 in the tunnel, while outdoors stems were slower to get going and the first stems were picked in week 33. Plants were very vigorous under protection, producing good, strong stems that some visiting growers stated were better than glasshouse crops; in the outdoor beds stems were much less numerous. Picking continued to weeks 44–45, when it was terminated to allow the tunnel to be de-skinned.

The tunnel crop overwintered well to 2015, starting to produce shoots for thinning as soon as the tunnel was covered in week 17. Marketable stems of high quality were picked starting, for the different cultivars, in week 23 to 26, one to two months earlier than in the first year. In the outdoor plots marketable stems were cropped starting between week 26 and 28, though overall growth was less vigorous than under protection. Marketable flowers were still being produced in the tunnel when cropping ceased for de-skinning (week 44), while the last pick outdoors was in week 41.

This generally strong performance continued into 2016 (Figure 1). For the different cultivars marketable stems were picked starting from week 22 or 23 in the tunnel and from week 26 to 29 outdoors. Marketable flowers were still being produced in the tunnel and outdoors when cropping ceased for de-skinning (week 41). The flower yields and picking periods are across the three years are summarised in Table 2.

Figure 1. Tunnel-grown alstroemeria in trial at CFC in 2016, taken in (top-left then *clockwise*) weeks 24, 32, 35 and 37

Table 2. Stem yields and (below) picking dates for twelve alstroemeria cultivars grown 2014–2016 in tunnel and outdoor beds

Measurement and cultivar	Tunnel (T)			Outdoors (O)			Marginal means				
	2014	2015	2016	2014	2015	2016	T	O	2014	2015	2016
Total marketable stems/m^2											
Apollo	113	327	249	42	65	217	230	108	78	196	233
Avanti	204	296	326	73	81	139	275	98	139	188	233
Bonanza	224	162	252	154	47	76	212	92	189	105	164
Candy	201	276	367	162	108	115	281	128	181	192	241
Dana	218	315	383	188	105	100	305	131	203	210	241
Flaming Star	151	400	337	57	58	291	296	135	104	229	314
Friendship	215	400	330	82	52	296	315	143	148	226	313
Golden Delight	117	351	280	29	95	202	249	109	73	223	241
Nina	259	331	355	131	191	254	315	192	195	261	304
Orange Supreme	130	203	179	49	53	162	171	88	90	128	170
Pink Sensation	187	278	347	120	35	122	270	92	153	156	234
Tanya	210	343	457	103	149	200	336	151	156	246	329
Average of above	185	307	322	99	87	181	271	122	142	197	251
Overall picking periods											
from week no.	31	23	22	33	26	26					
to week no.	44	44	41	45	41	41					

Overall, in the year of planting there was a slow build-up of flowering stems, with most picking in the second half of the season, while in the second and third years there was a shift to earlier picking with a rapid build-up to the main picking period; Figure 2 shows the profile of annual flower picking as totals across all cultivars. With this combination of twelve cultivars and tunnel and outdoor plots the supply of flowers was reasonably consistent and occurred over a long, five month period (which would have been longer had it been possible to leave the cover in place). Nevertheless the flower supply was still somewhat patchy, with few or no flowers available in some weeks each year, illustrating the typical cycling that occurs in alstroemeria flower production. Combining the yields from tunnel- and outdoor-grown plots failed to improve the consistency of supply, but this might be improved by growing new plantings alongside older ones, or by making a small number of sequential plantings.

Figure 3 shows the yields of marketable stems for each cultivar, location and year. Overall, yields in the tunnel were more than double those for outdoor plots, and annual production increased over the three years of the trial. In round terms, tunnel-grown crops produced about twice the yield of outdoor beds in 2014 and about three-times the yield in 2015, falling back to less than double in 2016. Despite the poorer yields obtained outdoors, growing alstroemeria in the open may still have a place for small growers. The overall yields of individual cultivars varied markedly. In the tunnel or outdoors, the productivity of half of the cultivars increased annually, while most of the rest peaked in the second year. Overall, ‘Nina’ was the highest yielder, being consistently so in the tunnel, outdoors and across the three years. ‘Dana’, Flaming Star’, ‘Friendship’ and ‘Tanya’ were also consistently among the higher producers, with ‘Dana’ doing particularly well as a first-year crop and in outdoor beds and ‘Friendship’ doing particularly well in the tunnel. Overall poorer performers were ‘Apollo’, ‘Bonanza’, ‘Golden Delight’ and ‘Orange Supreme’. Most cultivars appeared to crop over the whole picking period to some extent; the profiles of flower picking for individual cultivars were shown in the annual project report for 2015, where these cultivars were also illustrated.

In 2014 stems were taken for standard VL testing. With alstroemerias it appears to be important to allow the flowers to show good colour before picking, which makes them much more attractive without appearing to shorten their VL. Stems of eight cultivars, all at a similar stage of development, were sampled. The samples had a consistent average VL of 12 days, so exceeded the usual number of ‘guaranteed’ days. By vase-day 13 the petals were dropping and the foliage was senescing.

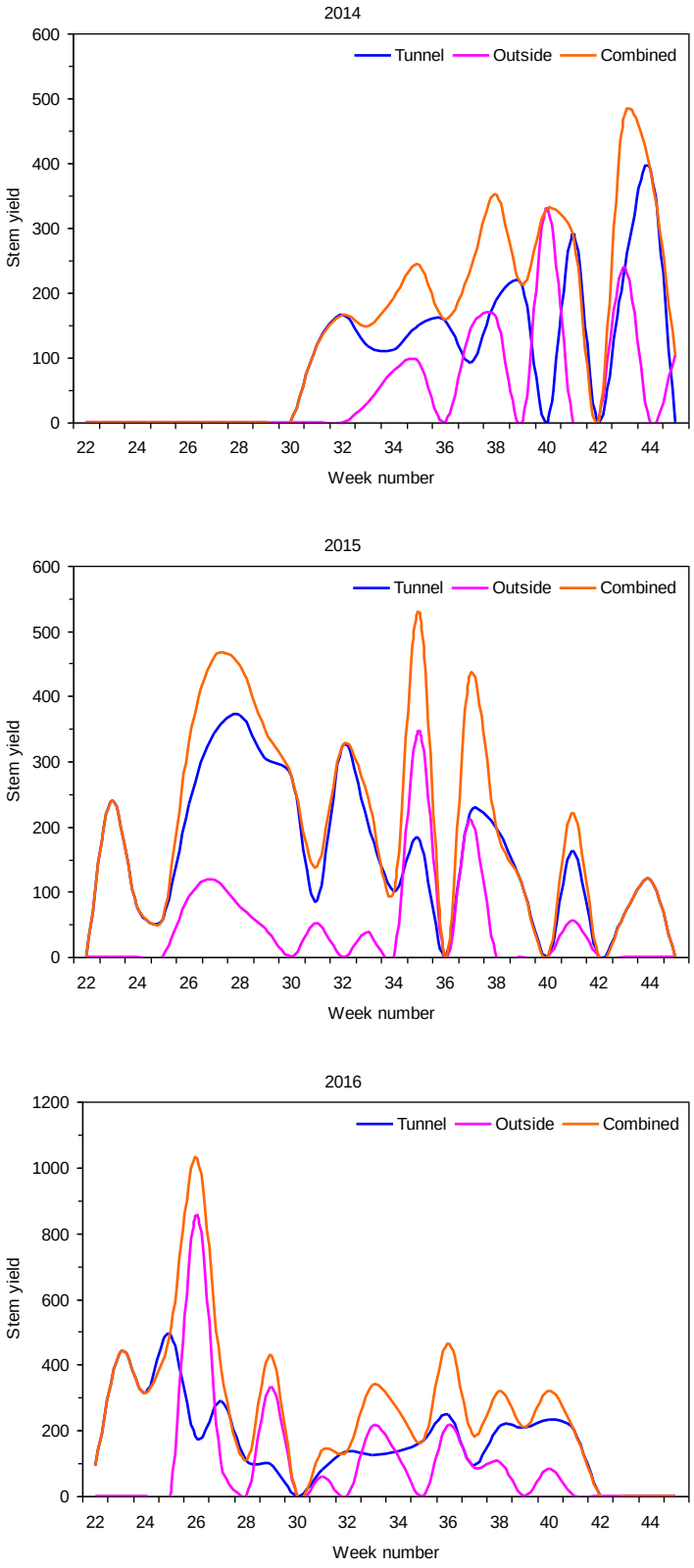


Figure 2. Total weekly stem yield across twelve cultivars of alstroemeria (1m^2 of each) in (top to bottom) 2014, 2015 and 2016. Yields are shown for tunnel and outdoor plots and as the combined total. Data plotted as 'smoothed' lines to show 'cycling'.

Growing non-PBR cultivars in tunnels appeared to have strong potential. As a direct result of this trial a number of small commercial plantings of these types of alstroemeria have been made. The current trial will be continued for one more year.

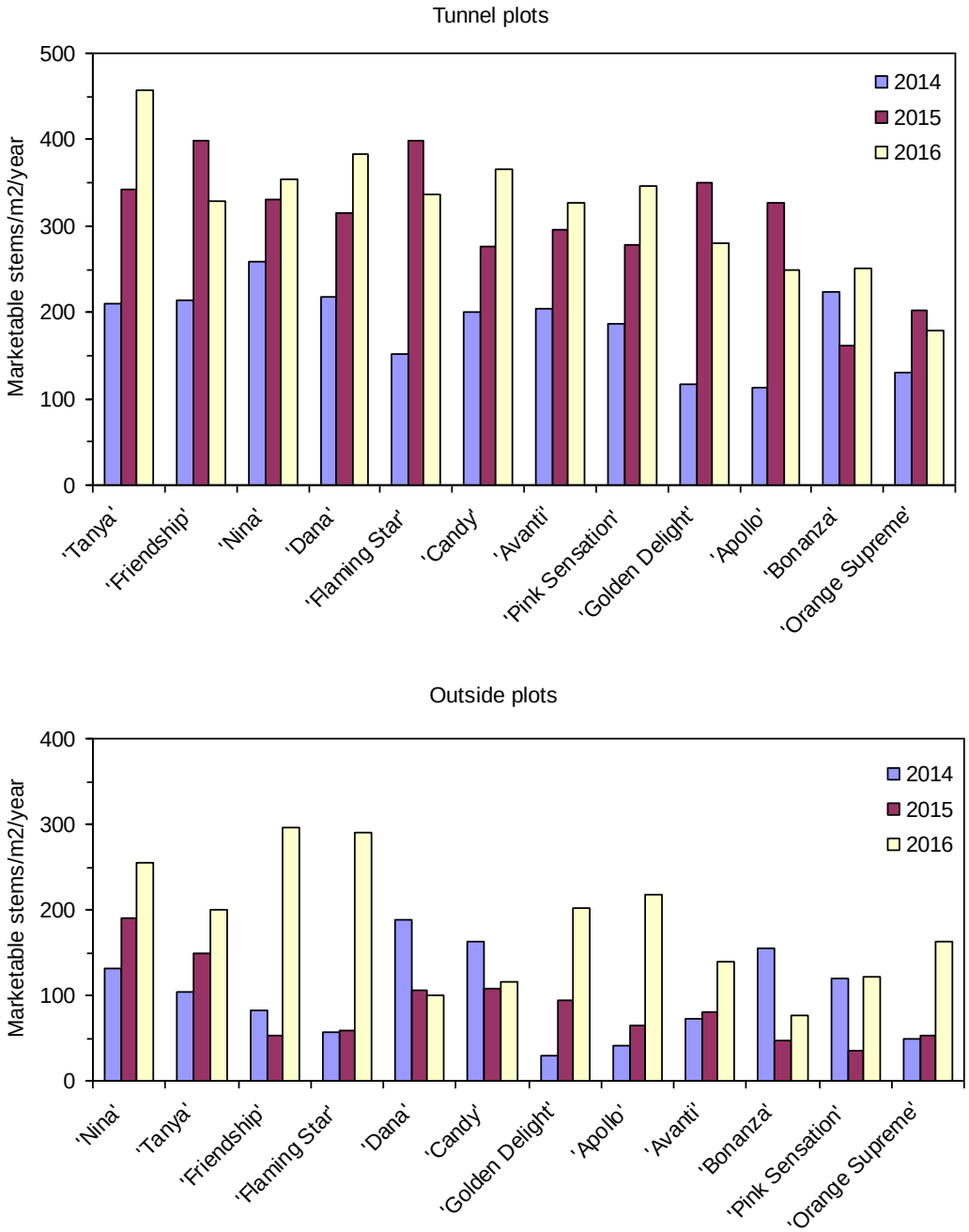


Figure 3. The number of marketable stems/m^2/y produced by plots of 12 alstroemeria cultivars (1m^2 of each) over three years growing (top) in a tunnel and (bottom) outdoors. To aid comparisons, the histograms are drawn to the same vertical scale. In each histogram the cultivars are ordered from left to right in descending number of total stems produced over the three-year period.

Brassica, ornamental (*Brassica oleracea* cultivars)

Using the heads of ornamental brassicas (cabbages, etc.) in vases and bouquets may have appeared quirky at first, but a substantial demand soon developed. Although several demonstrations and trials of ornamental brassicas were carried out at the CFC between 2008 and 2012, interest in the crop continues to be high in spite of uncertainties about some aspects of husbandry and the best cultivars to grow (see later text).

In 2015, a wide range of cultivars was sourced from the main propagators and grown in a tunnel to compare their performance (for photographs of these cultivars see the project annual report for 2015). 'Kysia' heads failed to show any signs of colouring-up and were not cropped. Some cultivars produced heavier ('Bright Wine' and 'Olga') or lighter ('Bogdana', 'Crane Queen' and 'Katya') stems than the norm, or larger ('Anthonia') or smaller ('Agathana', 'Crane White', 'Olga' and 'Varvara') heads than the norm. Overall, the heads were of high quality, and a number of the less familiar cultivars showed real promise and generated market interest exceeding that of the more familiar 'Crane' series. Samples of 'Condor Early White' and 'Katya' were taken for VL testing and gave very good results – VL of 10 and 17 days, respectively. Numerous samples from the trial were sent to potential customers and growers and some of the less familiar cultivars clearly impressed. However, the impression received from growers was that many would prefer to stick with the well-tried 'Crane' series until more experience with the alternative cultivars has been gained. Alternative cultivars appear to need more exposure in the industry before they are adopted. The new cultivars will need to show clear, economic advantages. 'Crane' cultivars do not always colour–up in mild weather (as found in some commercial crops in 2015) and this is an important factor in assessing alternative cultivars. It would not be surprising if different cultivars possessed different cold requirements. In the 2015 trial some of the newer cultivars produced lighter or smaller heads (others might be considered too heavy or large), which suggests manipulation of head size might be achieved by changing planting density.

By 2016 growers were still keen to see further demonstrations of the newer brassica cultivars grown alongside established types, and to see how they perform when grown outdoors. Selected cultivars from the 2015 trial were therefore planted in a further demonstration in 2016 (Table 3); it was not practical to include outdoor plots this year and this will be pursued later.

Table 3. Details of the 2016 ornamental brassica demonstration

Site	Rookery Farm
Varieties	'Agathana', 'Anthonia', 'Bogdana', 'Condor Pure White', 'Crane King', 'Crane Pink', 'Crane Queen', 'Crane White', 'First Lady', 'Ksenia', 'Kysia', 'Olga' and 'Vera'
Format(s) and supplier(s)	Plug-plants (Florensis)
Propagation and pre-planting treatment(s)	None
Planting or sowing date(s)	Transplanted week 30
Plant spacing(s)	64/m^2
Layout	Un-replicated demonstration plots
Post-planting treatment(s)	One layer of support net provided
Planting/housing site(s)	Beds in 'Pro-Tech' tunnel bay 3
Pests, diseases and disorders	Some caterpillar and aphid damage
Picking stage(s) and market specification(s)	Heart developed and coloured-up, stem length 60cm
Picking and recording date(s)	Week 42–43
Records taken	Not formally assessed but used as a demonstration of cultivars
VL testing	All cultivars sampled on 24 October 2016 for VL testing (Butters Group) Samples of glasshouse 'Crane Bicolor', 'Crane Red' and 'Crane White' taken 5 December 2016 also taken for VL testing (Holbeach Campus, University of Lincoln)

The cultivars are shown in Figure 4; with the exception of 'Kysia' all cultivars grew and coloured up well. On expert examination all cultivars were considered to have produced heads of high quality and within specifications. However, at this planting density (64/m^2) the yield of marketable heads was reduced in some cultivars, particularly those with dissected (rather than entire) foliage.

‘Agathana’

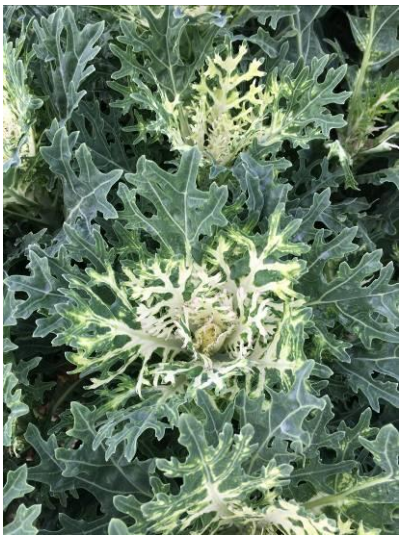
‘Anthonia’

‘Bogdana’

Figure 4. Ornamental brassica cultivars from the 2016 demonstration (week 42) (continued on next pages)

‘Condor Pure White’

‘Crane King’



‘Crane Pink’

Figure 4. (continued)

‘Crane Queen’

‘Crane White’

‘First Lady’

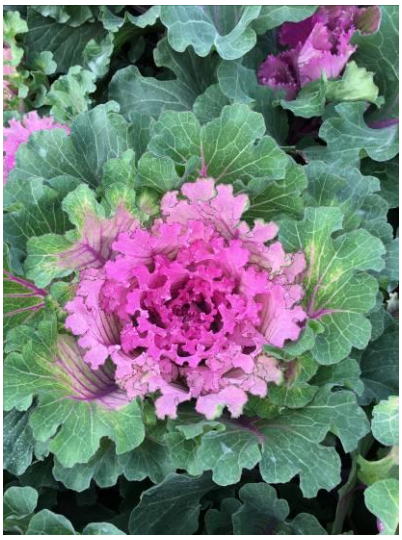


Figure 4. (continued)

‘Ksenia’

‘Kysia’

‘Olga’

Figure 4. (continued)

'Vera'

Figure 4. (continued)

In 2015, preliminary VL tests indicated a 10 day VL for 'Katya' and a 17 day VL for 'Condor Early White' sampled in week 42, a very satisfactory result. In 2016 all cultivars were sampled in week 43 and tested by Butters Group. The post-harvest treatment was 'CVBN' at the higher rate. All cultivars lasted for 5 or 6 days in the vase before dehydration and (or) yellowing started, thereby just exceeding the guaranteed 5 day.

To investigate the apparent discrepancy between the preceding results, stems of three 'Crane' cultivars were sampled from a commercial nursery's glasshouse crop in week 49. There were four post-harvest treatments ('CVBN' (standard and low dose), 'RVB Clear Intensive' and 'Lily and Alstroemeria BVB', followed by further storage in water with 'Chrysal Professional 2 T-bag' (one bag/2L water) and the VL test itself in water with 'Chrysal Universal Liquid Food' (one stick/L water) (Table 4). As some bouquet makers are reportedly not re-cutting the stems of ornamental brassicas before use, this factor was also tested: for each post-harvest treatments one sub-treatment had the basal 2cm of stem removed as usual when placed into the vases, and the other was left intact. There were two vases of three stems for each of the three cultivars and each of post-harvest treatments 1 to 6 (treatments 7 and 8 were not replicated). The stems were examined up to vase-day 10 (Figure 5) and stems written-off when >50% of the leaves had wilted, drooped or were showing browning. Bacterial contamination in the post-harvest treatment water was assessed at the end of the post-harvest phase using the 'Petrifilm' technique. With treatment averages of most treatments of 5–6 days, VL was just acceptable. However, these results gave no indication that VL might be significantly extended through either variety selection, using different post-harvest treatments, or choosing to re-cut or not re-cut stems. The 'Petrifilm' technique, a measure of bacterial contamination in the treatment water at the end of the post-

harvest phase, suggested that 'CVBN', particularly when used at the higher rate, was an effective bactericide treatment in this case (Figure 6). There was seen to be less leaf yellowing when 'Lily and alstroemeria BVB' had been used as the post-harvest treatment. While leaf quality begun to deteriorate from about vase-day 4 this was insufficient to result in an unpleasant smell at the end of VL.

Table 4. The results of post-harvest treatments in 2016 brassica VL testing

Treatments			Average VL (d)[1]	'Petrifilm' reading[2]
No.	Post-harvest	Stem base removal		
1	'CVBN' (1 tablet/3L water)	Re-cut	4.7	1
2		Not re-cut	5.8	
3	'RVB Clear Intensive' (1ml/L water)	Re-cut	4.9	2
4		Not re-cut	5.0	
5	'Lily and alstroemeria BVB' (2ml/L water)	Re-cut	6.6	4
6		Not re-cut	6.1	
7	'CVBN' (1 tablet/L water)[3]	Re-cut	5.3	0
8		Not re-cut	9.0	

[1] Average of vases of the three cultivars
[2] Assessed at the end of the post-harvest treatment and scored from 0 (no bacterial growth) to 5 (heavily infested)
[3] The grower's current treatment, cf. treatments 1 which is a recommendation

Despite carrying out VL tests on ornamental brassicas during this project, it is evident that substantially more needs to be done to achieve a consistently good VL and maintain the vase-water in good condition. This is important if the popularity of the product is to be maintained. The results to date suggest it may not be easy to identify ideal post-harvest and other treatments, nor to identify cultivars with longer VL. This lack of consistency may be due to growing conditions and the state of the crop at harvest. Ornamental brassicas can be grown outdoors, in tunnels or under glass. Growing in the field has the advantage of reducing costs, since direct-drilling and regular herbicide applications (for non-protected crops) can be used, but it cannot be relied upon to produce high quality stems beyond early-October as the weather deteriorates. The protected environment of tunnel-growing gives greater flexibility over picking dates, while growing in glasshouses ensures the possibility of later crops (which attract higher prices), though the heads will deteriorate slowly if picking is delayed too long. Planting density is another important factor, because only high planting rates (64/m^2) combined with a high percentage of marketable heads are likely to provide sufficient income to make the crop profitable. More economic data are needed before a decision on the profitability of ornamental brassicas can be made.

Treatment 1

Treatment 2

Treatment 3

Treatment 4

Treatment 5

Treatment 6

Figure 5. Ornamental brassica cultivars shown on vase-day 10 following different post-harvest treatments

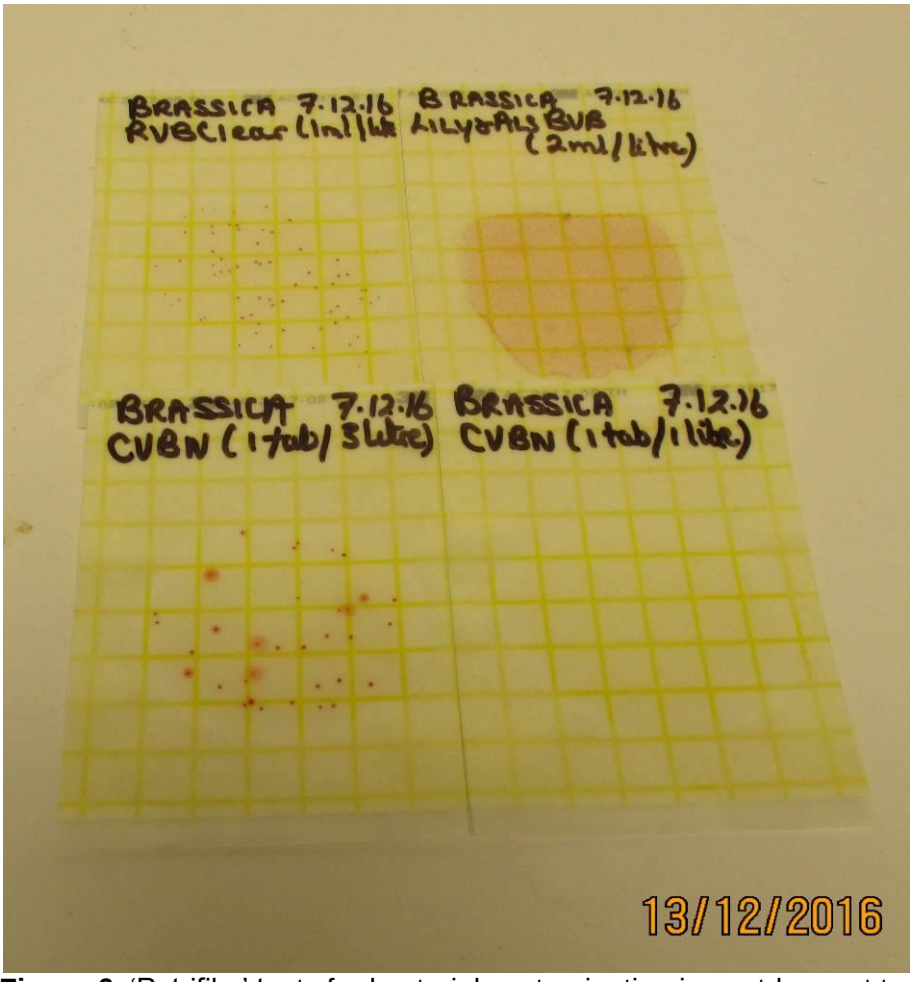


Figure 6. 'Petrifilm' tests for bacterial contamination in post-harvest treatment water: (top-right) 'Lily and alstroemeria BVB' – test paper covered with bacterial colonies; (top-left) 'RVB Clear Intensive' and (bottom-left) 'CVBN' (lower rate) – isolated bacterial colonies; and (bottom-right) 'CVBN' (higher rate) – no bacterial colonies

China aster (*Callistephus chinensis* cultivars)

In the last decade china asters (annual asters) have become an important outdoor summer cut flower in the UK. They are dominated by the 'Matsumoto' spray type which is grown in quantities of about 9 million stems annually. Work at CFC up to 2013 opened up a market for an alternative, the large–headed, 'bloom'-type for summer production. The search for a trouble-free variety of the very popular blue flowers has, however, proved difficult.

Two new series of large-headed china asters with vibrantly coloured blooms, 'Krallen' and 'Gala' were introduced in Germany and in 2007 demonstration plots were planted at the CFC. Generating distinct interest from growers, there appeared to be potential for commercialising these cultivars in the UK. In 2010 a multifactorial trial was carried out with 'Krallen' types 'Chinchilla', 'Golden', 'Kameo', 'Karthauser', 'Lux' and 'Perser' and 'Gala' types 'Lavender' and 'Purple'. With the exception of 'Golden Krallen', stems

of ‘Krallen’ cultivars were sufficiently long and particularly heavy, with stems of ‘Kameo’ and ‘Kartthausen’ reaching nearly 80g each; their larger, more impressive flowers were largely responsible for their high stem weight. Stems of the ‘Gala’ series were longer but lighter. The trials included investigating the effects of using plug- and block-raised plants, of planting date, and of growth retardant treatments.

Largely as a result of these trials ‘Krallen’ cultivars were grown by local producers in quantity in 2009 and 2010. ‘Karthauser’ and ‘Perser’ were in great demand by supermarkets. VL tests were undertaken by a packer on batches being sold through supermarkets, and showed their vase-life consistently met or exceeded the guaranteed 5 days. However, post-harvest quality became an issue when petal-spotting and browning of the flower-tips became apparent, and the cause of these problems remain unknown despite the numerous samples sent to laboratories in the Netherlands and the UK, and holding detailed discussions with both the breeder and the propagator. Losses became severe, and as a result ‘Krallen’ is unlikely to be grown again on any scale until this petal-spotting and petal-tip necrosis can be rectified. Consequently growers became interested in developing alternatives to these alternatives.

In 2010, 25 cultivars from the ‘Standby’, ‘Benary Princess’ and ‘Matador’ series were trialled at the CFC. Although they provided an additional range of colours, growers and buyers thought none matched the quality of ‘Krallen’. In 2012 further alternatives were trialled, from the ‘Bonita’, ‘Meteor’ and ‘Ribbon’ series. This trial, however, did not go well due to problems in seed supply, poor weather and (particularly on the ‘Meteor’ series) a severe attack of tomato spotted wilt virus, which resulted in stems of poor quality. It was evident that none of these cultivars had prospects as an alternative to ‘Krallen’. Hence a trial of further cultivars was arranged for 2013, using cultivars from the ‘Beautiful Day’, ‘Harlequin’, ‘Jewel’, ‘Lady Coral’ and ‘Meteor’ series (the ‘Bonita’ series was not included in these trials because at the time it was generating interest from ‘Matsumoto’ growers and it seemed likely that growers would undertake their own trials, although this in fact did not happen). Trial plots were planted in weeks 19 and 26. From an early planting (week 19) the main cropping period was weeks 32–34, with cultivars of the ‘Harlequin’ and ‘Meteor’ series producing taller plants and the remaining cultivars being shorter. For the later planting (week 26) the main cropping period was weeks 39–41 and the stems of all cultivars were relatively short (the tallest were cultivars of the ‘Harlequin’ and ‘Jewel’ series). Many of the cultivars tested had stem and flower attributes with promise for greater use in the UK: long, heavy stems and

flowers that were vibrant, uniform, positioned at the top of the plant and free of petal disorders; but none was considered as outstanding as, or likely to be an alternative for, ‘Krallen’.

China asters were included in herbicide trials at the CFC in 2014–2016, and brief reports are available in the 2014 and 2015 annual project reports and in the herbicide section later in the present report.

2016 saw a demonstration of a further series of spray-asters, ‘Julie’, as well as two coded bloom-types (Table 5). This new range had recently became available from Miyoshi, and has two important advantages: a different colour range and a claim (from the propagator) that they are two weeks earlier than ‘Matsumoto’ (this earliness has yet to be confirmed by growing them side by side with a commercial outdoor crop).

Table 5. Details of 2016 china aster ‘Julie’ cultivar demonstration

Site	Rookery Farm
Varieties	‘Julie’ series ‘Blue’, ‘Pink’, ‘Purple’, ‘Rose’, ‘Scarlet’ and ‘White’ along with the numbered lines 16-1 and 16-3
Format(s) and supplier(s)	Seed (Miyoshi)
Propagation and pre-planting treatment(s)	Sown in plugs week 18 and 20
Planting or sowing date(s)	Transplanted week 22 (bay 2) and 25 (bay 3)
Plant spacing(s)	64/m^2
Planting site(s)	1.5m-long plots in beds in ‘Pro-Tech’ tunnel bays 2 and 3
Layout	Non-replicated demonstration plots
Post-planting treatment(s)	One layer of support netting
Pests, diseases and disorders	Suffered from aphid damage (like ‘Matsumoto’) but was controlled by insecticides
Picking stage(s) and market specification(s)	N/A[1]
Picking and recording date(s)	Not formally assessed but picked when fully open in order to provide samples to packers
Records taken	No
VL testing	No
[1] N/A in these tables indicates not applicable or not available	

No formal assessments were made but the demonstration was used as a source of material for showing to packers and supermarkets. It was reported that samples were well received by one supermarket, but that they were similar in timing and quality to some other cultivars being grown in the industry; in favour of the ‘Julie’ series, though, the different colours and fresh seed stocks were appreciated. Grown under tunnels the plants were larger and paler in colour that outdoor-grown plants. No adverse petal or leaf-tip damage was noted. Photographs of the demonstration plots are shown in

Figure 7, and the cultivars are illustrated in Figure 8.

As a result of the trial, two local growers intend to trial commercial scale plantings of ‘Julie’ china asters in 2017.

Figure 7. Flowers of tunnel-grown china aster ‘Julie’ series at CFC in 2016. Left, planted week 22 and photographed week 32; right, planted week 25 and photographed week 36.

16-1

16-3

‘Julie Blue’

‘Julie Pink’

‘Julie Purple’

‘Julie Rose’

‘Julie Scarlet’

‘Julie White’

Figure 8. Flowers of the china aster ‘Julie’ series and two coded products, transplanted week 25 and photographed week 36, 2016

Column stocks (*Matthiola incana* cultivars)

Column stocks are a mainstay of UK protected cut flower production, so it is appropriate they have been the subject of several CFC trials concerned with crop improvement.

The year 2012 saw a variety trial of 48 lines, including cultivars from both standard and new series, grown in steamed and non-steamed soil in tunnels. As well as defining varietal differences, the results showed a strongly beneficial effect of steaming on stem weight but insignificant effects on stem and flower spike length. Due to ongoing interest in the 'Katz' series as a summer or late crop, several varieties were compared in 2013. For the 'Katz' lines grown at the CFC, stem strength was not as good as in previous years - possibly due to hot weather through most of the life of the crop – but their quality was far superior to that in the commercial glasshouse trial which was mostly un-marketable due to weak stems. On a commercial nursery the full range of Combinations Young Plants and Florensis Cut Flowers column stocks were (a) grown as a further cultivar trial and (b) planted under glass at a commercial nursery for testing for susceptibility to fusarium wilt (the glasshouse had a history of fusarium wilt). The hot weather brought plants on much quicker than anticipated and some of the 'Anytime' varieties and coded lines were ready for cropping in week 30. Despite the hot weather during this period, nearly all the varieties produced marketable stems. In the susceptibility trial the resilient and productive varieties were 'Avalanche White', 'Fantasy Red', 'Fantasy Red Imp', 'Phantom Cream Imp' and 'Phantom Red' in Combinations cultivars and, in the Florensis cultivars, 'Anytime' varieties 'Apple Blossom', 'Pink', 'Red', 'Sea Blue', 'White', and 'Yellow', 'Katz' varieties 'Bright Rose', 'Cherry Blossom', 'Figaro Lavender', 'Light Lavender', 'Pink' and 'Yellow' and some of the coded lines. In contrast, these properties were not shared by the 'Opera' series.

There was increasing concern among growers about poor establishment and growth and lack of flower uniformity in column stocks. No single factor was identified as responsible, but a combination of issues, such as the poor performance of some varieties on un-steamed soil and the presence of *Pythium* or *Fusarium*, were shown to have a role. As a result, separate HDC (AHDB)-funded projects were carried out in 2013 to survey cultural practices and investigate the role of *Pythium* and *Fusarium* in these findings (PO 005) and to consider the possibly of remedial effects of soil amendments (PO 005a). Reports for those projects are available from the CFC and AHDB websites. In 2014 the control of fusarium wilt using a range of fungicides was investigated at the CFC. Cercobin WG, Octave and Signum appeared to give options

for control, while Plover and Switch appeared successful initially, but most plants subsequently died. It had been hoped that, with further investigations, it may have been possible to optimise *Fusarium* treatment and include the new succinate dehydrogenase-inhibiting (SDHI) fungicides such as boscalid, but this was prevented by registration issues.

In 2016 a new demonstration of column stocks was set up to show the commercial varieties currently available from the only two suppliers to the UK (subsequently Noordam decided to withdraw from this market after 2016), and the effects of steam-sterilisation (Table 6).

Table 6. Details of 2016 column stocks cultivar and steaming demonstration

Site	Rookery Farm
Cultivars	'Centum' series 'Deep Blue' and 'Deep Rose', 'Pink', 'Red', 'White' and 'Yellow'; 'Anytime' series 'Rose', 'Sea Blue', 'White', 'Yellow'; 'Aida' series 'Apricot', 'Fedora Deep Rose' and 'Lavender'; 'Figaro' series 'Lavender' and 'Light Rose'; 'Jordyn White'; 'Mathilda' series ''Blue', 'Pink' and 'Yellow'; 'Opera' series 'Debora' and 'Francesca'; 'Milla' series 'Apricot', 'lavender' and 'White', (Florensis); 'Centum' series 'Cream', 'Deep Blue', 'Lavender', 'Red', 'Soft Pink', and 'White'; 'Jordyn' series 'Apricot', 'Cream', 'Deep Rose', 'Lavender', 'Red' and 'White'; 'Milla' series 'Lavender' and 'White' (Noordam)
Format(s) and supplier(s)	Plug-plants (Florensis, Noordam)
Propagation and pre-planting treatment(s)	The south half of the tunnel was steam-sterilised on 15 April 2016 and the north half left un-treated
Planting or sowing date(s)	Transplanted week 25
Plant spacing(s)	64/m^2
Planting site(s)	1.5m-long plots in beds in 'Haygrove' tunnel
Layout	One replicate of 38 variety stocks planted in the steam-sterilised half of the house and a second in the non-sterilised half
Post-planting treatment(s)	None
Pests, diseases and disorders	The new transplants suffered some grazing by rabbits but grew out of the damage Downy mildew, diamond backed moth and Sclerotinia were also problems
Picking stage(s) and market specification(s)	N/A
Picking and recording date(s)	N/A
Records taken	Not formally assessed but used as a demonstration of cultivars and steam-sterilisation
VL testing	No

The plugs established well despite initial grazing from rabbits, but were also stressed by hot weather in mid-July. As was the case with late-planted commercial crops this year, the trial suffered from uneven flowering with the 'Milla' cultivars being the worse of all, only 'Milla Apricot' producing a reasonable number of marketable stems (although 'Milla White' did produce a late flush of flowers towards the end of August). Downy mildew, diamond-backed moth and sclerotinia were further problems, necessitating rouging of the crop and an intensive spray programme. As expected, performance in the non-steamed soil was poorer than in the steamed area, but it was less marked than had been seen in previous trials. General views of the demonstration are shown in Figure 9, and of the 'Milla' cultivars in Figure 10.

With the weather-related problems that occurred in 2016, no formal records of the trial were taken, but it gave growers an opportunity to view the recent new introductions, such as 'Mathilda' and 'Milla', side-by-side with the older, longer established varieties.

Figure 9. Views of the 2016 demonstration of column stocks in week 32. Left: from the steam-sterilised end; right: from the non-sterilised end; the poor performance of 'Milla' may be seen in the right-hand bottom corner of each photograph

Figure 10. Plots of (left to right) ‘Milla Apricot’, ‘Milla Lavender’ and ‘Milla White’ in the 2016 demonstration: top, week 32; bottom, week 35

Lily (Lilium cultivars)

Bulbous ornamentals were included in CFC trials for the first time with the start of the current project in 2013. Lilies remain hugely popular with UK customers, and generally the bulbs are grown in crates of growing media in order to avoid soil-borne pathogens common in glasshouse soil. For many years peat was used as the growing medium, either alone or mixed with other materials; more recently a number of growers have developed their own bespoke peat-based media for lilies (referred to below as ‘grower’s peat-based medium’). There has obviously been interest from growers and customers in discovering suitable alternatives or diluents for peat, and this has been the object of CFC trials.

In 2013, a selection of new cultivars was grown in a grower’s peat-based medium, (representing a typical lily growing medium), 100% green-waste or a 50:50 v/v mixture

of the two. With minor exceptions, stems were longest when grown in grower's peat-based medium, shorter in the 50:50 mixture, and shortest in 100% green-waste. Bud count did not vary between the three media.

For 2014 lily 'Dynamite' was grown in a grower's peat-based medium, 100% coir, 100% 'Forest Gold' (a wood-derived potting medium), or mixtures of grower's peat-based medium with coir (50:50 v/v), anaerobic digestate (AD) (80:20 and 60:40 v/v) and re-cycled green-waste (50:50 v/v). Compared with grower's peat-based medium, stem length varied little in alternative media. Production in grower's peat-based medium + AD and in 'Forest Gold' gave heavier stems than growing in grower's peat-based medium, though the differences were slight. Using grower's peat-based medium + AD mixtures produced plants with better leaf colour than grower's peat-based medium alone (possibly due to the base dressing added at blending), but growing in grower's peat-based medium + green-waste resulted in some stunted stems, chlorotic leaves, slightly reduced yield and delayed picking for a week. In a repeat of this trial later in the season the visual differences between treatments were less pronounced.

Two trials were carried out in 2015, concentrated on using AD added to peat (or coir) growing media. The lilies were grown in 100% grower's peat-based medium, coir or AD, grower's peat-based medium + AD mixtures (60:40, 40:60 or 20:80 v/v) and a coir + AD mixture (33:67 v/v). In both trials the lilies grown in 100% AD were stunted, chlorotic and distorted, while stems from the grower's peat-based medium + AD 20:80 mix were only marginally better. Lilies grown in AD + coir, despite making good height, had chlorotic, mottled foliage. On the other hand, plants grown in grower's peat-based medium, 100% coir or the 'weaker' mixes of grower's peat-based medium + AD (40:60 and 60:40 v/v) were normal and marketable. In trial 1 (cultivar 'Capistrano') grown in grower's peat-based medium gave the longest stems but generally stem weight was greater where higher rates of AD were added. In trial 2 (cultivar 'Alma Ata') the differences between growing media were less pronounced. On the basis of these results 40 to 60% AD might be mixed with grower's peat-based medium to reduce peat use without having detrimental effects. Analysis of nutrients in the different growing media suggested that some effects of AD were due to differences in N, P, K and Mg concentrations between supplies.

In 2016 the emphasis of lily trials changed to the assessment of growing in 100% grower's peat-based medium, 100% coir, or mixtures of peat with wood fibre or cocopeat (Table 7).

Table 7. Details of 2016 alternative growing media trial for lily production in crates

Location	Rookery Farm
Varieties	'Dynamite' (Oriental group)
Format(s) and supplier(s)	14-16cm grade bulbs (AWE Horticulture)
Propagation and pre-planting treatment(s)	None
Planting or sowing	Planted in standard lily crates using the following media: 1. Coir (100%) 2. Grower's peat-based medium (100%) 3. Mix 1 + 2.0kg/m^3 LD 4. Mix 2 + 1.8kg/m^3 LD + 10% 'Chip-N' (wood fibre) 5. Mix 3 + 1.6kg/m^3 LD + 20% 'Chip-N' (wood fibre) 6. Mix 4 + 1.4kg/m^3 LD + 30% 'Chip-N' (wood fibre) 7. Mix 5 + 2.0kg/m^3 LD + 10% washed coir (cocopeat) 8. Mix 6 + 2.0kg/m^3 LD + 20% washed coir (cocopeat) 9. Mix 7 + 2.0kg/m^3 LD + 30% washed coir (cocopeat) Mixes 1 to 7 were trial media supplied by Bulrush Horticulture, all based on 18mm peat with added base fertiliser (15:10:20 N:P:K and trace elements, 0.5kg/m^3), wetting agent and variable amounts of lime and dolodust (LD) The wood fibre used, 'Chip-N', was different to the material used in 2015
Planting or sowing date(s)	Bulbs planted week 28
Plant spacing(s)	18 bulbs/crate
Layout	Three replicate crates per growing medium, arranged in three blocks
Post-planting treatment(s)	Crates placed in cold-store (9°C) for 3 weeks after planting Liquid feed regime was the standard across the trials site
Planting/housing site(s)	Crates moved to 'Pro-Tech' tunnel bay 3, week 31. Buds were developing during September but, because of their subsequent slow growth and the approach of winter, the crates moved to a heated glasshouse at 20/15/25°C day/night/vent temperatures on 7 November (week 45)
Pests, diseases and disorders	None evident
Picking stage(s) and market specification(s)	Buds starting to show colour
Picking and recording date(s)	9 November (week 45) for all treatments
Records taken	Total stem length before trimming and stem weight after trimming to 70cm (on a random sample of 12 stems per crate)
VL testing	No

The sprouting and early growth of the crop were normal but (perhaps because of the relatively late planting this year) subsequent growth and development was slow and was expedited by transferring the trial to a heated glasshouse shortly prior to picking.

The lilies grown in 100% coir were stunted (probably this treatment needed a different irrigation regime to the others), but otherwise there were no indications of visual differences between plants in any treatment and all treatments were picked within a few days. Total stem lengths and trimmed stem weights are shown in Figure 11, and the analysis of variance (Tables 8 – 9) showed that the effects of growing medium were statistically significant at $P<0.001$ on both length and weight. Growing in 100% coir produced stunted stems that were significantly (70cm) shorter than stems grown in the other eight growing media, in which stem lengths hardly varied (averages between 77 and 80cm).

Stem weight was light in 100% coir (99g): all other growing media yielding significantly heavier stems, with averages between 126 and 151g. Using grower's peat-based medium gave stems weighing an average of 126g, lighter (but not significantly so) than for the peat + wood fibre mixes (mixes 2–4; averages between 136 and 141g), and significantly lighter than those growing in peat mix 1 and the peat + cocopeat mixes (mixes 5–7), all of which averaged between 147 and 151g. The results suggested that all trial mixes were worthy of further investigation as growing media for lilies in crates, but particularly the peat + cocopeat mixes. These had no adverse effects on lily growth, appearance and cropping with the potential to reduce peat usage by 30% (and possibly more).

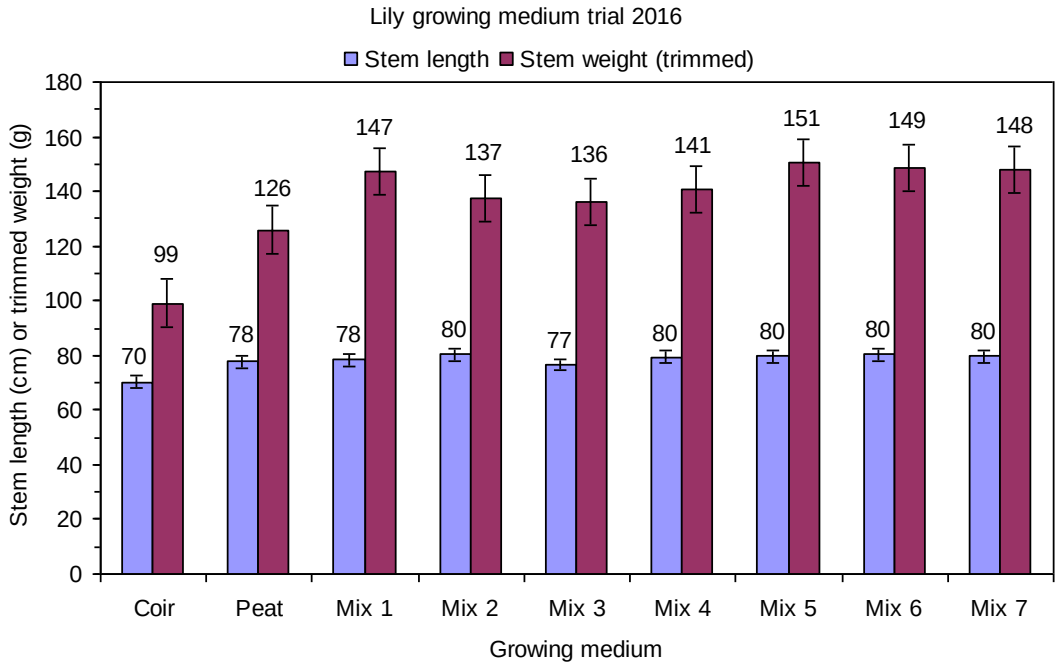


Figure 11. Stem lengths and trimmed weights of lily 'Dynamite' produced in nine growing media (for details, see text; 'peat' in the figure refers to grower's peat-based medium), 2016 trial (the error bars represent the LSD (5%) values either side of the means, ±2.3 for length and ±8.6 for weight)

Table 8. Analysis of variance for the stem length data of Figure 11

Source of variation	SS	DF	MS	F	P	
Growing medium	248.876	8	31.109	5.954	<0.001	***
Residual	94.046	18	5.225			
Total	342.922	26				

Table 9. Analysis of variance for the stem weight data of Figure 11

Source of variation	SS	DF	MS	F	P	
Growing medium	6367.874	8	795.984	10.475	<0.001	***
Residual	1367.796	18	75.989			
Total	7735.670	26				

General topic: herbicide trials

The loss of key active ingredients, such as chlorthal-dimethyl, propachlor and oxadiazon, continues to be a major concern for growers of outdoor cut flowers. Trials of other active ingredients were carried out in 2014 and 2015, mainly at the Rookery Farm site adjacent to the regular CFC trials and under the project leadership of John Atwood, ADAS, in AHDB Horticulture-funded projects HNS PO 192 and 192a. The crops included drilled and transplanted china aster, drilled larkspur, sweet william and wallflower. The main findings are summarised below and full details can be obtained

from project reports available from AHDB Horticulture.

- The tank-mix of 'Stomp Aqua' + 'Gamit 36 CS', applied post-drilling, pre-emergence, was safe and effective when used on **drilled china aster**; it could then be followed by a post-emergence application of 'Shark' if required.
- 'Stomp Aqua' + 'Gamit 36 CS' was also found to be the best on **transplanted china aster**, applied pre-planting.
- The tank-mix of 'Stomp Aqua' + 'Goltix 70 SC' provided the best weed control and was the safest option in the **drilled sweet william** trials.
- In the **drilled wallflower** trial 'Butisan S', 'Gamit 36 CS' and (at the lower rate) 'Wing-P' appeared safe when applied at drilling, and 'Wing-P' at the lower rate + 'Gamit 36 CS' also appeared to be safe as a tank-mix. 'Benfluralin' was safe as a pre-drilling incorporated treatment on wallflower, and could be combined with other post-drilling treatments, but it is not yet available in the UK.
- **Drilled larkspur** proved to be a challenging subject because of their slow emergence and growth of the crop combined with phytotoxic effects from the herbicides used; nevertheless the trial gave some pointers to investigate more in future trials.

In collaboration with John Atwood during 2016, a selection of herbicide treatments were further evaluated on **transplanted china aster** and **drilled sweet william** as part of the core CFC project. The main problem weeds present on-site were chickweed, groundsel, redshank and shepherd's purse.

Transplanted china aster trial 2016 For china aster the aim was to follow-up the current recommendation for applying a pre-planting treatment of 'Stomp Aqua' + 'Gamit 36 CS' (2.0 + 0.25L/ha). The details of the trial, including herbicide treatments, are summarised in Table 10.

Table 10. Details of 2016 herbicide trial on transplanted china aster

Location			Rookery Farm
Cultivar			Matsumoto 'Blue Tipped'
Format(s) and supplier(s)			Plug-plants (Hillgate Nursery)
Propagation and pre-planting treatment(s)			None
Planting or sowing date(s)			Transplanted week 27 (having been delayed by wet weather)
Plant spacing(s)			64/m^2
Planting site(s)			1.5m-long plots in outdoor beds
Layout			Randomised block with three replicates
Herbicide programmes	No.	Application - pre-planting	Application - 3 weeks post-planting
	1	Untreated (control)	Untreated (control)
	2	'Stomp Aqua' + 'Gamit 36 CS' (2.0 + 0.25L/ha)	'Butisan S' (1.0L/ha)
	3		'Venzar Flo' + 'Flexidor 500' (0.75 + 0.125L/ha)
	4		'Successor' (2.0L/ha)
	5		Untreated
	6	'Nirvana' (3.0L/ha)	'Butisan S' (1.0L/ha)
	7		'Venzar Flo' + 'Flexidor 500' (0.75 + 0.125L/ha)
	8		'Successor' (2.0L/ha)
	9		Untreated
	10	'Wing-P' (2.5l/ha)	'Butisan S' (1.0L/ha)
	11		'Venzar Flo' + 'Flexidor 500' (0.75 + 0.125L/ha)
	12		'Successor' (2.0L/ha)
	13		Untreated
Pests, diseases and disorders			Aphids (kept under control)
Picking stage(s) and market specification(s)			N/Aa
Picking and recording date(s)			N/A
Records taken			Numbers of weeds/plot assessed 12 August 2016 Phytotoxicity assessed on 22 July and 30 July (before post-planting treatment) and 9 August 2016 (after post-planting treatment) Stem length and weight recorded for a random sample of 12 stems per plot at picking
VL testing			No

The number of weeds per plot, phytotoxicity scores and stem weight and length are shown in Figure 12, with analysis of variance in Table 11. Phytotoxicity was primarily expressed as slight crop stunting (assessed on a scale from 0, no stunting, to 5, severe stunting) and was evident as a result of two of the pre-planting treatments from the first to the last phytotoxicity assessment (i.e. both before and after the post-planting application was made). In addition, following some post-planting herbicide treatments, there was some very slight marginal leaf scorch on the youngest leaves.

Looking solely at the overall effects of the pre-planting treatments on weed numbers, 'Wing-P' and 'Nirvana' were most effective, with averages of 11 and 15 weeds/plot, respectively. Plots treated with 'Stomp Aqua' + 'Gamit 36 CS' averaged 27 weeds/plot, while the untreated controls had 46/plot. The application of 'Wing-P', and, especially 'Nirvana', resulted in mild stunting of the crop. The application of 'Stomp Aqua' + 'Gamit 36 CS' resulted in only very slight stunting - no more than occurred in the untreated control.

Considering the overall effects of the post-planting treatments, 'Butisan S' was the most effective herbicide, with an average of 13 weeds/plot, while 'Venzar Flo' + 'Flexidor 500' (22 weeds/plot) and 'Successor' were less effective (17/plot) (for the untreated controls averaged 46/plot). Treatment with 'Butisan S' or 'Successor' resulted in very slight marginal leaf scorch to the youngest leaves at the time of spraying, though this was rapidly outgrown and inconsequential; there was no scorch after the application of 'Venzar Flo' + 'Flexidor 500'.

The data for weed numbers were quite variable, and consequently only the largest differences between treatment means were statistically significant; thus in Figure 12 only the untreated control and the least effective of the herbicide programmes ('Stomp Aqua' + 'Gamit 36 CS' followed by ''Venzar Flo' + 'Flexidor 500') were significantly bettered by the other programmes, the overall herbicide effect being significant only at the 5% level of probability (Table 11). On the other hand the effects of the herbicide programmes on the plant phytotoxicity (i.e. stunting) scores were much more distinct and were significant at the 0.1% level of probability. The untreated controls and programmes starting with 'Stomp Aqua' + 'Gamit 36 CS' all gave phytotoxicity scores of 1.0 or less, while the programmes starting with 'Nirvana' or 'Wing-P' gave scores of 1.0 or more, up to nearly 2.0 in the case of 'Nirvana'. There were corresponding reductions in stem weight (significant at the 0.5% level of probability) and (to a lesser extent) stem length when 'Nirvana' was used pre-planting, reductions in both weight and length being strongly correlated with higher phytotoxicity scores (Figure 13, note

R^2 scores of 0.86 and 0.79, respectively); hence the phytotoxicity observed earlier appears to have had a real impact on stem quality at picking. Overall, the combination of ‘Stomp Aqua’ + ‘Gamit 36 CS’ followed by ‘Butisan S’ was probably the best compromise between weed control and crop safety. Pre-planting ‘Wing-P’ (but not ‘Nirvana’) would probably be an alternative, either alone or followed by ‘Venzar Flo’ + ‘Flexidor 500’.

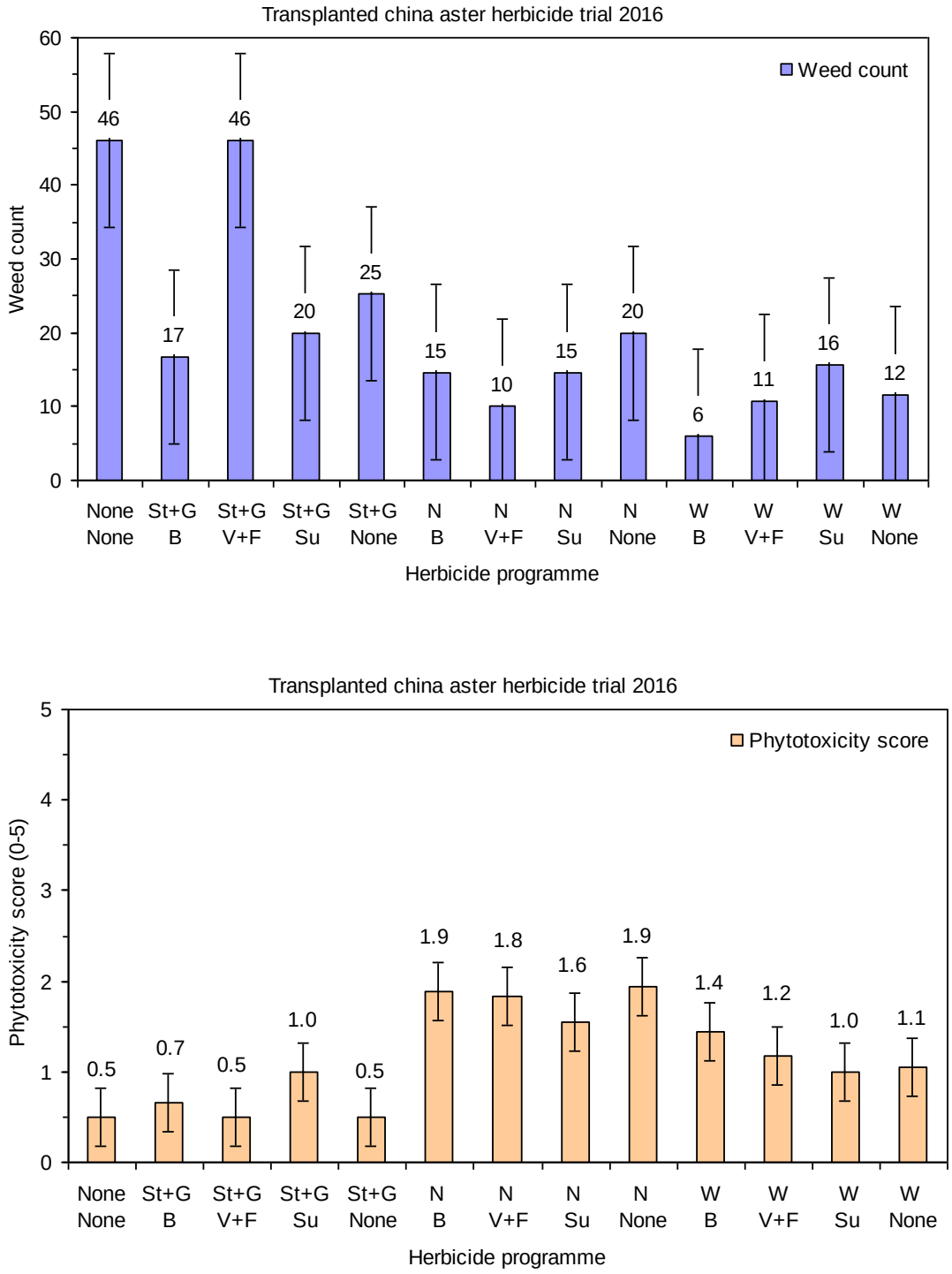
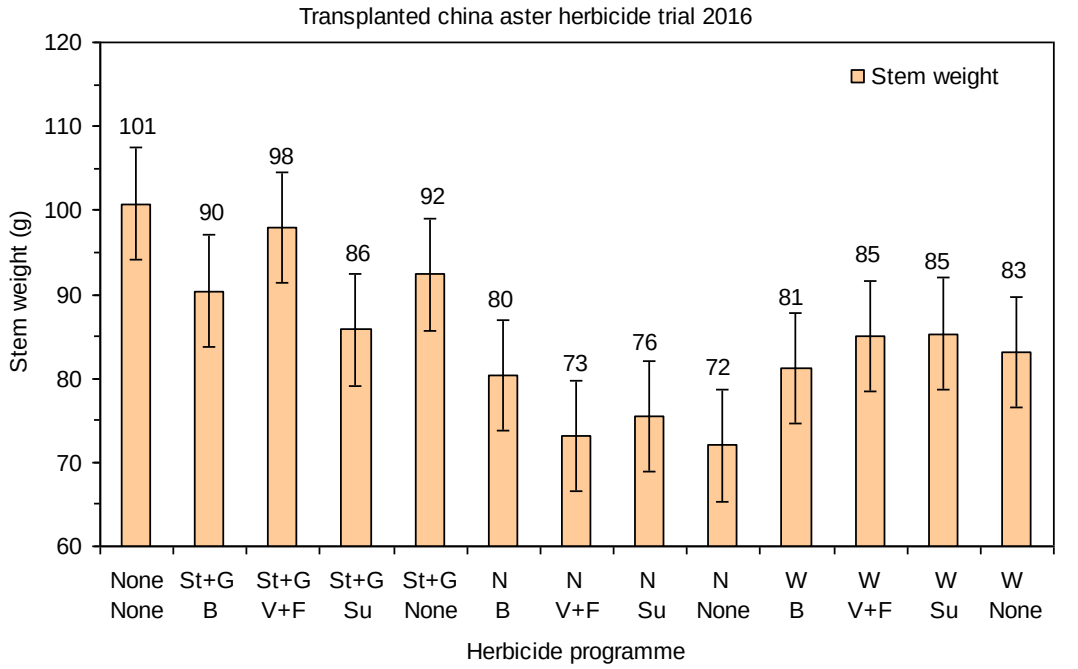
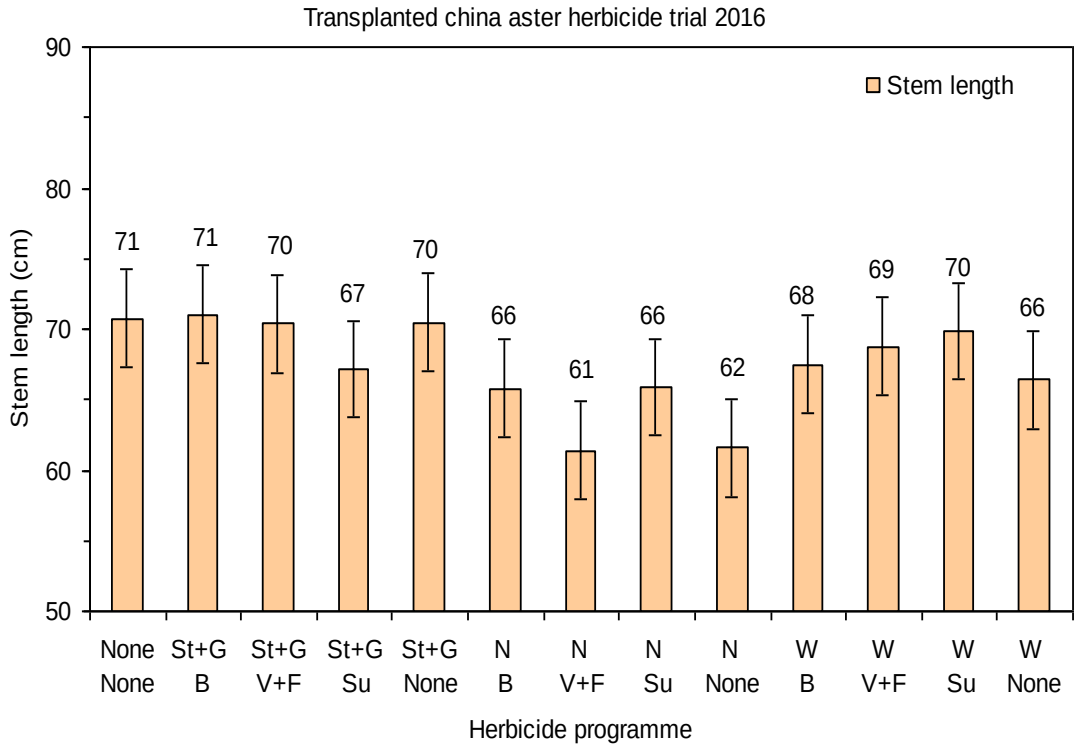


Figure 12. Weed numbers, phytotoxicity score (stunting assessed on a scale from 0, no stunting, to 5, severe stunting, averaged across three assessment dates), stem weight and stem length for transplanted china aster under 13 herbicide programmes (herbicides indicated by initial letters, see text, with pre-planting treatment followed by post-planting treatment) in 2016 trial; the error bars represent the LSD (5%) values either side of the means (±11.8 for weed count, ±0.3 for phytotoxicity score, ±6.6 for stem weight and ±3.5 for stem length); figure continued on next page





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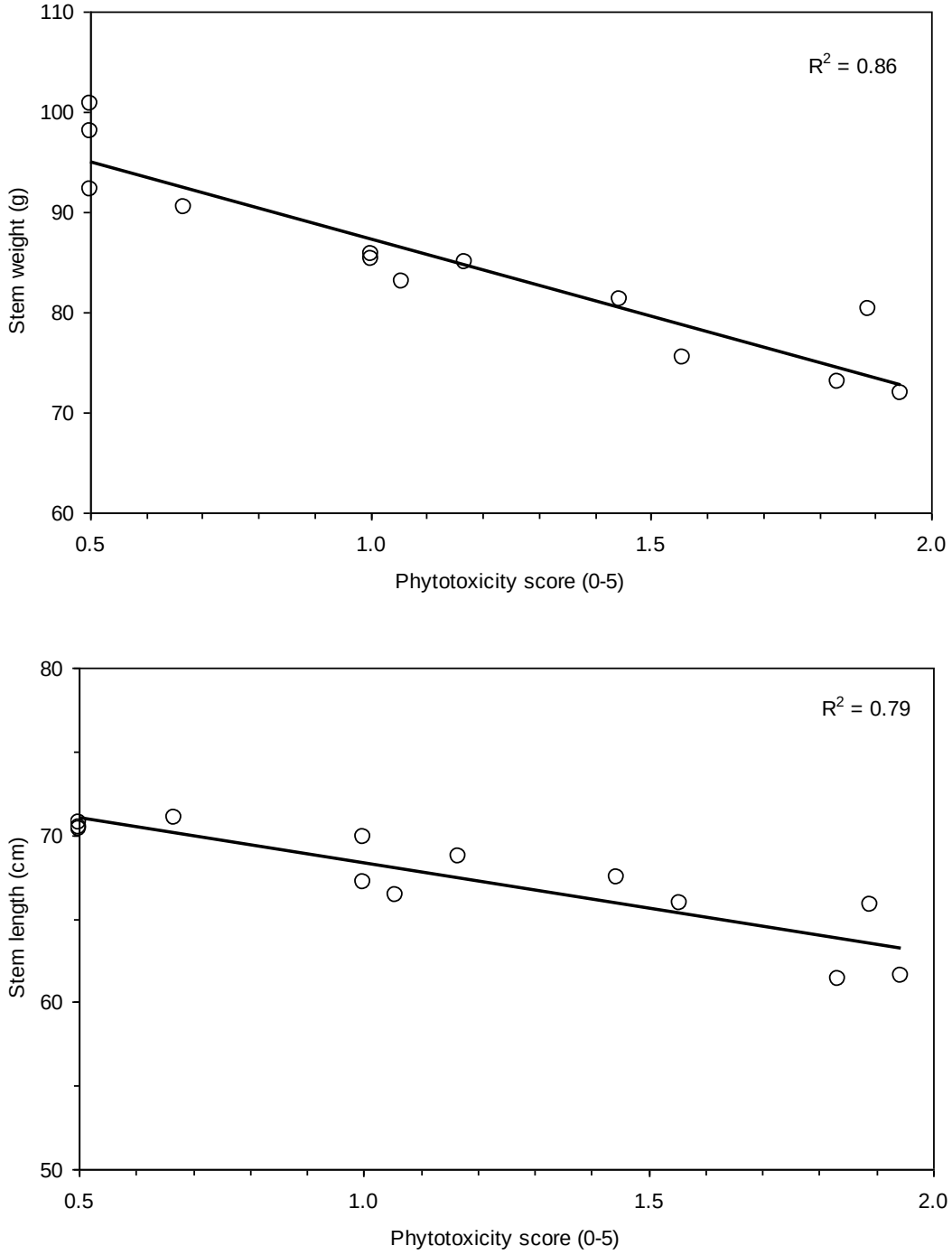

Figure 13. Plots of (above) stem weight and (below) stem length against phytotoxicity score in the 2016 transplanted china aster herbicide trial; the R^2 values approaching 1.0 indicate strong correlations

Table 11. Analysis of variance for the data in Figure 12

Source of variation	SS	DF	MS	F	P	
Weed count						
Herbicide treatment	5757.692	12	479.807	2.253	0.040	*
Residual	5534.667	26	212.871			
Total	11292.359	38				
Phytotoxicity score						
Herbicide treatment	10.3490	12	0.8624	5.3340	<0.001	***
Residual	4.2037	26	0.1616			
Total	14.5527	38				
Stem weight						
Herbicide treatment	2830.573	12	235.8811	3.5269	0.0035	**
Residual	1738.904	26	66.8809			
Total	4569.478	38				
Stem length						
Herbicide treatment	379.3937	12	31.6161	1.7085	0.1228	NS
Residual	481.1265	26	18.5049			
Total	860.5202	38				

Drilled sweet william trial 2016 For sweet william the current recommendation is to apply ‘Stomp Aqua’ + ‘Goltix 70 SC’ (0.75 + 1.0L/ha) at drilling, followed-up at the four true leaf stage by ‘Shark’ (0.4L/ha). The aims of the trial were to see if this programme could be bettered by using other herbicides as follow-up treatments, and to determine the effect of an additional, winter herbicide. The details and herbicides are presented in Table 12.

Table 12. Details of 2016 herbicide programme trial on drilled sweet william

Location			Rookery Farm	
Cultivar			’Auricula-eyed’ and ‘Floriade Mix’	
Format(s) and supplier(s)			Seed (Belmont Nurseries)	
Propagation and pre-planting treatment(s)			None	
Planting or sowing date(s)			Drilled week 28	
Plant spacing(s)			Drilled by hand to give a dense plot that would be easier for assessment; the plots were split and each of the two cultivars was drilled into one half of each plot	
Planting site(s)			2.0m-long plots in beds outdoors	
Post-drilling treatments			Plots weeded by hand on 6 October 2016	
Layout			Randomised block with three replicates	
Herbicide programmes	No.	At drilling (17 Jul. 2016)	Follow-up (24 Aug. 2016)	Winter (15 Feb. 2017)
	1	Untreated (control)	Untreated (control)	Untreated (control)
	2	‘Goltix 70 SC’ (1.5L/ha)	‘Shark’ (0.4L/ha)	‘Shark’ (0.4L/ha)
	3	‘Stomp Aqua’ + ‘Goltix 70 SC’ (0.75 + 1.0L/ha)	‘Butisan S’ (1.5L/ha)	‘Devrinol’ + ‘Flexidor 500’ (7.0 + 0.25L/ha)
	4		‘Butisan S’ + ‘Shark’ (1.5 + 0.4L/ha)	
	5		‘Springbok’ (1.6L/ha)	‘Venzar Flo’ + ‘Flexidor 500’ (3.0 + 0.25L/ha)
	6		‘Springbok’ + ‘Shark’ (1.6 + 0.4L/ha)	
	7		‘Successor’ (2.0L/ha)	‘Butisan S’ + ‘Flexidor 500’ (1.5 + 0.25L/ha)
	8		‘Successor’ + ‘Shark’ (2.0 + 0.4L/ha)	
	9		Venzar Flo’ + ‘Flexidor 500’ (0.75 + 0.125L/ha)	‘Venzar Flo’ + ‘Flexidor 500’ (3.0 + 0.25L/ha)
	10		‘Venzar Flo’ + ‘Flexidor 500’ + ‘Shark’ (0.75 + 0.125 + 0.4L/ha)	
Pests, diseases and disorders			Late attack of ring-spot in early 2017	
Picking stage(s) and market specification(s)			N/A	
Picking and recording date(s)			N/A	
Records taken			Germination of the ’Auricula-eyed’ type was very sparse and all further records were taken on ‘Floriade Mix’ only Crop emergence recorded 12 August 2016 Percentage of weed cover assessed on 18 September 2016 Phytotoxicity assessed on 10 September and 25 November 2016, and 9 February and 29 March 2017	
VL testing			No	

Germination of the ‘Auricula-eyed’ sweet william was very sparse, a problem noted on another nursery this year and so possibly a seed issue; hence all subsequent records and discussions refer only to ‘Floriade Mix’. Following the herbicide treatments at drilling, crop emergence averaged 102 seedlings/plot in untreated controls, 56 seedlings/plot following ‘Goltix 70 SC’ and 48/plot following ‘Stomp Aqua’ + ‘Goltix 70 SC’. However, emergence varied widely between the replicates of a treatment and these difference were not statistically significant. Crop emergence following either of the initial herbicide treatments was considered acceptable.

Percentage weed cover, recorded on 18 September, about four weeks after the post-emergence application, is shown in Figure 14. In the untreated control, weed cover was complete. Using ‘Goltix 70 SC’ followed by ‘Shark’ (treatment 2) weed cover had reached 47%. For the other eight programmes, all based on an initial application of ‘Stomp Aqua’ + ‘Goltix 70 SC’ followed by various herbicides post-emergence, weed growth varied widely, from 5 to 60% cover. The most effective programme for weed control was treatment 10 (‘Stomp Aqua’ + ‘Goltix 70 SC’ followed by ‘Venzar Flo’ + ‘Flexidor 500’ + ‘Shark’) with only 5% weed cover, followed by treatments 5, 6 and 9 (‘Stomp Aqua’ + ‘Goltix 70 SC’ followed by ‘Springbok’, ‘Springbok’ + ‘Shark’ or ‘Venzar Flo’ + ‘Flexidor 500’ + ‘Shark’) with 18–22% weed cover; all other programmes resulted in a weed cover of 33% or more. Analysis of variance (Table 14) indicated that the effect of herbicide programmes on weed cover was significant at the 1% level of probability; only the largest differences between treatment means were significantly different from each other.

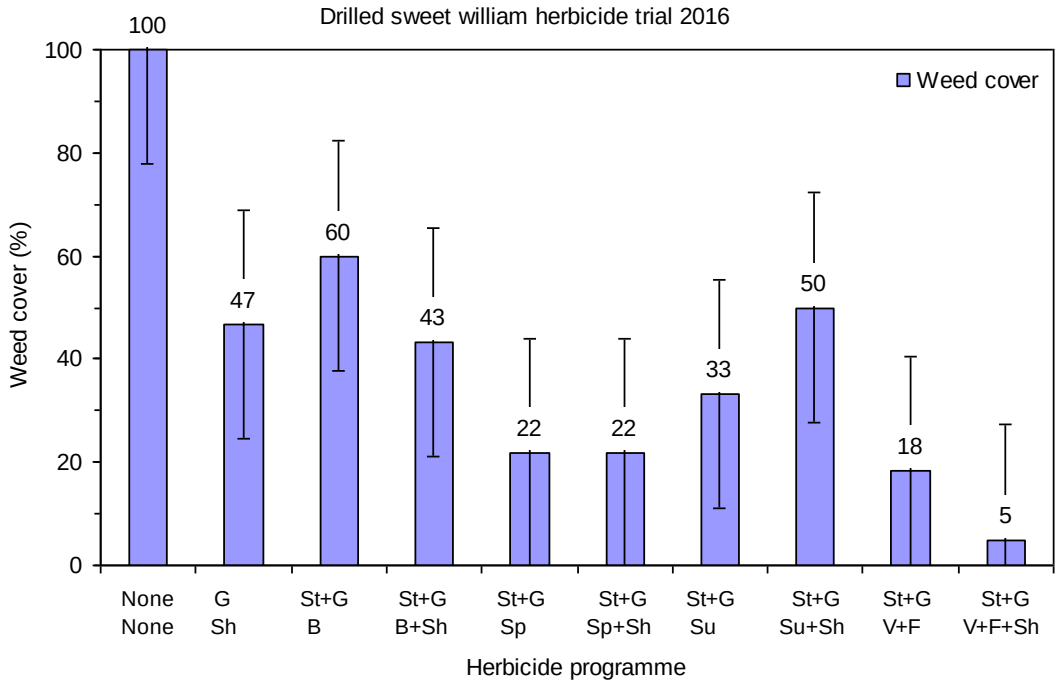

Figure 14. Weed cover on 18 September for drilled sweet william 'Floriade Mix' under 10 herbicide programmes (herbicides indicated by initial letters (see text) with treatment at drilling followed by post-emergence treatment) in 2016 trial; the error bars represent the LSD (5%) values either side of the means, ±22.2

Table 14. Analysis of variance for the percentage weed cover data in Figure 14

Source of variation	SS	DF	MS	F	P	
Herbicide treatment	19700	9	2188.89	3.8571	0.006	**
Residual	11350	20	567.50			
Total	31050	29				

Following application of the post-emergence treatment, phytotoxicity symptoms were visible in the form of stunting, which occurred in all treatments except the control. Figure 15 shows the data recorded on 10 September, about 3 weeks after the post-emergence application. At this stage the four treatments giving good (≤22% cover) weed control also gave higher levels of phytotoxicity (scores between 2 and 4), with the remainder having lower scores (between 0.7 and 1.3). Analysis of variance (Table 15) shows that these effects were significant at the 1% level of probability. Despite this early effect, the plants subsequently recovered from this stunting, and in almost all cases the records taken on 25 November and 9 February (before the winter treatment) and 29 March (after the winter application) show the phytotoxicity score was either 0 (no stunting) or 1 (insignificant stunting). In February 2017 some plants in five seemingly random plots across the trial exhibited slight to moderate ring-spot symptoms, from which they had largely recovered by the time of the next assessment (29 March). For all practical purposes, therefore, the initial stunting effect of some

herbicide treatments may be discounted. As a result of the trial, the recommended herbicide programme would be the one giving the best weed control: ‘Stomp Aqua’ + ‘Goltix 70 SC’ at drilling followed by ‘Venzar Flo’ + ‘Flexidor 500’ + ‘Shark’ post-emergence.

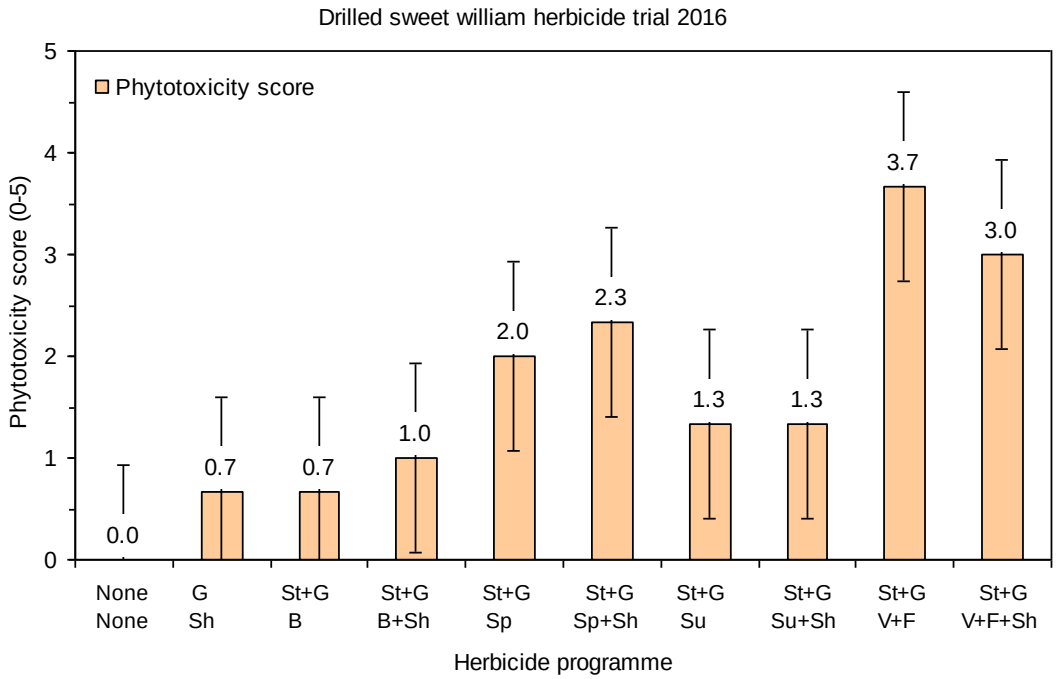

Figure 15. Phytotoxicity score (stunting assessed on a scale from 0, no stunting, to 5, severe stunting) for drilled sweet william ‘Floriade Miix’ under 10 herbicide programmes (herbicides indicated by initial letters (see text) with treatment at drilling followed by post-emergence treatment) in 2016 trial; the error bars represent the LSD (5%) values either side of the means, ±0.93

Table 15. Analysis of variance for the stunting score data in Figure 15

Source of variation	SS	DF	MS	F	P	
Herbicide treatment	35.2	9	3.9111	3.9111	0.005	**
Residual	20.0	20	1.0000			
Total	55.2	29				

Crop introduction (1) Crops first trialled in 2016

On the basis of the new crops and trials programmes review[6], suggestions from growers and information from seed and young-plant suppliers, several novel crops were selected for testing each year. At the end of each year new crops showing promise for UK production, and those for which further information was needed before such a decision could be made, were taken forward for further testing.

In this report the trials have been grouped into two sections: (1) crops first trialled in 2016, and (2) crops trialled before 2016 with on-going trials. Only those trials actually carried out in 2016 are described in detail in this report; the earlier trials are summarised and full details can be found in previous project reports.

Cleome (*Cleome hassleriana* and cultivars)

Cleome hassleriana is a sturdy, attractive garden annual with unusual flowers - a possible candidate as 'something different' in cut flowers. Demonstration plots were planted in 2016 (Table 16).

Table 16. Details of 2016 demonstration of cleome cultivars

Location	Rookery Farm
Varieties	'Cherry Queen' 'Colour Fountain Mix' 'Rose Queen' 'Violet Queen'
Format(s) and supplier(s)	Seed from EconSeeds
Propagation and pre-planting treatment(s)	Sown into plugs weeks 13 and 20
Planting or sowing date(s)	Transplanted weeks 18 and 25
Plots	3m-long plots
Planting/housing site(s)	'Pro-Tech' tunnel bays 2 and 3
Layout	Un-replicated demonstration plots
Plant spacing(s)	25 and 65/m^2
Post-planting treatment(s)	One layer of support netting
Pests, diseases and disorders	Leaf miner and powdery mildew evident week 30 and adequately controlled
Picking stage(s) and market specification(s)	When the first buds are fully open
Picking and recording date(s)	Week 26 onwards (still picking in October)
Records taken	Observations and picking dates
VL testing	Samples taken (mix of 'Colour Fountain Mix', 'Rose Queen' and 'Violet Queen') week 31

[6] http://www.thecutflowercentre.co.uk/wp-content/uploads/2013/11/Cut-Flower-Review-Final.pdf

The plug plants established well. There were no obvious differences in growth or development of the plants grown at the two plant spacings. The later planting started flowering a month later, but both were still flowering in October so possibly there was no need for two plantings to extend the season. Apart from their colours, there were no difference between the cultivars. Cleome proved a very prolific crop that kept producing constant flushes of flowers over a long period, the flowers being large, showy and distinctive (Figure 16).

Figure 16. Cleome plots at CFC in 2016: top pictures taken week 28, bottom picture week 39

Samples were subjected to standard VL testing incorporating alternative post-harvest treatments – either 'RVB Clear' or 'CVBN'. Cleome wilted very quickly after harvesting but recovered when re-hydrated in the chilled cabinet. Flowers, leaves and stems remained in acceptable condition with no desiccation on VL day 7, although there was some abscission of flowers and shedding of the fine, black pollen, which was worse when 'CVBN' had been used (Figure 17). Further tests are recommended, including using 'Chrysal AVB' as a post-harvest treatment to see if this reduces flower abscission. The stems were also somewhat difficult to handle because of their spines, and the plants and cut flowers have a distinctive aroma that some may find unpleasant.

VL day 4 with ‘RVB Clear’

VL day 4 with ‘CVBN’

VL day 7 with ‘RVB Clear’

VL day 7 with ‘CVBN’

Figure 17. Cleome stems from 2016 VL testing on VL days 4 and 7 following two post-harvest treatments.

Despite their attractive and unusual flowers, and adequate VL, further trials are probably not appropriate because some consider that the cleome’s spines and aroma render them unsuitable for supermarket sales. They are also difficult to handle and unsuitable for use on a processing line. They may, however, be suitable for supplying to florists for use in specialised situations where the flowers will not be handled by customers.

Craspedia (*Craspedia globosa* and cultivars)

With its slender unbranched stems and ball-shaped clusters of yellow flowers, craspedia is another example of a cut flower produced abroad but unfamiliar as a UK-grown crop. It is useful as a filler and may also be used as a dried flower. Three

cultivars were grown in demonstration plots at the CFC in 2016 (details in Table 17).

Table 17. Details of 2016 demonstration of craspedia cultivars

Location	Rookery Farm
Varieties	'Ellisse' and 'Paintball Globe' (Danziger) 'Sun Ball' (Genesis)
Format(s) and supplier(s)	Rooted cuttings (Ellisse' and 'Paintball Globe') Seed ('Sun Ball')
Propagation and pre-planting treatment(s)	Cuttings potted to 1L-pots week 16 Plugs seeded week 13
Planting or sowing date(s)	Potted cuttings transplanted week 21 Plug-plants transplanted weeks 18
Plots	3m-long plots
Planting/housing site(s)	'Pro-Tech' tunnel bay 2
Layout	Un-replicated demonstration plots
Plant spacing(s)	10/m^2
Post-planting treatment(s)	One layer of support netting
Pests, diseases and disorders	None evident
Picking stage(s) and market specification(s)	Long, straight and undamaged stems with fully coloured flower-heads
Picking and recording date(s)	Week 28 onwards, still flushing in October
Records taken	Observations and picking dates
VL testing	Samples of 'Ellisse' and 'Paintball Globe' taken in week 31

'Ellisse' and 'Paintball Globe', both grown from cuttings, gave large flushes of very strong, tall flowers (Figure 18). These cultivars were very similar to each other, and consultation with the propagator (Danziger) indicated that the two cultivars may not differentiate the head shape when grown in temperate climates. The seed-raised 'Sun Ball' were weaker plants, with smaller flower heads, shorter, kinked stems and fewer stems per m^2 (Figure 19).

Figure 18. Craspedia 'Paintball Globe' from the 2016 demonstration, (left) week 25, (middle) week 32 and (right) week 41

Figure 19. Craspedia ‘Sun Ball’ from the 2016 demonstration; note kinked stems (week 30)

Samples of ‘Ellisse’ and ‘Paintball Globe’ were subjected to standard VL testing incorporating alternative post-harvest treatments – either ‘RVB Clear’ or ‘CVBN’. All stems remained in acceptable condition on VL day 7, with no obvious differences between either the post-harvest treatments or the cultivars. Further samples showed that craspedia also dried well, with the flowers retaining their colour.

Samples were well received by the industry. Craspedia is an unusual product that is considered to have high potential for sales as fresh or dried flowers (Figure 20) and as a filler in bouquets. Two disadvantages are the high labour inputs needed to pick the crop, i.e. disentangling stems without causing damage (with a more uniform crop a once-over cut might be possible) and the single flower colour - yellow. Nevertheless craspedia deserves further testing.

Figure 20. Craspedia ‘Paintball Globe’ from the 2016 demonstration, shown (left) in the VL trial at vase-day 7 and (right) as a dried flower

Eremurus (*Eremurus stenophyllus* and other species and cultivars)

Eremurus stenophyllus is a rhizomatous plant producing tufts of linear leaves at ground level, bearing upright stalks (up to 1.5m-high) with dense racemes of yellow flowers. Interspecific hybridization has produced a wider range of colours including oranges, pinks and whites. Three cultivars were grown in demonstration plots in 2016 (Table 18).

Table 18. Details of 2016 eremurus cultivar demonstration

Site	Rookery Farm
Varieties	'Cleopatra', 'Moneymaker' and 'Tapdance'
Format(s) and supplier(s)	Rhizomes (Kolster)
Propagation and pre-planting treatment(s)	None
Planting or sowing date(s)	Planted week 45, 2015
Plant spacing(s)	16/m^2
Planting site(s)	Duplicate ca. 4m-long plots in 'Pro-Tech' tunnel bay 1
Layout	Demonstration plots
Post-planting treatment(s)	None
Pests, diseases and disorders	None evident
Picking stage(s) and market specification(s)	Spikes with the top 50 to 75% of the florets still closed (and with no open florets having turned brown); buds must have formed up to the tip of the spike
Picking and recording date(s)	N/A
Records taken	No formal assessments but used as samples
VL testing	No

In 2016 there was a low yield of flowers and all plants showed a lot of leaf senescence, even when flowering (Figure 21). The long, impressive stems are shown in Figure 21. The crop was left in place and as of January 2017 many shoots were emerging, so the plots will be assessed further.

Figure 21. Eremurus demonstration plots showing sparse flowering and leaf senescence in 2017 and (bottom image) cropped stems (week 15)

Gomphrena (Gomphrena globosa and G. haageana cultivars)

Gomphrena is another example of a cut flower produced abroad but unfamiliar to UK customers. An annual herbaceous plant bearing pink, purple, red or white solitary flower spikes at the stem tips, gomphrena can be used fresh-cut or dried. Nine cultivars were grown in demonstration plots at CFC in 2016 (Table 19).

Table 19. Details of 2016 gomphrena cultivar demonstration

Site	Rookery Farm
Varieties	'Globosa Lilac', 'Globosa Pink', 'Globosa Rose', 'Globosa White', 'Fireworks', 'Haageana Carmine', 'Haageana Orange', 'Haageana Red' and 'Haageana Strawberry'
Format(s) and supplier(s)	Seeds from EconSeeds (all except 'Fireworks') Plug-plants from Burpee ('Fireworks' only)
Propagation and pre-planting treatment(s)	Sown into plugs weeks 13 and 20 (EconSeeds cultivars)
Planting or sowing date(s)	Transplanted weeks 19 and 25 (EconSeeds cultivars) Transplanted week 25 ('Fireworks')
Plant spacing(s)	25 and 64/m^2
Planting site(s)	2m-long plots in 'Pro-Tech' tunnel bay 2 (week 19 planting) or bay 3 (week 25 planting)
Layout	Non-replicated demonstration plots
Post-planting treatment(s)	No support but it should be provided in future
Pests, diseases and disorders	None evident
Picking stage(s) and market specification(s)	Long stems with flowers in full colour
Picking and recording date(s)	Week 29 onwards
Records taken	Observations and picking dates
VL testing	Samples of mixed cultivars taken in week 31

The gomphrena started flowering around week 29, but initially the stems were very short, looking unlikely to suit as a cut flower. After 3–4 weeks, however, much longer stems were being produced, with real potential as a cut flower (Figure 22). Plots of the 'Globosa' and 'Haageana' series and of 'Fireworks' are shown in Figures 23 and 24.

Samples of mixed cultivars were subjected to standard VL testing, incorporating alternative post-harvest treatments – either 'RVB Clear' or 'CVBN'. Although the stems wilted rapidly after picking, they recovered once they were placed in the post-harvest treatment and were cooled. The stems, flowers and foliage remained in acceptable condition on VL day 7, with no obvious differences between either the post-harvest treatments or the cultivars (Figure 25).

Gomphrena was very prolific, with stems that increased in length through the season, an acceptable VL and the possibility of once-over cropping. However, the soft foliage might make it difficult to handle in a commercial situation. Gomphrena has potential as a filler, and further trials will be carried out in 2017 with a view to forming an economic assessment.

Figure 22. Gomphrena in 2016 demonstration plots showing (above) typical short stems early in the season (week 29) and tall stems produced later in the season (below left) week 32 and (below right) 35

Figure 23. Gomphrena (‘Haageana’-type and ‘Fireworks’) in 2016 demonstration (week 36): (top-left then clockwise) general view and ‘Haageana Orange’, White’, ‘Carmine’ and ‘QIS Red’, and ‘Fireworks’

Figure 24. ‘Globosa’-type gomphrena in 2016 demonstration: (top-left then clockwise) general view (week 30), ‘Rose’ (close-up and bed view, week 20), ‘Lilac’, ‘White’ and ‘Pink’ (week 32)

Figure 25. Gomphrena (mixed cultivars) from the 2016 demonstration, shown (left) on vase-day 4 and (right) on vase-day 7

Grasses, ornamental

There is interest in a wide range of ornamental grasses as bouquet fillers, and several species and cultivars were demonstrated in 2016; as shown in Table 20.

Table 20. Details of 2016 demonstration of ornamental grasses

Varieties	Bromus macrostachys* B. secalinus Eragrostis elegans* Panicum elegans 'Sprinkles' * P. miliaceum violaceum * Setaria italica 'Mix' * Setaria pumila glauca Sorghum nigrum * Stipa capillata 'Lace Veil' * Uniola paniculata (sea oats)
Format(s) and supplier(s)	Seed from EconSeeds (expect sea oats) Seed from Genesis Seeds (sea oats only)
Propagation and pre-planting treatment(s)	Plugs seeded week 12
Planting or sowing date(s)	Plugs transplanted to tunnel week 16, outdoors week 17 Seeds direct-drilled to tunnels weeks 18 and 28, outdoors week 18
Plots	3m-long plots
Planting/housing site(s)	Outdoors and 'Pro-Tech' tunnel bays 1 and 2
Layout	Un-replicated demonstration plots
Plant spacing(s)	25 and 64/m^2
Post-planting treatment(s)	No support netting (but should be provided in future)
Pests, diseases and disorders	Powdery mildew was severe on *Bromus secalinus*, otherwise they were free of P&D
Picking stage(s) and market specification(s)	As soon as the individual florets are becoming visible
Picking and recording date(s)	From week 27; from week 36 for the week 28 planting
Records taken	Observations and picking dates
VL testing	Samples of those marked * above taken in week 31

When grown in tunnels all species showed good germination and vigorous growth (Figure 26). Within a species or variety, the only substantial difference was that the plugs took slightly longer to mature. Later planted crops flowered later, and it looks like this may be the way to achieve continuity: this will be investigated in 2017. Powdery mildew was severe on *Bromus secalinus* in tunnels and outdoors and with both planting dates.

The outdoor plots were not a success in 2016 because of the prevailing weather conditions. The plants were frosted soon after planting, with some species severely affected, the plants then partially recovered but they were held back by the wet weather

in June. Outdoor cropping will be examined again in 2017.

Bromus macrostachys

B. secalinus
(note powdery mildew)

Eragrostis elegans
(in centre of
photograph)

Panicum elegans
'Sprinkles'

P. miliaceum
violaceum

Setaria italica
'Mix'

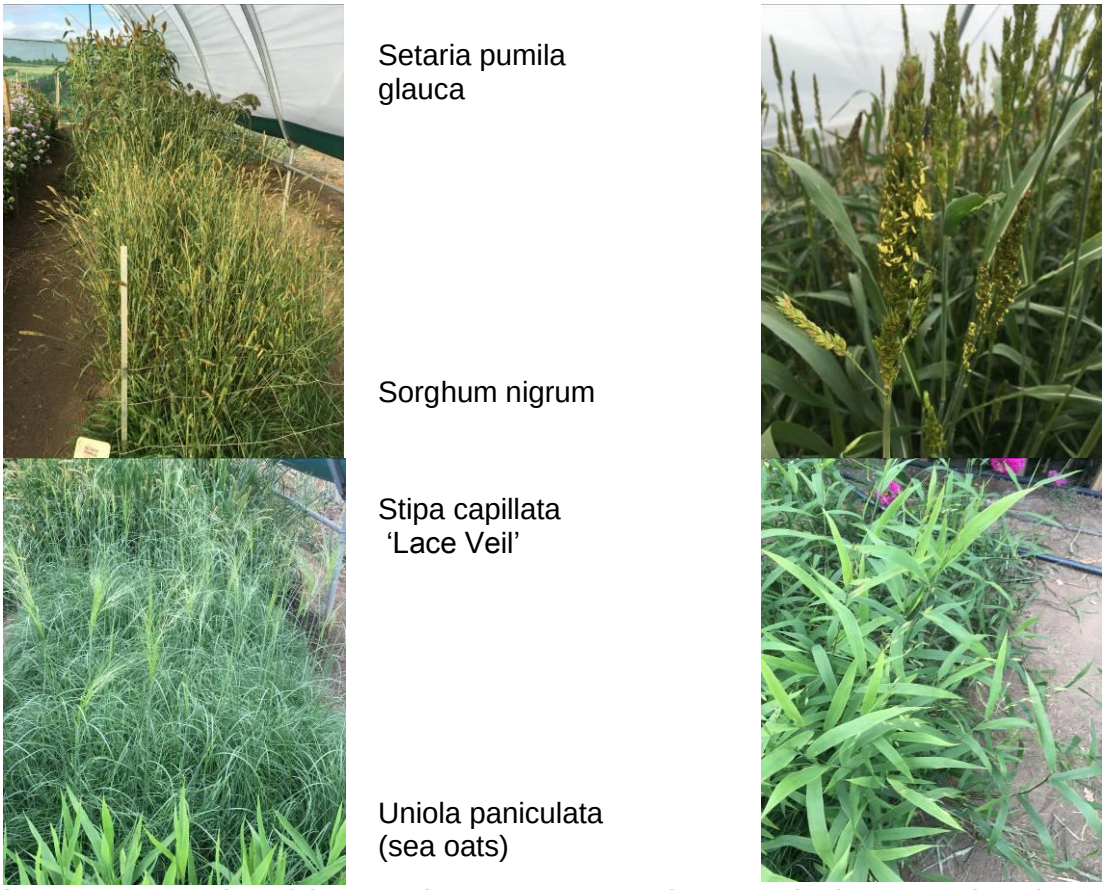

Figure 26. Examples of the tunnel-grown ornamental grasses in demonstration plots in 2016 (taken on various dates)

Samples of *Bromus macrostachys*, *Eragrostis elegans*, *Panicum elegans* 'Sprinkles', *P. miliaceum violaceum*, *Setaria italica* 'Mix', *Sorghum nigrum* and *Stipa capillata* 'Lace Veil' were subjected to standard VL testing incorporating alternative post-harvest treatments – either 'RVB Clear' or 'CVBN'. All samples remained in an acceptable condition on vase-day 7, with no obvious differences between the post-harvest treatments (Figure 27). On vase-day 7 some leaves of *Bromus macrostachys*, *Panicum miliaceum violaceum* and *Setaria italica* 'Mix' were showing some yellowing or dehydration, but not to an extent that would have resulted in the failure of a mixed bouquet; all leaves of the other grasses were unaffected. Little or no shedding of anthers or pollen was seen.

Of all of the trials in 2016, the ornamental grasses generated the most interest amongst growers and others. There was a great variety in head form amongst the species grown, with *Panicum elegans* 'Sprinkles' and *Stipa capillata* 'Lace Veil' particularly eliciting positive comments at the Open Day. All species tested have potential for use in mixed bouquets with a 7-day guaranteed VL. They all appeared relatively easy to grow, and being regarded as fashionable there was a lot of interest from packers and supermarkets; they would also be appropriate for direct-mail. As they show real

promise for greater production in the UK, further trials of the most promising ones will be carried out in 2017, including sequential sowings to achieve continuity. It is also suggested that plots of regular cereals could be included (as observed during the CFC/AHDB study tour to Israel in January 2017).

Bromus macrostachys

Eragrostis elegans

Panicum elegans ‘Sprinkles’

P. miliaceum violaceum

Setaria italica ‘Mix’

Sorghum nigrum

Stipa capillata
'Lace Veil'

Figure 27. A selection of ornamental grasses at vase-day 7 in standard post-harvest testing

Scabious (Scabiosa caucasica and S. atropurpurea cultivars)

Scabious are annual and perennial herbs up to 0.6m tall that, with their attractive flowers in a wide range of colours, and high yields, are often grown outdoors as cut flowers. A large demonstration was set up at CFC in 2016, using cutting-raised plants of a new series, 'Scoop', from Danziger (Table 21).

Table 21. Details of 2016 demonstration of scabious

Varieties	'Scoop' series 'Blackberry', 'Cotton Candy', 'Lavender', 'Marshmallow' and 'Raspberry'(tunnel and outdoor plots);'Cherry Vanilla' and 'Vanilla' (outdoor plots only)
	Plugs from Danziger
Propagation and pre-planting treatment(s)	None
Planting or sowing date(s)	Transplanted to tunnel week 17 Transplanted outdoors weeks 18 and 20
Plots	3m-long plots
Planting/housing site(s)	Outdoors and 'Pro-Tech' tunnel bay 1
Layout	Un-replicated demonstration plots
Plant spacing(s)	8/m^2 in two rows along bed
Post-planting treatment(s)	Pinched 3 weeks after transplanting One layer of support netting
Pests, diseases and disorders	None evident initially. Some cultivars developed leaf chlorosis during August, the plants were able to grow away from it as the weather improved; no viruses were found, and chlorosis may have been stress induced, requiring further investigation
Picking stage(s) and market specification(s)	When first whorl of petals opens
Picking and recording date(s)	Few flowers from week 26 onwards Cropped in quantity from week 29 onwards and still cropping in October when records were discontinued
Records taken	Observations and picking dates
VL testing	Samples taken (mix of all cultivars from tunnel and outdoor plots) week 31

The plants were slow to establish but, like the zinnias, grew vigorously after pinching Figures 28 and 29). In the tunnel, flowering started in week 26, with a heavy flush from week 29 onwards, and was still continuing in October when the trial was terminated. The total yield of stems and the yield of stems >45cm in length are shown for the July to September period in Figure 30. The highest number of longer stems were produced in July, but overall many stems were short (<45cm). The percentage of longer stems was 30% for 'Marshmallow', 28% for 'Blackberry', 25% for 'Cotton Candy', 24% for 'Lavender' and only 15% for 'Raspberry'.

Figure 28. Cultivars of the 'Scoop' series of scabious in trials at CFC in 2016 (photographed weeks 28 to 30)

Figure 29. 2016's scabious 'Scoop' demonstration plots at CFC: pictured in (top-left then clockwise) weeks 28, 31, 35 and 38

The outdoor plantings cropped surprisingly well, considering the prevailing conditions: there was frost a week after planting, water-logging in June, drought and high temperatures in August, etc. The high outdoor yields and lack of resources prevented the full recording of these plots. Unfortunately it was not possible to obtain plugs of 'Cherry Vanilla' and 'Vanilla' in time for planting in the tunnel, so they were only planted outdoors, in week 20. 'Cherry Vanilla' was very prone to leaf chlorosis (see Table 21), while 'Vanilla' performed poorly.

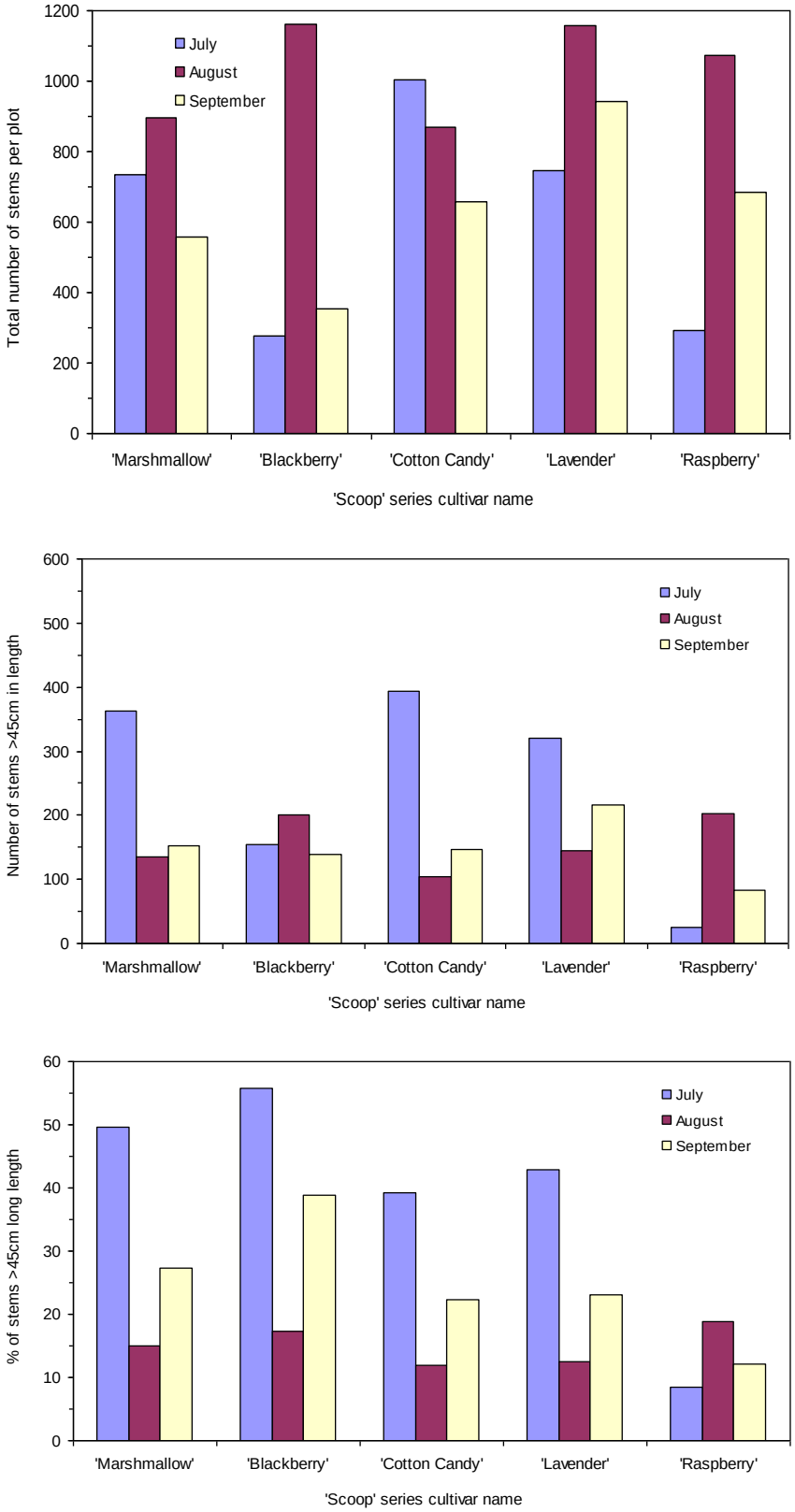

Figure 30. Stem yield for five cultivars of the 'Scoop' series of scabious planted in demonstration plots in tunnel in week 17, 2016: (top) total number of stems, (middle) number of stems >45cm-long, and (bottom) percentage of stems >45cm-long

Samples were subjected to standard VL testing incorporating alternative post-harvest treatments – either ‘RVB Clear’ or ‘CVBN’. All stems remained in acceptable condition on VL day 7, and there were no differences between the post-harvest treatments (Figure 31). In VL testing they were robust, easy to handle, and did not appear to have complicated post-harvest requirements.

VL day 4 with ‘RVB Clear’

VL day 4 with ‘CVBN’

VL day 7 with ‘RVB Clear’

VL day 7 with ‘CVBN’

Figure 31. Scabious stems from 2016 VL testing on vase-days 4 and 7, following post-harvest treatment with ‘RVB Clear’ or ‘CVBN’

Scabious certainly appear to have great potential for cut flower production in the UK, both under plastic and outdoors. The initial plantings were left down to see if they are hardy under our conditions. ‘Cherry Vanilla’ and ‘Vanilla’ are cultivars worth pursuing and will also be further investigated in 2017.

The new cultivars, with their attractive range of flower colours, high yields and good VL, have been well received by the industry. They have good potential for use by

retailers in mixed bouquets. The only problem is the lack of stem length, which would limit how they could be utilised, which might be investigated in 2017 by using other cultivars and planting densities.

Solanum, ornamental (*Solanum aethiopicum* cultivars)

'Pumpkin-on-a-stick' is an unusual novelty that really caught the imagination of trial participants in the USA. The bright red 'pumpkins', actually resembling small (but toxic) tomatoes. The species is related to the winter cherry (*S. pseudocapsicum*), sold as a brightly fruiting house plant. 'Pumpkin-on-a-stick' and 'Golden Eggs' were grown to assess the UK trade's response. Details are given in Table 22.

Table 22. 2016 demonstration of ornamental solanums

Varieties	'Pumpkin-on-a-stick' 'Golden Eggs'
Format(s) and supplier(s)	Seeds from Genesis
Propagation and pre-planting treatment(s)	Sown in 104 plugs (week 13)
Planting or sowing date(s)	Transplanted to tunnel week 18 ('Pumpkin-on-a-stick') or 19 ('Golden Eggs')
Plots	3m-long plots
Planting/housing site(s)	'Pro-Tech' tunnel bay 2
Layout	Un-replicated demonstration plots
Plant spacing(s)	25 and 64/m^2
Post-planting treatment(s)	No
Pests, diseases and disorders	A lot of damage from mice (and possibly rats) which destroyed a lot of the fruits
Picking stage(s) and market specification(s)	With fruits fully coloured
Picking and recording date(s)	N/A
Records taken	Observations and picking dates
VL testing	No

'Pumpkin-on-a-stick' was an incredibly vigorous plant that started flowering in July, with fruits seen developing soon after (Figure 32). As would be expected the lower density produced sturdier stems than the higher density, although, depending on the outlet, there could be a market for both. However, the plants have vicious spines on both the stems and leaves; in the USA it is usual to remove them at harvest, but this adds costs and makes it a specialty crop rather than a mainstream one. The labour involved in harvesting the crop and removing the leaves and thorns means that the product would only be considered by a specialist, perhaps artisan growers who can sell them at a premium price. 'Golden Eggs' was interesting but very slow to mature and was not fully ripe before the covers had to be removed for the winter, subsequently being frosted. The industry did not appear to be enthusiastic about either of these novelties.

Figure 32. ‘Pumpkin-on-a-stick’ demonstration plots through the season: (top-row to bottom-row) weeks 30, 35, 38 and 40; note spines on stems and leaves (e.g. in top-right picture) and mouse predation (right-hand picture of third row down)

Crop introduction (2) crops with trials on-going

Trials on several novel crops were started in previous years and have been continued in order to address specific issues or carry out further cultivar comparisons.

Basil (Ocimum basilicum)

There has been interest in growing basil as a fragrant filler for mixed bunches and bouquets, and in 2014 cultivars 'Dark Red Opal', 'Floral Spires Lavender', 'Floral Spires White' and 'Sweet Dani Lemon' were tunnel-grown as demonstration plots. They made good growth, with some cultivars having attractive foliage with potential for the suggested use. But as the VL of these cultivars was poor (<5 days) further trials were postponed until better cultivars became available. 'Aromato' and 'Cardinal' are basil cultivars that were well received in ASCFG trials and in 2016 they were grown in demonstration plots in a tunnel (Table 23).

Table 23. 2016 demonstration of basil cultivars

Varieties	'Aromato', 'Cardinal'
Format(s) and supplier(s)	EconSeeds
Propagation and pre-planting treatment(s)	Sown in plugs week 17
Planting or sowing date(s)	Transplanted week 21
Plots	1m-long plots
Planting/housing site(s)	'Pro-Tech' tunnel bay 2
Layout	Un-replicated demonstration plots
Plant spacing(s)	64/m^2
Post-planting treatment(s)	None
Pests, diseases and disorders	None evident
Picking stage(s) and market specification(s)	Mature stems
Picking and recording date(s)	August
Records taken	Observations and picking dates
VL testing	No

The plants grew well and produced good stems in August. However, tests showed that the stems failed to take up water, confirming their poor VL, and no further work on basil cultivars is planned.

Caryopteris (blue spiraea) (*Caryopteris clandonensis* cultivars)

Caryopteris is a popular garden shrub up to 1.5m-tall and bearing usually bright blue flowers in clusters near the branch ends. It had been included in CFC trials in 2008, but concerns had been expressed then about the unacceptable smell sometimes associated with the crop. Although individual opinions varied and there appeared to be

differences between cultivars, sufficient concerns had been raised to discourage further trialling at that point. In 2016 Danziger introduced a new range of caryopteris bred specifically for cut flower production – the 'Pagoda' series - and three were grown in demonstration plots. Plug-plants were transplanted into beds in a tunnel in week 21 (Table 24).

Table 24. Details of 2016 caryopteris cultivar demonstration

Site	Rookery Farm
Varieties	'Pagoda Blush', 'Pagoda Lagoon' and 'Pagoda Ocean'
Format(s) and supplier(s)	Plug-plants (Danziger)
Propagation and pre-planting treatment(s)	None
Planting or sowing date(s)	Transplanted week 21
Plant spacing(s)	24/m^2
Planting site(s)	1m-long plots in beds in 'Pro-Tech' tunnel bay 1
Layout	Non-replicated demonstration plots
Post-planting treatment(s)	One layer of support net provided
Pests, diseases and disorders	None evident this year
Picking stage(s) and market specification(s)	Stems with bulbs showing colour or with the lowermost whorl of flowers open
Picking and recording date(s)	Started cropping mid-September
Records taken	Observations only
VL testing	No

The cultivars are shown in Figure 33. This was the first year of trials, but 'Pagoda Lagoon' showed real promise because of its rich colour. 'Pagoda Blush' was disappointing because of its rather insipid colour and short stems. The previous issue, of the sometimes unpleasant smell of the crop, did not appear to have been raised this year: it may be cultivar specific, or perhaps lessens or dissipates over time. The crop has been left *in situ* and its performance will be assessed in 2017.

Figure 33. Caryopteris in the 2016 demonstration (from top-left then clockwise): ‘Pagoda Blush’, ‘Pagoda Lagoon’ and ‘Pagoda Ocean’ (all week 38), and general view (week 40)

Delphinium (*Delphinium elatum* cultivars)

Delphinium cultivars have previously been trialled extensively, but growers and others continue to debate whether more of their potential might be realised, say by the arrival of new cultivars. In 2014 ‘Sea Waltz’, ‘Sky Waltz’ and ‘Tango Dark Blue’, examples of new series from HilverdaKooij, were grown in demonstration plots at the suggestion of growers. They produced attractive flower spikes and were highly productive, giving potentially three flushes a year when cut-back after the first and second flushes (although in this instance the third flush was developing when the plants were flattened by gales in late-October). Grown-on to a second year they produced dense growth with productive flushes in mid- to late-June and mid- to late-August, and a weak flush on October.

Examples of a further new series with interesting flower spikes, ‘Trick’ from Miyoshi,

were grown in demonstration plots in 2016 (Table 25).

Table 25. Details of 2016 delphinium new cultivars demonstration

Varieties	'Trick Lilac', 'Trick Pink' and 'Trick Yellow'
Format(s) and supplier(s)	Plugs ex tissue culture (Miyoshi)
Propagation and pre-planting treatment(s)	None
Planting or sowing date(s)	Transplanted week 19
Planting site(s)	2m-long plots in beds in 'Pro-Tech' tunnel bay 2
Layout	Non-replicated demonstration plots
Plant spacing(s)	25/m^2
Post-planting treatment(s)	One layer of support netting Cut back to ground after first and second flushes
Pests, diseases and disorders	There was a low level of powdery mildew but on the whole it was controlled through the spray programme The first flush showed virus-like symptoms (blotchy leaf colour and chlorosis) but this was not evident in the second flush
Picking stage(s) and market specification(s)	N/A
Picking and recording date(s)	First flush weeks 28-29 Second flush weeks 35-36
Records taken	Observations only
VL testing	Samples of each cultivar taken in week 38

The crop produced a good flush of flowers in mid- to late-July and a second heavy flush in early-September. The flowers, beds and chlorotic symptoms are shown in Figures 34 to 35). The flowers were elegant, upright and well liked by growers.

Figure 34. Delphinium 'Trick' plots at CFC in 2016, left to right: photographed at weeks 28, 35 and 38

Figure 35. Delphinium ‘Trick’ cultivars in demonstration plots at CFC in 2016, left to right: ‘Trick Lilac’, ‘Trick Yellow’ and ‘Trick Pink’, week 28

Figure 36. Foliage of delphinium ‘Trick’ showing blotchy, chlorotic symptoms (week 28)

Samples of each cultivar were taken for VL testing, the two post-harvest treatments in this case being ‘AVB’ and ‘RVB Clear’. The end of VL being taken as when >50% of the flowers on a stem had wilted or dropped. By vase-day 4 the stems treated with ‘AVB’ showed no flower abscission, while ‘Trick Pink’ stems treated with ‘RVB Clear’ were shedding flowers and 40% of the stems had been terminated. The first stem deaths occurred in ‘Trick Blue’ and ‘Trick Yellow’ on vase-days 7 and 8, respectively, with ‘Trick Yellow’ losing hardly any flowers in any treatment (Figure 37), suggesting there are varietal differences in sensitivity to ethylene. All stems treated with ‘AVB’ lasted >8 days in VL, and flowers opened better and were visibly larger when this product had been used.

The ‘Trick’ series of delphiniums were considered to have good potential as straight bunches or for use in bouquets. The information from these trials is known to have helped the industry explore new cultivars, receiving a positive response from the market. At present ‘AVB’ would be recommended as a post-harvest treatment, but there is clearly scope for further post-harvest work and improvements through cultivar selection. At present, the colour range is limited. The key factor is whether the product would command a price high enough to justify the purchase of expensive tissue-cultured plants; if not, delphinium ‘Trick’ may be a niche crop for the artisan grower. Further assessments will be made in 2017.

Treated with ‘AVB’ Treated with ‘RBV Clear’

Figure 37. Delphinium ‘Trick’ series shown on vase-day 7, having been pre-treated with (left) ‘AVB’ and (right) ‘RVB Clear’

Fillers, seed-raised

Recent years have seen an increase in growers’ interest in producing cheap, seed-raised fillers, either in tunnels or outdoors. A range of fillers was demonstrated in 2014 and 2015, with some follow-up trials in 2016.

Ammi majus and *A. visnaga*. In the 2014 demonstration *A. visnaga* seed germinated poorly and the consequent wide plant spacings led to stems that were too large and branching for use as a filler. Ammi was ready for picking starting weeks 33, 38 and 42 from week 21, 25 and 27 sowings, respectively, while plants from the week 30 sowing were not ready by week 43 when the tunnel was de-skinned. These poor results suggested that *A. visnaga* should either be drilled at a higher density to reduce plant size, or grown more reliably from plugs; alternatively the more robust *A. majus* might be grown instead. In the 2015 trials *A. visnaga* was slower to mature than in the previous year, perhaps because of the very cold spring and early summer. Its potential to produce large flower-heads may indicate its use in the larger, more expensive bouquets. *A. majus* was also slow to mature, but produced marketable stems from the later sowings both in tunnels and outdoors. In post-harvest tests in 2015, stems of both species achieved very long VL: 17 and 22 days.

There was marked enthusiasm from customers and growers for the CFC carrying out further comparative trials of ammi in 2016, hence a range of cultivars was investigated (Table 26).

Table 26. Details of 2016 demonstration of *Ammi* cultivars

Varieties	*Ammi majus* 'Bishop's Flower' *A. majus* 'Queen of Africa' *A. majus* 'Snowflake' *A. visnaga* 'Green Mist' *A. visnage* 'Mystique' *A. visnaga* 'Queen Anne's Lace' *A. visnaga* 'White Spray'
Format(s) and supplier(s)	Seed (Chilton Seeds and Genesis Seeds)
Propagation and pre-planting treatment(s)	None
Planting or sowing date(s)	Seed direct-drilled by hand in three rows along the bed in week 18 (tunnel) and week 20 (outdoors)
Plots	3m-long plots
Planting/housing site(s)	'Pro-Tech' tunnel bay 2 Outdoor beds
Layout	Non-replicated demonstration plots
Plant spacing(s)	Seedlings not thinned
Post-planting treatment(s)	None
Pests, diseases and disorders	No problems evident
Picking stage(s) and market specification(s)	When the umbel is showing colour
Picking and recording date(s)	Week 28 onwards for *A. majus* cultivars Week 30-31 onwards for *A. visnaga* cultivars
Records taken	Observations and picking dates
VL testing	No

The main cropping period for *Ammi majus* cultivars was week 28 onwards, and for *A. visnaga* cultivars weeks 30 or 31 onwards. Differences between ammi cultivars were subtle rather than obvious. In general, growing ammi in tunnels resulted in plants that were rather too vigorous, so growing outdoors may be the better option, but this has to be balanced against the crop damage that may be incurred.

Apart from ammi, the only other seed-raised filler trialled in 2016 was the ornamental carrot (Table 27).

Table 27. Details of 2016 demonstration of ornamental carrot

Varieties	Daucus carota 'Dara'
Format(s) and supplier(s)	Seed (Chilton Seeds)
Propagation and pre-planting treatment(s)	None
Planting or sowing date(s)	Seed direct-drilled by hand in three rows along the bed in week 18 (tunnel)
Plots	3m-long plots
Planting/housing site(s)	'Pro-Tech' tunnel bay 2
Layout	Non-replicated demonstration plots
Plant spacing(s)	Seedlings not thinned
Post-planting treatment(s)	None
Pests, diseases and disorders	No problems evident
Picking stage(s) and market specification(s)	When the umbel is showing colour
Picking and recording date(s)	Week 25 onwards
Records taken	Observations and picking dates
VL testing	No

Ornamental carrot 'Dara' was grown in the same way as ammi, but only in the tunnel. Even though there was not much of it, it generated a lot of interest from growers for its distinctive flowers produced from week 25 onwards.

Because of the industry's enthusiasm for fillers, it is suggested that further trials of ammi species, of other ornamental carrot cultivars, and of *Atriplex* and *Oglala* should be carried out in 2017.

Gypsophila (*Gypsophila paniculata* cultivars)

In 2014–2015 two new gypsophila cultivars with improved stem and flower qualities, 'Zinzi Discovery' and 'Zinzi Tyree', were grown in demonstration plots, but, probably due to late delivery and planting, the results were disappointing. However, further cultivars were demonstrated in 2016: details are given in Table 28.

Table 28. Details of 2016 gypsophila cultivar demonstration

Site	Rookery Farm
Varieties	'Andromeda', 'Beauty Bride', 'Dynamic Love', 'My Pink', 'Orstar', 'Paniculata', 'White Victoria' and 'Xlence'
Format(s) and supplier(s)	Plugs (Danziger)
Propagation and pre-planting treatment(s)	None
Planting or sowing date(s)	Planted week 21
Plant spacing(s)	6/m^2
Planting site(s)	1m-long plots in beds in 'Pro-Tech' tunnel bay 1
Layout	Non-replicated demonstration plots
Post-planting treatment(s)	One layer of support netting provided
Pests, diseases and disorders	None evident
Picking stage(s) and market specification(s)	When 50% of flowers are open
Picking and recording date(s)	Flowering from week 30 onwards
Records taken	Observations only
VL testing	No

All varieties produced some marketable stems in 2016, and the cultivar 'Dynamic Love' is shown in Figure 38. Their potential for second year production will be assessed once the plants are established in 2017.

Figure 38. An example of the gypsophila cultivars trialled in 2016, 'Dynamic Love'

Solidago (Solidago media)

Solidago is often used as a filler with flowers such as freesia, requiring small stems (weighing about 15g) which can be supplied cheaply from imports. Solidago had previously been included in CFC demonstrations in 2008, when stems from tunnel plantings averaged 124cm in length and 274g in weight and those from outdoor plots

106cm and 222g. Solidago stems of this size would be suitable only for bunch sales, for which there is unlikely to be a demand. To examine the crop further, three cultivars were grown in demonstration plots in 2016 (details in Table 29).

Table 29. Details of 2016 solidago demonstration

Site	Rookery Farm
Varieties	'Golden Glory', 'Moonlight' and 'Solar Glory'
Format(s) and supplier(s)	Plugs (Danziger)
Propagation and pre-planting treatment(s)	None
Planting or sowing date(s)	Planted week 21
Plant spacing(s)	25/m^2
Planting site(s)	1m-long plots in beds in 'Pro-Tech' tunnel bay 1
Layout	Non-replicated demonstration plots
Post-planting treatment(s)	One layer of support net
Pests, diseases and disorders	Powdery mildew is a potential problem but managed through a spray programme
Picking stage(s) and market specification(s)	About 50% of flowers open
Picking and recording date(s)	Samples provided to growers from week 24 onwards
Records taken	Observations and samples
VL testing	No

The plots produced a heavy crop of high quality stems in mid- to late-August (Figure 39) but did not achieve a second flush. The plants were left *in situ* for their potential to be assessed in 2017.

Figure 39. Examples of the solidago cultivars trialled in 2016

Trachelium (Trachelium caeruleum)

Trachelium is not well known in the UK, although it is widely grown in the Netherlands and has been trialled and grown in the USA. Seed is supplied by many of the well-know seed houses and several series are available, including the 'Lake Collection' (Kieft Seeds) which is marketed as a cut flower trachelium. Trachelium seemed well worth testing.

In 2013 seeds of a selection of cultivars were sown into plugs but all failed to germinate. Some reports state that germination is sometimes poor, though no unusual germination requirements are indicated in the seed catalogues consulted. However, discussions at the time with other growers and propagators in the UK and the Netherlands revealed that germination seemed to have been an industry-wide issue in 2013 (though it does not seem to have caused any issues subsequently). Subsequently, plug-plants of cultivar 'Corine Purple' (Combinations Young Plants) were obtained as replacements. They were transplanted in week 23 at 64/m^2 to a 2m-long plot in 'Pro-Tech' tunnel bay 1. The plants grew well and produced an attractive display that started in late-August.

With its colour and form evident, trachelium may have potential for UK production, so the trial was repeated in 2014 using plug-plants of 'Corine Purple' and examples from the 'Lake Michigan' series, mostly transplanted in week 22. Although the initial growth appeared weak and budding-up occurred early, the stems lengthened and strengthened as the plants matured and each plant produced at least one heavy lead stem and a number of marketable side-shoots. The colours were impressive. The total yield of marketable stems ranged from 86/m^2 for 'Corine Purple' to 158/m^2 for 'Lake Michigan Blue'. For the lead stems, average lengths varied between 57 and 66cm and average weights (trimmed to 55cm) from 23g ('Lake Michigan White') to 32g ('Corinne Purple'). A later (week 27) planting of 'Lake Michigan Purple' proved too late to achieve natural season flowering and the stems obtained were short.

A further trial was set up in 2015 to investigate transplanting dates (weeks 18, 22 and 25) and compare pinched and non-pinched (single-stemmed) crops; the planting density was kept at 64/m^2 for the non-pinched plants but reduced to 25/m^2 in the plots destined for pinching. Pinching was to 4 or 5 leaves 2 weeks after transplanting. As in

2014, initially growth was weak and budding-up premature, the plants strengthening later to produce large numbers of marketable stems. Stem length was satisfactory, though with large varietal differences, 'Lake Forrest White' and 'Lake Michigan Red' producing the tallest stems (70cm) and 'Lake Forrest Blue' and 'Lake Forrest Purple' the shortest (64cm); for three cultivars ('Lake Forrest Purple', 'Lake Michigan Purple' and 'Lake Michigan White') the stems from non-pinched plants were significantly taller than their pinched equivalents. Trimmed stem weight, however, varied little between the treatments. Again, the non-pinched plants grew vigorously, producing at least one or two side-shoots. Overall, stem yields were quite variable, with mean numbers of marketable stems/m^2 of between 133, equivalent to 5.3 stems/plant (for pinched 'Lake Forrest Blue') and 273, equivalent to 4.3 stems/plant (for non-pinched 'Lake Michigan White'). Non-pinched plants cropped around 10 days earlier than pinched plants. VL testing showed a range of cultivar averages from 14 to 17 days.

The effects of pinching were further investigated with 'Lake Forrest Blue' and 'Lake Michigan White' in 2016 (Table 30). In week 21 plugs were transplanted into beds in a tunnel at the same planting rates as in the previous experiment. Pinching appropriate plots of plants took place two weeks after transplanting.

Table 30. Details of 2016 trachelium pinching trial

Varieties	'Lake Forrest Blue' and 'Lake Michigan White'
Format(s) and supplier(s)	Plugs from Florensis
Propagation and pre-planting treatment(s)	None
Planting or sowing date(s)	Transplanted week 21
Plots	1m-long plots
Planting/housing site(s)	'Pro-Tech' tunnel bay 2
Layout	Three replications
Plant spacing(s)	64 plants/m^2 for the non-pinched plots 26 plants/m^2 for the pinched plots
Post-planting treatment(s)	Half of plots pinched 2 weeks after transplanting, others not pinched One layer of support netting
Pests, diseases and disorders	None evident
Picking stage(s) and market specification(s)	Florets just starting to open Stem length 55cm Flower diameter minimum 8cm
Picking and recording date(s)	2, 9 and 23 August
Records taken	Picking date Total number of stems picked per plot per date Stem length before trimming and stem weight after trimming to 55cm (for a random sample of 10 stems per plot at the first and second picking dates)
VL testing	No

The crop established and grew away well and ultimately produced a superb crop with long, strong healthy stems. Pinched plants, planted at 26/m^2, produced an average of just over 5 stems per plant, while single-stemmed plants, planted at a rate of 64/m^2, gave about 3.5 stems per plant (Table 31). This means that the pinched crop produced more stems per plant, but less per m^2. 'Lake Michigan White' gave taller stems than 'Lake Forrest Blue' and non-pinched plants taller stems than pinched ones, meaning that many of the stems of 'Lake Forrest Blue' did not reach the 55cm specification. There were no statistically significant effects on trimmed stem weight.

Table 31. Means and statistical significance for the 2016 trachelium pinching trial

Cultivar	Treatment	Total number of stems		Mean stem length (cm)	Mean stem weight (trimmed) (g)
		per m^2	per plant		
'Lake Forrest Blue'	Pinched	142.7	5.5	52.1	14.5
	Non-pinched	216.3	3.4	58.0	12.6
'Lake Michigan White'	Pinched	134.3	5.2	61.5	15.0
	Non-pinched	216.0	3.4	64.5	12.7
	SED (5%)	28.96	0.50	1.55	2.26
Significance	Cultivar	NS	NS	***	NS
	Treatment	**	***	**	NS
	Interaction	NS	NS	NS	NS

There appears to be very good potential for growing tunnel-raised trachelium in the UK. In the past, trachelium had a poor reputation because of browning and the low weight of imported stems: the UK product seems much better – greener, taller and heavier. At present the high cost of young plants is deterring growers from trying trachelium, but the additional stems thrown by pinched plants would reduce costs.

Veronica (*Veronica longifolia* cultivars)

Cultivars of *Veronica longifolia* are the most suitable veronica for cut flower production, having sufficient height (up to 1.2m) and a good range of colours, including the important blues. Veronicas had previously been demonstrated at the CFC in 2008, when four colours from the 'Spark' series had been grown in tunnels and outdoors. Across the cultivars, stems from tunnel plantings averaged 63cm in length and 29g in weight, and those from outdoor plots 44cm and 18g. At the time it was concluded that, for a number of reasons, not least a small production window, veronica cut flowers were unlikely to be economic in the UK. However, following revived interest, a further tunnel demonstration was suggested in 2016 and plots of three cultivars of the 'Skylark' series were grown (Table 32). Plugs were transplanted to beds in a tunnel in week 19

at a density of 20/m^2.

Table 32. Details of 2016 veronica cultivar demonstration

Site	Rookery Farm
Varieties	‘Skylark Blue’, ‘Skylark Pink’ and ‘Skylark White’
Format(s) and supplier(s)	Plugs (Danziger)
Propagation and pre-planting treatment(s)	None
Planting or sowing date(s)	Transplanted week 19
Plant spacing(s)	20/m^2
Planting site(s)	1m-long plots in Pro-Tech’ tunnel bay 1
Layout	Non-replicated demonstration plots
Post-planting treatment(s)	One level of support netting
Pests, diseases and disorders	Powdery mildew later in season
Picking stage(s) and market specification(s)	With a maximum of 30 to 50% of florets open
Picking and recording date(s)	Mid- to late-August
Records taken	Observations and samples
VL testing	No

These cultivars produced a good crop of flowers during August; they were prolific, the stems were straight and the spikes well coloured (Figure 40). A programme against powdery mildew was necessary. Veronicas show real potential as a cut flower in the UK and should be trialled further in 2017.

Figure 40. Veronica 'Skylark' cultivars in 2016 trial at CFC: top row, left, 'Skylar White' and, right, 'Skylar Blue' ('Skylar Pink' was later to flower but some can be seen to the right of the 'White' plot) in week 32; bottom row, left to right, 'White', 'Pink' and 'Blue' in week 35; note mildew on leaves later in season indicating the need for a spray programme right through to flowering.

Zinnia (*Zinnia elegans* cultivars)

Zinnias have been grown previously at the CFC, in 2007 and 2008, when the industry was enthusiastic about their wide range of cheerful, vibrant colours. However, after picking, the hollow stems can collapse and bend just below the flower-head, making them unusable. Trials with zinnia were put on hold until varieties with improved stem strength became available. Meanwhile, a different conclusion had been reached in trials in the USA. For example, in the Santa Rosa Specialty Cut Flower Trials zinnia were rated "the most dependable flower in the trial [with] continuous flowering on 18" [45cm] stems", whilst admitting that "cultivar selection [was] critical." In the 2010 ASCFG trials, zinnia 'Queen Red Lime' and 'Benary's Giant Lime' created most discussion with their colours, and 'Benary's Giant Lime' made the 'top-five' in that year's trials. It seemed appropriate to revive CFC trials on zinnia.

In 2013, seed of seven varieties of the 'Oklahoma' series and of thirteen varieties of the 'Benary's Giant' series were transplanted in weeks 22-23 into plots in tunnel and outdoor beds. When the plants were only a few inches high, premature buds became visible, apparently a common occurrence (John Dole, personal communication, 2013), and when pinched they grew away vigorously. Some stems were ready for picking by mid-July and some interesting flower colours and forms were evident. 'Benary's Giant' varieties were stronger and attracted more interest than the 'Oklahoma' series, but the latter were considered far superior to the cultivars previously grown at the Centre. The tunnel crop was much more vigorous than those grown outdoors, with more and longer stems. Samples were taken for VL testing throughout summer, but flower quality was barely acceptable with a maximum vase-life of 7 days despite testing various flower conditioners and foods (using a hydrating solution was ineffective in retaining quality). Bending of the neck had previously occurred soon after transfer to the vase, but in the 2013 tests it was apparent only once the flowers were almost dead. This was a promising indication of potential commercial use, and it was suggested that they might benefit from earlier picking and treatment with flower food immediately after picking.

In 2014 a selection of cultivars was tunnel-grown specifically to provide material for VL testing. 'Benary Giant' cultivars 'Bright Pink', 'Coral', 'Deep Red', 'Golden Yellow', 'Lilac', 'Lime', 'Orange'. 'Purple', 'Salmon Rose', 'Scarlet', 'White', and 'Wine' and

‘Oklahoma’ cultivars ‘Carmine’, ‘Ivory’, ‘Pink’, ‘Salmon’, ‘Scarlet’ and ‘White’, were transplanted in weeks 18 and 22 respectively. Establishment was good and buds were visible within three or four weeks of transplanting (though stems were too short at that stage) and growth was prolific until bacterial blight (*Xanthomonas campestris*) appeared. Once the disease had been treated by pruning-out the affected foliage and spraying the crop with Amistar, the crop grew away vigorously and continued producing flowers in abundance until well into October. The crop provided plenty of stems for VL testing, but post-harvest quality was unsatisfactory with stems failing to last to the end of the 4 day retail store phase. It was suggested that this may have been due to adverse effects of the cool-chain, resulting in early dehydration. Further VL was therefore desirable, and consultants from Chrysal UK suggested there may be treatments available that could avoid such damage and further work was planned for 2015 with a view to mitigating the effects of the cool-chain and investigating the use of growth regulators to strengthen the neck. Despite these shortfalls zinnia appeared to be a good candidate for ambient direct sales such as mail-order.

In 2015 further ‘Benary Giant’ cultivars were grown to provide stems for a VL study commissioned by Chrysal UK with ADAS. The aim was to assess the effects of post-harvest conditioning treatments on VL once they had reached the final, consumer phase. As in previous years the crop grew well, starting to produce marketable flowers by week 28. Because of the unavailability of a VL test room earlier in the season, stems of zinnia (mixed cultivars) were not sampled until 1 September (week 36). Equal numbers of stems were sampled with un-opened flowers, almost fully open flowers (open stamens and disc florets) and flowers at an intermediate stage. They were cold-stored overnight in clean buckets in water with added conditioning solution, either (1) ‘Chrysal Clear RVB Clear Intensive’ at 1ml/L, (2) ‘Chrysal Clear CVBN’ at 1 tablet/2L or (3) ‘Chrysal Clear CVBN’ at 1 tablet/L before delivery to ADAS Boxworth. The cut-stems were then transferred to buckets of water with added shipping treatment (‘Chrysal Clear Professional 2 T-Bags’) and kept in the VL room until 4 September when the VL test was set-up. The stems were de-sleeved, re-cut and placed in vases containing 1L of water with added flower food (‘Chrysal Clear Liquid Universal’). With three conditioning treatments and using three mixtures of cultivars there were nine treatment combinations, each with two replicate vases containing six stems each and using standard VL conditions. The stems were fully assessed daily for 10 days (any stems not written-off by vase-day 10 were assigned a nominal VL of up to 12 days. The write-off criteria were >90° bending of the stem or >75% of the petals wilted or showing signs of discolouration. Overall they performed reasonably well, most stems

lasting beyond the guarantee day, day 5. But between vase-days 5 and 10 they failed quickly and on average <50% survived beyond vase-day 10. Stems failed for a variety of reasons, including botrytis in the bud and bending of the neck, but mainly for discolouration around the edges of the petals. Interestingly, stems harvested at the early stage with apparently weak necks, appeared to become firmer in the neck rather than bending, as had been expected from earlier trials. However, VL was not obviously shorter for the most advanced stems than for those cropped at an earlier stage. It was suggested that neck bending may occur only when stems are picked at an over-mature stage, and that otherwise the developmental stage at picking is of little importance (Tracey Thomas, personal communication, 2015; Claire Streit, personal communication, 2015). No consistent differences in these metrics were found between the three conditioning treatments. There did, however, appear to be large differences in performance between cultivars: at the extremes, 'green' had the longest average VL (9.9 days) and stems remaining at vase-day 10 (94%), whereas 'white' had the poorest responses (6.3 days and 25%). There were some differences in flower quality scores between conditioner treatments, 'CVBN' treatments resulting in marginally better scores. The leaf quality score remained at 5 throughout. Water quality was good across the trial, with very little clouding seen until after vase-day 5.

In 2016 further supplies of tunnel-raised zinnia from the 'Benary Giant' series were grown for VL testing (Table 33).

Table 33. Details of 2016 zinnia production for VL testing

Site	Rookery Farm
Varieties	'Benary Giant Lime', 'Benary Giant Purple', 'Benary Giant White' and 'Benary Giant Wine'
Format(s) and supplier(s)	Seed (Benary)
Propagation and pre-planting treatment(s)	None
Planting or sowing	Sown into module trays week 14
Planting or sowing date(s)	Transplanted week 19
Plant spacing(s)	25/m^2
Layout	2m-long plots
Post-planting treatment(s)	One layer of support net provided
Planting/housing site(s)	Beds in 'ProTech' tunnel bay 2
Pests, diseases and disorders	Occasional aphids and caterpillars No problem with bacterial blight this year
Picking stage(s) and market specification(s)	Mixture of half- and fully open flowers
Picking and recording date(s)	Week 28 onwards (until the cover was removed)
Records taken	Grown for VL samples only
VL testing	Sampled week 36 and tested at Holbeach Campus, University of Lincoln

Mixed samples of the four ‘Benary Giant’ cultivars were taken in week 36 and subjected to standard VL testing incorporating alternative post-harvest treatments – in this case either ‘CVBN’ or ‘Professional 2 T-bag’. In previous tests petal browning had been noted in zinnia during the cold cabinet (2°C) treatment, and had been attributed to cold damage, but this was not observed in the present case; petal browning was, however, noted towards the end of VL testing and it was now concluded that this was a natural part of the aging process. The relatively weak stems typical of zinnia were noted to have strengthened after harvest, resulting in very few flowers with neck damage. The first stem deaths occurred on VL day 6 and the last on vase day 10, with an average VL of 8.5 days over both post-harvest treatments (Figure 41). In most cases the leaves remained green until the termination of VL.

The ‘Benary Giant’ and ‘Oklahoma’ series grown in the CFC trials were considered superior to other cultivars previous trialled, with better overall vigour, attractive flowers in a wide range of colours, and long stems. Overall, however, the VL results have given a rather unclear picture. Early concerns about stem bending, due to the hollow stem, were not seen until late in vase-life, though VL was barely acceptable at a maximum of 7 days (2013 trials). In 2014 VL samples failed to survive until the end of the retail store phase; this may have related to earlier infection with bacterial blight, although it was also suggested that zinnias may be sensitive to cool-chain conditions. In tests in 2015 they performed reasonably well, most stems lasting beyond the guarantee day, day 5, but between vase-days 5 and 10 they failed quickly, and on average <50% survived beyond vase-day 10. Stems failed for a variety of reasons, including botrytis in the bud and bending of the neck, but mainly for discolouration around the edges of the petals. Interestingly, stems harvested at the early stage with apparently weak necks, appeared to become firmer in the neck rather than bending, as had been expected, but VL was not obviously shorter for the most advanced stems than for those cropped at an earlier stage. It was suggested that neck bending may occur only when stems are picked at an over-mature stage, and that otherwise the developmental stage at picking is of little importance. There appeared to be large differences in performance between cultivars, with extremes of 10 days and 6 days. There were only minor differences in flower quality scores between conditioner treatments (‘CVBN’ treatments and ‘RVB’). Finally, in 2016, the petal browning seen earlier did not arise until later in VL, and seemed a part of natural aging; very few instances of stem bending were observed; and the first stem deaths occurred on VL day 6 and the last on vase day 10, with an average VL of 8.5 days (Figure 41). Although further post-harvest work is ideally needed, at the present time it seems zinnias have an acceptable VL, and with

the colour range available their presence in a bouquet should ensure they are of interest to retailers.

Figure 41. Zinnia stems from 2016 VL testing on vase-day 10, following post-harvest treatment with (left) ‘CVBN’ or (right) ‘Professional 2 T-bag’

Discussion

Aims

An important aim of the Cut Flower Centre project (PC/BOF 002a) is to encourage growers in the UK to think about producing new and/or alternative cut flowers currently imported or unavailable here. The advantages of this would include import-substitution, fresher flowers for UK customers, and enhanced sales for the small UK outdoor cut flower sector. The emphasis is on species that could be grown in the UK relatively cheaply, either outdoors or in 'Spanish'-type tunnels. As explained in the introduction section, the terms 'novel' or 'alternative' crops are interpreted very broadly – they could include species new to production horticulture, those with which UK growers are currently unfamiliar, or those for which a better understanding of husbandry is required to achieve commercial success. The project includes foliage and fillers as well as cut flowers *per se*.

A review of the global cut flower trade, carried out as part of this project, showed that production horticulture businesses across western Europe and North America are seeking novel cut flower crops to develop as production of the traditional mass-market species – rose, carnation, chrysanthemum and lily – is taken up by emerging producers in Africa and Central and South America. Business will become even more competitive for UK cut flower growers, who nevertheless have the considerable advantage of expertise in dealing with supermarkets and demanding requirements – amongst European countries the UK sees by far the greater proportion of its cut flowers sold through supermarkets rather than smaller, more traditional outlets.

Crop introduction (1) Crops first trialled in 2016

Each year, several new crops are added to the trials programme. Included in trials for the first time in 2016, **craspedia**, **gomphrena**, **ornamental grasses** and **scabious** attracted particular attention. On the other hand **cleome**, **eremurus** and **ornamental solanums** appeared, at present, unsuitable for introduction to the UK as commercial cut flowers, or required further investigation before a decision could be made.

With its slender, unbranched stems and ball-shaped clusters of yellow flowers, **craspedia** (*Craspedia globosa*) is an example of a cut flower grown abroad but unfamiliar in the UK. Plots of 'Ellisse' and 'Paintball Globe' were grown and gave large flushes of very strong, tall flowers with an acceptable VL. Craspedia is an unusual product considered to have good potential for sales as fresh or dried flowers and as a

filler in bouquets. Two disadvantages are the high labour inputs needed to pick the crop (i.e. disentangling stems without causing damage, so growing a more uniform crop is desirable) and the single (yellow) colour range. Another cultivar, 'Sun Ball', was weaker, with smaller flower-heads and shorter, kinked stems, and it will be grown-on to check its ability to overwinter. Further cultivars and growing systems should be evaluated.

Cut flower **gomphrena** (*Gomphrena globosa* and other species) are produced abroad but like craspedia are largely unfamiliar to UK customers. Bearing pink, purple, red or white solitary flower spikes at the stem tips, gomphrena can be used fresh cut or dried. Demonstration plots initially produced plants with very short stems, looking unsuitable for use as a cut flower, but after a few weeks much longer stems were produced, and very prolifically. In post-harvest testing the stems remained in acceptable condition on vase-day 7. The soft foliage might hinder its handling in a commercial situation, though once-over harvesting would compensate for it. Gomphrena has potential as a filler, and further trials are proposed for 2017, with a view to forming an economic assessment. Both gomphrena and craspedia were well received by the industry and should be promoted to UK growers.

Interest has recently increased in growing various **ornamental grasses** as bouquet fillers, and, of all crops grown at the Centre in 2016, the ornamental grasses attracted most attention. The plants were *Bromus macrostachys*, *B. secalinus*, *Eragrostis elegans*, *Panicum elegans* 'Sprinkles', *P. miliaceum violaceum*, *Setaria italica* 'Mix', *Setaria pumila glauca*, *Sorghum nigrum*, *Stipa capillata* 'Lace Veil' and *Uniola paniculata* (sea oats). They produced flower-heads in a great variety of sizes and forms, with *Panicum elegans* 'Sprinkles' and *Stipa capillata* 'Lace Veil' particularly, receiving positive comments. The grasses were grown in a tunnel and outdoors: in the tunnel all species made vigorous growth, but outdoors a frost after planting and wet weather later gave rise to poor crops. *Bromus secalinus* was seriously attacked by powdery mildew in both plantings. In post-harvest testing all samples examined remained in an acceptable condition by vase-day 7. The prospect for UK production of ornamental grasses is, therefore, encouraging. In 2017 further trials are planned and should include further species (including common cereals) and sequential plantings.

Although familiar in the UK as a garden plant, **scabious** (*Scabiosa caucasica* and other species) is not known here as a cut flower. Already successful in cut flower trials in the USA, the advent of a new series of cut flower scabious prompted its inclusion in trials. The 'Scoop' cultivars were found to grow vigorously after pinching, flowering in

a tunnel starting in week 26 and continuing to October (when the trial was terminated for the removal of the polythene cover for winter). Cultivars were available in a wide variety of colours (black, lavender, mauve, pink and red) and were prolific, with a good percentage of stems >45cm in length. In post-harvest testing stems remained in an acceptable condition by vase-day 7, and were robust, easy to handle and did not appear to have complicated post-harvest requirements. The outdoor plantings also cropped heavily, and surprisingly so, considering the frost, water-logging and high temperatures which occurred through the 2016 growing season. Further trials are proposed to assess cultivar differences (e.g. for productivity, stem length and VL), improve stem length (e.g. by manipulating planting density), and make a further assessment of the value of outdoor plots. The initial plantings were left down to see if the cultivars are hardy under UK conditions. Cut flower scabious have good potential for use by retailers in mixed bouquets, and should now be promoted to the UK industry. As in many other cases, the economics of the crop needs to be assessed, especially in relation to the relatively high cost of planting material and the anticipated disappointing returns from supermarkets.

Cleome (*Cleome hassleriana*) has very attractive and distinctive flowers with an adequate VL, but is probably not appropriate for mainstream cut flower producers because its spines and aroma make it difficult or unpleasant to handle and unsuitable for supermarket sales. Stems may, however, be suitable for supplying to florists for use in specialised situations where the flowers will not be handled by customers.

Eremurus (*Eremurus stenophyllus* and other species) is a rhizomatous plant producing basal, linear leaves and tall, upright stalks with dense racemes of pink, orange, yellow or white flowers that look impressive in a vase. Three cultivars were trialled in 2016 but the flower yield was low and all plants showed substantial leaf senescence from the tip throughout the season. The plants were left *in situ* and will be assessed in 2017 before a decision is made.

Ornamental solanums, such as ‘pumpkin-on-a-stick’, a variety of *Solanum aethiopicum*, were successful in USA trials with their bright red ‘pumpkins’ (that actually resemble small tomatoes) and so were tested on site in 2016. ‘Pumpkin-on-a-stick’ was an incredibly vigorous plant that started flowered in July, with fruits seen developing soon after. However, the plants have vicious spines on both the stems and leaves, which are usually removed prior to marketing when grown in the USA, which adds costs and probably makes it a specialty crop rather than a mainstream one. The labour involved in harvesting ‘pumpkin-on-a-stick’ and removing the leaves and spines

means the product would only be considered by specialists, perhaps artisan growers, who could sell them at a premium price. The UK industry did not appear to be enthusiastic about them.

Crop introduction (2) crops with trials on-going

Trials on some other new crops were started in previous years and were still ongoing in 2016. Amongst these, **caryopteris**, **delphinium**, **seed-raised fillers**, **trachelium**, **veronica**, and **zinnia** attracted particular attention. However, **basil** appeared unsuitable for use as a cut-flower because of its short VL, while **gypsophila** and **solidago** required further trialling before a decision could be made.

Caryopteris (blue spiraea; *Caryopteris clandonensis*) is a popular garden shrub also used as a cut flower. It had been included in CFC trials in 2008, but concerns were expressed then about the smell sometimes associated with the crop. In 2016 a new series of caryopteris bred specifically for cut flower production – the 'Pagoda' series - became available. 'Pagoda Blush', 'Pagoda Lagoon' and 'Pagoda Ocean' were trialled. 'Pagoda Lagoon' in particular showed real promise because of its rich colour. The issue of the smell of the crop was not apparent. The crop has been left *in situ* and its performance will be assessed in 2017.

Over the course of the CFC project, **delphinium** (*Delphinium elatum*) cultivars have been trialled extensively, with growers and others divided whether further trials were needed. Since the advent of new or improved cultivars might affect these discussions, the emphasis of the trials has been on the demonstration of recent introductions. 'Sea Waltz', 'Sky Waltz' and 'Tango Dark Blue' were trialled in 2014–2015, and they produced attractive flower spikes and, in the second year, dense growth and productive flushes in mid- to late-June and mid- to late-August. Another new series, 'Trick', became available in 2016 and three examples ('Trick Lilac', 'Trick Pink' and 'Trick Yellow') were trialled. They produced a good flush of flowers in mid- to late-July and a second heavy flush in early-September; the flowers were elegant, upright and well-liked by growers, and in post-harvest testing all stems lasted at least 7 days. They were considered to have good potential in the UK as straight bunches or for use in bouquets. However, the colour range of the series is limited at present, so there is scope for further cultivar selection and post-harvest work. The 'virus-like' symptoms that occurred early in the season also need to be investigated. Since the planting material is *ex* tissue culture and therefore relatively expensive, it is not known at present whether it would command a sufficiently high return to cover costs; if not, 'Trick'

may be a niche crop for the artisan grower.

Recent years have seen great interest in producing cheap **seed-raised fillers** in tunnels or outdoors. In 2014–2015 the results of CFC trials with *Ammi majus, Ammi visnaga*, *Anethum graveolens*, *Anthriscus sylvestris*, *Bupleurum rotundiflorum*, *Euphorbia oblongata* and *Ridolfia segetum* were generally positive, showing that a range of attractive flower heads could be produced. A general problem in direct-drilling was poor or slow germination, leading to difficulties in establishing the desired plant spacings and hence the desired plant height and stem strength. Growth in tunnels was often over-vigorous, while outdoor crops were subject to the effects of inclement weather. With better seed germination and understanding of their husbandry, it seems likely that any of these species could be grown successfully. This work was followed in 2016 by trialling a range of *Ammi majus* and *A. visnaga* cultivars, as well as the ornamental carrot *Daucus carota* 'Dara'. The attractive flower heads of the ornamental carrot generated considerable interest among growers. Subjects being considered for trials in 2017 include other cultivars of ornamental carrot and *Orlaya grandiflora* (white lace flower) in order to fulfil the request from packers for seed-raised fillers.

Trachelium (*Trachelium caeruleum*) is not currently grown in the UK, but substantial trials showed it can be grown to a high standard and is very well liked. Cultivars from the 'Lake Forrest' and 'Lake Michigan' series have been used mostly. Often initial growth appeared weak, but stems lengthened and strengthened as the plants matured, each plant produced at least one heavy lead stem and a number of marketable side-shoots. In 2015 and 2016 production was compared between non-pinched plants (grown at a density of 64/m^2) and plants pinched two weeks after transplanting (grown at 25/m^2). In 2016 the pinched plants gave an average of just over 5 stems per plant, while single-stemmed plants gave about 3.5 stems per plant. Non-pinched plants gave taller stems than pinched ones, but there were no statistically significant effects on trimmed stem weight. There appears to be good potential for growing tunnel-raised trachelium in the UK. In the past they have had a poor reputation because of petal browning and the low weight of imported stems: the UK product seemed much better – greener, taller and heavier. At present, the high cost of plants is one of the factors deterring growers from trying trachelium, but it may be possible to reduce costs by manipulating the number of marketable stems produced by pinching, varying planting density and testing other cultivars.

Cultivars of *Veronica longifolia* are suitable for cut flower production as they are tall and have a good range of colours, including blues. **Veronica** had previously been

trialled in 2008, when it was concluded they were unlikely to be suitable in the UK because of their small production window. Following revived interest, three cultivars of the 'Skylark' series were trialled in 2016. They produced a good crop of flowers in August and were prolific, with straight stems and well coloured spikes. Veronica showed real potential as a UK cut-flower and a further trial is proposed for 2017 to investigate the continuity that can be achieved by combining overwintered crops with new plantings.

Several years of trials of **zinnia** (*Zinnia elegans*) demonstrated that the 'Benary Giant' series in particular, but also the 'Oklahoma' series, were superior to other cultivars trialled because of their overall vigour, attractive flowers in a wide range of colours, and long stems. However the VL of zinnia has caused concern since the hollow stems often appear to lead to the stem bending just below the flower. In post-harvest tests the 5-day guaranteed VL was usually attained, though subsequently stems failed rapidly due to bending stems, botrytis in the buds and a discolouration of the petal-edge. It was noted that stems harvested at an early stage, with apparently weak necks, appeared to become firmer, rather than bending as expected: it was suggested that neck bending may occur only when stems are picked at an over-mature stage, and that otherwise the developmental stage at picking is of little importance. Some differences in performance between cultivars were noted, with mean VL between 6 and 10 days. In the latest trial, in 2016, petal browning did not arise until later in VL, seeming to be a part of natural aging. Although further post-harvest work is ideally needed, at the present time it seems that zinnias do have an acceptable VL, and with the colour range available their presence in a bouquet should ensure they are of interest to retailers.

Interest in growing **basil** (*Ocimum basilicum*) as a fragrant filler for mixed bunches and bouquets led to trials in 2014, when 'Dark Red Opal', 'Floral Spires Lavender', 'Floral Spires White' and 'Sweet Dani Lemon' were grown as demonstration plots. They grew well and some had attractive foliage with potential for the suggested use, but their VL was poor (<5 days). Further trials were carried out in 2016 with 'Aromato' and 'Cardinal', recommended cultivars from ASCFG trials: they grew well and produced good stems, but tests showed they failed to take up water and had poor VL. No further work on basil is therefore planned.

Some new **gypsophila** (*Gypsophila paniculata*) cultivars have been trialled previously, with disappointing results, and a new range was trialled in 2016 ('Andromeda', 'Beauty Bride', 'Dynamic Love', 'My Pink', 'Orstar', 'Paniculata', 'White Victoria' and 'Xlence').

All varieties produced some marketable stems in 2016 but should to be assessed in 2017, once established.

Solidago (*Solidago media*) is another previously-studied subject that was re-examined in 2016 with new cultivars ('Golden Glory', 'Moonlight' and 'Solar Glory'). The plots produced a heavy crop of high quality stems in mid- to late-August and were left *in situ* for their potential to be assessed in 2017.

Crop improvement

This section covers cut flowers that are already established in the UK but which could provide further opportunities, either by using new or different cultivars or by improved husbandry. Thus growing older cultivars of **alstroemeria** in tunnels has been shown to provide an alternative, cheaper crop than the usual modern cultivars grown under glass, while new cultivars of **china aster**, **column stocks** and **ornamental brassica**, could provide further opportunities. Similarly, **lily** production would benefit by the development and testing of reduced-peat or peat-free growing media, while many cut flower crops would benefit from the development of more effective **herbicide programmes** or the testing of alternatives to replace withdrawn products.

The **alstroemeria** trial showed that a familiar crop can sometimes be grown in a new way: production costs were reduced by using older cultivars (free of PBR) along with production in tunnels rather than under glass. Over a three-year trial the quality of tunnel-grown alstroemeria was highly rated by the industry, while the average VL was about 12 days, even when cut with the flowers showing good colour and therefore looking more attractive at the point of sale. The tunnel-grown crops produced about twice the yield of outdoor beds in 2014 and about three-times the yield in 2015, falling back to less than double in 2016. The overall yields of individual cultivars varied markedly; the productivity of half of the cultivars increased annually, while most of the rest peaked in the second year. With a combination of twelve cultivars in tunnel and outdoor plots the flower supply was reasonably consistent over a five month period but still a little patchy, illustrating the typical cycling that occurs in alstroemeria flower production. The consistency of supply might be improved by growing new plantings alongside older ones, or by making a small number of sequential plantings. Growing non-PBR cultivars in tunnels appeared to have strong potential for the UK, but as usual the economics of the operation will be the key to success. To gain acceptance of the crop there would be disincentives to overcome: the labour-intensive and long-term nature of the crop, and the long-term agreements of UK supermarkets with overseas

growers. Despite the poorer yields obtained outdoors, growing alstroemeria in the open may still have a place for small growers.

Ornamental brassica are an established UK crop, but several questions remain and they have been the subject of a number of CFC trials. These have concentrated on growing a selection of newer cultivars in tunnels alongside cultivars of the familiar 'Crane' series. Most cultivars trialled produced heads of high quality, though 'Kysia' failed to colour-up in both 2015 and 2016, and yields of cultivars with dissected leaves tended to be lower than those of standard cultivars grown at the same spacing. The uncertainties of growing ornamental brassicas in the UK seem to mean that growers are unwilling to take on alternative cultivars at this time – they would need to show clear economic advantage over the established 'Crane' cultivars. Post-harvest studies have given rather variable results with ornamental brassicas, with VL of 10–17 days in testing in 2015, but only a barely acceptable 5–6 days in 2016. From small-scale testing, there were no clear varietal differences in VL, and no obvious benefits of either using different post-harvest treatments or of re-cutting or not re-cutting stems when moving into vases. It has been suggested that VL may be adversely affected by longer holding periods prior to picking and sale (cropping may sometimes be delayed depending on the state of the market at the time). If the popularity of the product is to be maintained, evidently substantially more needs to be done to achieve a satisfactory VL and maintain the vase-water in good condition. Ornamental brassica can be grown outdoors, in tunnels or under glass: growing in the field has the advantage of reducing costs, since direct-drilling and regular herbicide applications can be used, but it cannot be relied upon to produce high quality stems beyond early-October as the weather deteriorates. The protected environment of tunnel-growing gives greater flexibility over picking dates, while growing in glasshouses ensures the possibility of later crops (which attract higher prices), though the heads will deteriorate slowly if picking is delayed too long. Planting density is another important factor, because only high planting rates (64/m^2) combined with a high percentage of marketable heads are likely to provide sufficient income to make the crop profitable. More economic data are needed before a decision on the profitability of ornamental brassicas can be made. A coordinated, industry-led project, similar to the column stock project PO005 in 2011, could well help to provide answers to questions of marketable percentage, length of holding periods, head colouring and VL.

In the last decade, **china aster** (*Callistephus chinensis*) have become an important seasonal outdoor summer cut flower in the UK, dominated by the 'Matsumoto' spray

type. Two new series of large-headed china asters with vibrantly coloured blooms, the 'Gala' and 'Krallen' series, became available in 2007 and demonstrations were planted at CFC, generating real interest from growers with the potential for commercialising them in the UK. Initially very promising, post-harvest quality became an issue when petal-spotting and browning of the flower tip became apparent, the cause of which has remained unknown despite testing. Growers were therefore interested in developing alternative cultivars, and several trials followed. Cultivars of a range of large headed and spray type varieties ie 'Beautiful Day', 'Benary Princess', 'Bonita', 'Harlequin', 'Jewel', 'Lady Coral', 'Matador' 'Meteor', 'Ribbon' and 'Standby' series were trialled over 2010–2013. Although many of these were successful, none was considered a replacement for 'Krallen'. Considering another alternative type, 2016 saw a demonstration of a series of spray-asters, 'Julie': although no formal assessments were made, samples were well regarded, and it is known that two local growers intend to make commercial plantings in 2017.

Column stocks (*Matthiola incana*) are a mainstay of UK protected cut flower production, so it is appropriate they have been the subject of several crop improvement trials in tunnels. The trials centred on cultivar demonstrations and the effects of steaming. Additional AHDB funded trials have also investigated the issues of *Fusarium oxysporum* in column stocks. In 2012, cultivars from standard and new series were grown in steamed and non-steamed soil in tunnels, with a strongly beneficial effect of steaming on stem weight. Due to interest in the 'Katz' series as a summer or late crop, several varieties were trialled in 2013, and although stem strength was poorer than before, possibly due to hot weather, their quality was superior to that of a comparable crop, showing the benefit of growing in tunnels under some conditions. In 2016, a new demonstration of column stocks was set up to show the commercial varieties currently available from the only two suppliers to the UK (subsequently reduced to one) and the effects of steam-sterilisation. As with the case with late-planted commercial crops this year, due to high summer temperatures, the trial suffered from uneven flowering, with the 'Milla' cultivars being the most seriously affected. Performance in the non-steamed soil was poorer than in the steamed area, but it was less marked than had been seen in previous trials. In conjunction with Warwick University who are leading on a cross sector *Fusarium* project, it is proposed to infect the CFC Haygrove tunnel with laboratory cultured *Fusarium* (originally isolated from commercial column stock crops) and use this as a permanent facility for future trial work on this very important disease.

Crate-grown **lilies** (*Lilium* cultivars) remain an important cut flower in the UK. They used to be routinely grown in heavily peat-based media, but since the 1980s substitutes or diluents for peat have been evaluated as growing media. More recently green-waste/green-compost products and anaerobic digestate (AD) have become available, and were evaluated in by the CFC in 2014 and 2015. Results with green-waste-derived materials varied, probably reflecting the varied origins and nutrient contents of the different products. In the best case, lily growth and cut flower quality in a 100% green-compost was as good as in a grower's peat-based medium, while with other materials growing in a 50:50 (v/v) mix of grower's peat-based medium and green-waste resulted in stems up to 10% shorter than in grower's peat-based medium alone or, in another case, marketable yield was reduced through chlorotic foliage and stunting. Growing in grower's peat-based medium + AD mixtures, led to varied results depending upon the source or prior treatment of the AD, but in the best case growing in grower's peat-based medium + AD mixes containing 40 or 60% AD produced high-quality and heavier stems. In other treatments, lily quality was similar to that obtained in grower's peat-based medium when grown in a wood-derived commercial potting medium, in coir and in a 50:50 grower's peat-based medium + coir mix, but growing in a coir + AD (67:33) mix resulted in chlorotic, mottled foliage. In 2016, lilies were assessed growing in peat + wood fibre mixtures, peat + cocopeat mixtures, coir and grower's peat-based medium, The lilies grown in 100% coir were stunted, but otherwise there were no indications of visual differences between plants in any treatment and all treatments were picked within a few days. The results suggested that all trial mixes were worthy of further investigation as growing media for lilies in crates, but particularly the peat + cocopeat mixes which had no adverse effects on lily growth, appearance and cropping, with the potential to reduce peat usage by at least 30%. The trials showed there is clearly scope for lily growing media based on these materials.

The loss of key active ingredients in **herbicides**, such as chlorthal-dimethyl, propachlor and oxadiazon continues to be a major concern for growers of outdoor cut flowers. A number of herbicide trials have been carried out at the CFC, covering drilled and transplanted china asters and drilled larkspur, sweet william and wallflowers. In 2016, further trials were carried out on transplanted china aster and drilled sweet william. Some alternative herbicide programmes have been suggested, but it is likely that this work will need to be continued.

Knowledge and technology transfer

Events

There was a National Cut Flower Centre Open Day on 10 August 2016, which featured the experimental deep pool hydroponics facility at J.A. Collison and Sons (Walpole St Andrew PE14 7LX), the new vase-life test facility at the National Centre for Food Manufacturing, University of Lincoln (Holbeach PE12 7PT) and the trials at the National Cut Flower Centre (Holbeach St Johns PE12 8SG). Handouts are available from http://www.thecutflowercentre.co.uk/ or from AHDB Horticulture.

Website

The Centre's website was kept updated during 2016. Annual project reports and the specialist reviews and leaflets cited in this section are available for downloading from the website, along with relevant EAMUs and Centre news.

Articles published

These articles on or relating to the Centre's work were published during 2016:

- Anon. (2016). Herbicides: the search continues. *Ornamentals Review 2015-16* (*AHDB Grower* supplement), p.10
- Anon. (2016). Cut flowers trialled on water. *Ornamentals Review 2015-16* (*AHDB Grower* supplement), p.22
- Anon. (2016). Interest sparked in new flower lines. *Ornamentals Review 2015-16* (*AHDB Grower* supplement), p.23
- Anon. (2016). Cut flower trials highlight potential new lines. *AHDB Grower*, no. 220, p.11
- Atwood, J, Whiteside, C & Worrall, E (2016). A head start for flowers. *AHDB Grower*, no. 221, p.20-22
- Mason, L (2016). A testing summer. *AHDB Grower*, no. 224, p. 16-18
- Shaddick, C (2016). All the way from nursery to vase. *AHDB Grower*, no.226, p.19-21
- Sherer, B (2016) Growers successfully challenge Dutch cut flower growers. *Commercial Greenhouse Grower*, December 2016, p 13-15

Reports and databases

- Cut flower seed and young plant suppliers' directory. Revised June 2015. Compiled by Gordon Hanks.
- Field- and tunnel-grown cut flowers with potential for UK exploitation: A review of trials programmes and research on 'novel subjects. Revised September 2015. Compiled by Gordon Hanks.
- A review of production statistics for the cut flower and foliage sector. 2015. Compiled by Gordon Hanks.

Leaflets

- Delphinium as a cut flower grown in tunnels. Information Sheet, National Cut Flower Centre/AHDB Horticulture. Gordon Hanks and CFC MG (2016)
- Woody foliage production. Information Sheet, National Cut Flower Centre/AHDB Horticulture. Gordon Hanks and CFC MG (2016)

Other examples of technology and knowledge transfer

The work of the Centre includes a number of aspects of obvious value, but difficult to quantify. For example, many samples of cut flowers are made available from the trial plots for supply to packers and retailers as examples of the quality and variety of cut flowers that can be grown in the UK. There is little doubt that this process stimulates ideas and a demand and desire for novel UK-grown produce alongside established products.

The major example of the KT from the project, however, is the take-up on a commercial scale of the following new crops following trials by the CFC:

- Antirrhinum
- Bupleurum
- Hypericum
- Lisianthus
- Salix
- Sedum
- Symphoricarpos
- Trachelium
- and on a smaller scale of:
- Alstroemeria (seasonal)

- Annual dianthus
- Aster ericoides
- Carnation ‘Solomio’
- Dahlia ‘Karma’
- Phlox
- Scented pinks
- Zinnia

Reasons of commercial confidentiality will routinely prevent full disclosure of the financial benefits resulting from the project.

Acknowledgements

Special thanks go to David and Elaine Robinson (R Robinson & Son) and their team, who have been amazing hosts to the Centre at Rookery Farm. Special thanks to Tabitha Irvine and Verban Toromanov who manage the trials and recording on a daily basis, and to Ludmila ('Lucy') Markova who did so in earlier years.

We thank all members of the MG for the time they have dedicated to the project: Philip Collison (JA Collison & Sons) (chair), Sue Lamb (Lambs Flowers), Mark Eves (PS & JE Ward), Gordon Flint (New Horizon Flowers), Graham Whitehead (Whiteheads of Boston), Emma Coupe (Waitrose), Jane Stanbury (Asda), Tracey Thomas (Butters Flowers), Jayne Winter (JZ Flowers), Wayne Brough (AHDB Horticulture), Debbie Wilson (AHDB Horticulture) and Gordon Hanks (independent consultant).

We thank all those who have provided plants and seeds: Armada Young Plants, Ball Colegrave, Bartels Stek, Benary, Noordam Plants, Florensis, HilvedaKooij, Kolster and Sakata. Thanks are due to those who provided specialist advice or carried out trials and VL testing: Philip Collison (JA Collison & Sons), Claire Streit (Chrysal UK), Jayne Winter (SuperFlora UK), James Cole (EM Cole Farms Ltd), Stephen Munson (Smith and Munson Ltd.), Dick Evenden (consultant) and Dr Martin McPherson (STC).

Particular thanks are due to Sue Lamb for her vigorous promotion of the Centre and especially her work in ensuring a large number of cut flower samples have been made available to the trade.

Annex 1: Index to crops in CFC reports

The white squares with years indicate when the species was included in trials

	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
GENERAL TOPICS (various species)											
Anaerobic digestate, green-waste, peat alternatives, etc.							‘13			‘16	
Herbicides								‘14	‘15	‘16	
Spectral filters							‘13				
ALPHABETICAL INDEX											
Ageratum (Ageratum houstonianum)	‘07										
Alstroemeria (Alstromeria cultivars)								‘14	‘15	‘16	
Amaranthus (Amaranthus caudatus)		‘08			‘11	‘12					
Ammi (Ammi spp.)								‘14	‘15	‘16	
Anethium (Anethium graveolens)								‘14	‘15		
Anthriscus (Anthriscus sylvestris)								‘14	‘15		
Antirrhinum (Antirrhinum majus)		‘08	‘09	‘10	‘11	‘12					
Aster (Aster pringlei)		‘08									
Aster, September-flowering (Aster ericoides)	‘07			‘10	‘11	‘12	‘13	‘14	‘15		
Basil (Ocimum basilicum)							‘13			‘16	
Brassica, ornamental (Brassica oleracea)		‘08	‘09	‘10	‘11	‘12			‘15	‘16	
Bupleurum (Bupleurum rotundifolia)								‘14	‘15		
Campanula (Campanula spp.)						‘12					
Capsicum SEE Pepper, ornamental											
Carnation and pinks (all types) (Dianthus spp.)	’07	‘08	’09			‘12	‘13	‘14	‘15		
Carrot, ornamental (Daucus carota)										‘16	
Carthamus (Carthamus tinctorius)								‘14	‘15		
Caryopteris (Caryopteris x clandonensis)		‘08								‘16	
Celosia (Celosia cristata)						‘12					

	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Chasmanthium spp. SEE Grasses, Ornamental											
China aster (Callistephus chinensis)	’07	‘08	‘09	‘10	‘11	‘12	‘13			‘16	
Clarkia grandiflora SEE Godetia											
Cleome hassleriana										‘16	
Column stocks SEE Stocks, column											
Consolida ajacis SEE Larkspur											
Cosmos (Cosmos bipinnatus)							‘13	‘14	‘15		
Craspedia globosa										‘16	
Cynara (Cynara cardunculatus)	‘07	‘08									
Dahlia (Dahlia hortensis)			‘09	‘10		‘12	‘13				
Delphinium (Delphinium elatum)	‘07	‘08				‘12		‘14	‘15	‘16	
Delphinium consolida SEE Larkspur											
Dianthus, annual SEE Carnations and pinks (all types)											
Dianthus barbatus SEE Carnations and pinks (all types)											
Dianthus caryophyllus SEE Carnations and pinks (all types)											
Dill SEE Anethium											
Echinops (Echinops spp.)	‘07	‘08									
Eremurus stenophyllus										‘16	
Eryngium (Eryngium spp.)	‘07	‘08			‘11	‘12	‘13	‘14	‘15		
Euphorbia (Euphorbia oblongata)								‘14	‘15		
Eustoma SEE Lisianthus											
Fillers, seed-raised SEE under individual species											
Foliage SEE Hardy foliage											
‘German’ asters SEE China aster											
Godetia (Godetia grandiflora)	‘07	‘08									

	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Gomphrena globosa, G. haageana										‘16	
Grasses, ornamental (various species)	‘07	‘08								‘16	
Gypsophila (Gypsophila paniculata)								‘14		‘16	
Hardy foliage (various species)				‘10	‘11	‘12	‘13	‘14			
Heath aster SEE Aster, September-flowering											
Helianthus annuus SEE Sunflower											
Larkspur (Consolida ajacis)	‘07	‘08									
Lathryus odoratus SEE Sweet pea											
Leonotis SEE Lion’s ear											
Leucanthemum (Leucanthemum x superbum)								‘14	‘15		
Lion’s ear (Leonotis leonurus)							‘13	‘14			
Lily (Lilium hybrids)							‘13	‘14	‘15	‘16	
Lisianthus (Eustoma grandiflorum)				‘10	‘11	‘12					
Love-lies-bleeding SEE Amaranthus											
Lupin (Lupinus hybrids)							‘13	‘14			
Lupinus SEE Lupin											
Lychnis (Lychnis chalcedonica)		‘08									
Matthiola incana SEE Stocks, column											
Miscanthus SEE Grasses, ornamental											
‘Monte Cassino' aster SEE Aster (Aster pringlei)											
Ocimum SEE Basil											
Ornamental brassica, cabbage SEE Brassicas, ornamental											
Ornamental grasses SEE Grasses, ornamental											
Panicum spp. SEE Grasses, ornamental											
Pepper, ornamental (Capsicum annuum)								‘14			

	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Phlox (Phlox paniculata)	‘07	‘08	‘09	‘10	‘11	‘12					
Physostegia (Physostegia virginianum)								‘14			
Pinks SEE Carnations and pinks (all types)											
Ridolfia (Ridolfia segetum)								‘14	‘15		
Rudbeckia (Rudbeckia hirta)					‘11	‘12	‘13				
Scabious (Scabiosa caucasica, S. atropurpurea)										‘16	
Sedum (Sedum spp.)		‘08	‘09	‘10	‘11	‘12	‘13	‘14			
Setaria italica SEE Grasses, ornamental											
Snapdragons SEE Antirrhinum											
Solanum, ornamental (Solanum aethiopicum)										‘16	
Solidago (Solidago media)		‘08								‘16	
Spray carnation SEE Carnations and pinks (all types)											
Stock, column (Matthiola incana)			‘09		‘11	‘12	‘13	‘14		‘16	
Sunflower (Helianthus annuus)				‘10	‘11	‘12	‘13	‘14			
Sweet pea (Lathyrus odoratus)					‘11	‘12					
Trachelium (Trachelium caerulum)							‘13	‘14	‘15	‘16	
‘Trumpet' antirrhinums SEE Antirrhinums											
Veronica (Veronica spp.)	‘07									‘16	
Zinnia (Zinnia elegans)	‘07	‘08					‘13	‘14	‘15	‘16	

Annex 2: Survey of the extent and causes of petal spotting in UK cut sunflower crops

Rational for the project

Sunflowers have been produced as cut flowers on a commercial scale in the UK for over 20 years. In 2015 the area of production was estimated to be around 400 ha with a farm gate value in excess of £3 million. The bulk of flowers are sold via the UK supermarkets.

As would be expected, sunflowers are very prone to adverse weather conditions especially rain and high humidity. Such weather can lead to direct damage while the crop is still in the field, or of more economic importance, problems can show up afterwards in the supply chain - during cold storage, at the packhouse or even in the supermarket itself. Symptoms usually take the form of petal spotting or blemishing which often turn brown and necrotic making the flower totally unmarketable. Obviously once the stem has been harvested, packed, sleeved and delivered to the supermarket, all of the costs have been incurred making this the worse-case scenario for all concerned.

Over the years, businesses appear to have accepted the possibility that they will potentially incur large losses with this crop, but the owner of a large business, who is also packing a large amount of local sunflowers, has recently questioned if we really understand this issue and have adequately investigated its cause and possible mitigation actions. It has been assumed that the problem is caused by the germination of botrytis spores (much like ghost spotting in tomato fruit) but this has not been proven conclusively via reliable laboratory tests and there is the possibility of *Itersonilia perplexans* (petal blight of sunflower) being involved. At the current time there is much anecdotal evidence about the issue, but there are conflicting reports as to what stages in the supply chain cut flowers are the most vulnerable, if there are varietal differences, the actual level of losses incurred etc. There is also very little knowledge of the success of current mitigating activities such as fungicide applications and dehumidifiers in the cold store. Hence, as with the quality problems in column stocks a few years ago, there is a need to undertake a survey of the industry in order to determine the underlying facts.

Methodology

This survey was undertaken during the 2016 sunflower production season with most of the petal spotting problems being seen in September. However, a combination of severe levels of spotting towards the end of September and mild weather bringing the crop forward meant that the sunflower season ended in early October which was two to three weeks earlier than normal.

Four of the main sunflower producing businesses were visited, some on numerous occasions, regular visits were also undertaken to packers using UK sunflowers and to local supermarkets stocking sunflowers. All aspects of production and marketing were discussed with the key individuals in the business in an attempt to find both common issues as well as explore the mitigation measures undertaken. Tiny Tag monitors were

also placed in the cold stores of one of the large businesses to monitor both humidity and temperature. Samples of blooms showing the petal spotting symptoms were also sent to STC in order to test for a pathogenic cause of the problem.

Survey of businesses

Business 1

Large business supplying most UK packers.

The business cuts the crop quite tight in the field then brings the stems back to the yard to be put into buckets and then into crates. The crates were not cleaned out and in many cases had detritus in the bottom of the crates which varied from fresh green leaves to black and slimy decaying organic matter (most of this organic material originated from the various packhouses that the business supplies). The buckets were filled from a large hose which in most cases spilled water over the bucket edge and into the base of the crate meaning that in many cases water was dripping from crate to crate when they were stacked. Logic would therefore dictate that the boxes at the top of the stack in the cold store would suffer less spotting issues (if the issue was related to humidity). However, this was not actually the case and could perhaps be explained by the low humidity in the store generally, as outlined in the next paragraph.

The crate were then stored in a modern, very efficient cold storage unit. This cold storage unit was monitored using TinyTag monitors which recorded humidity and temperature. The results showed that humidity was maintained at close to zero while the temperature was kept within half a degree of the set point. The very low humidity was a surprise to all and as such the monitoring process was repeated and showed very similar results. It had been previously assumed that the store humidity had been contributing to the flower spotting issues but these results seem to negate that theory. It would have been useful to place the monitors in the older, less efficient stores of business 2 but time did not allow for this in 2016 so this will be undertaken in 2017.

Business 2

Large business supplying mainly one local packer.

The business cuts the crop tight and places the stems directly into buckets in the field, if the crop is wet it is dried in a glasshouse with fans before being placed into cold store. As required, stems are brought out of the cold store and again put into glasshouse to open them before being put back into the cold store prior to packing for the end customer. The cold stores used are old and probably inefficient.

This business has experimented with late sprays of fungicides prior to harvest but nothing seems to have made any difference to the levels of spotting which tend to run at 40 to 50% in September compared to 2 to 5% for the earlier cropping period.

Business 3

Medium sized business supplying mainly one packer.

The picking stage with this business was weather dependent, crops being picked tighter when the weather is wet. The flowers are cut directly into buckets in the field and then either packed immediately or stored in modern cold stores until required.

Business 4

Medium sized business supplying a wide range of packers.

The business cuts directly into buckets in the field and the cutting stage can be quite variable. The crop is then held in a number of variable age cold storage units until required by the customer. Over the years this business has probably done more than any other to try and solve the issue of petal spotting but with limited success. Examples of mitigating actions include: running dehumidifiers in the cold stores, packing into cardboard boxes (the theory being that the cardboard will absorb moisture) and the late application of fungicides to the crop. While some of these actions appear to have had a small degree of success, none could be either maintained or reliably replicated.

Survey of supermarkets

The author and growers and technologists with an interest in the project regularly visited supermarkets to assess the levels of flower spotting in store. It would be fair to say that no one particular retailer had more or less of a problem with petal spotting. However, one very interesting observation was that in late September it was hard to find any local supermarkets that did not have a serious petal spotting issues. An exception to this was a green centred sunflower sold in a bouquet by a retailer and this particular sunflower was showing no signs of spotting. It was thought that these were actually imported blooms, and this observation was borne out by sunflower blooms sold at other times in the UK out of season (e.g. Easter) which seldom showed signs of spotting. This is actually contra to what would be expected owing to imported blooms spending longer in transit before reaching the end customer. At the time of writing this report this anomaly cannot be explained and requires further investigation.

Laboratory samples

In previous years, samples of sunflower petals showing symptoms of spotting have been submitted to laboratories and botrytis has been consistently isolated from the lesions. However, discussions with Martin McPherson of STC raised the possibility of petal blight (*Itersonillia perplexans)* being implicated in the problem. But in order to potentially isolate this fungus from the petals it was necessary to set up a different laboratory test for the 2016 samples.

Three samples were sent to STC during September 2016 and of these, botrytis was isolated twice but the final sample also isolated *Itersonilia.* Unfortunately owing to the abrupt end to the season it was not possible to collect any further samples so this aspect of the survey needs to be continued into 2017.

Summary of the findings of the survey

- As a year on year average, businesses actually only market stems that equate to between 40 and 50% of the total number of seeds sown.
- There are a number of factors that contribute to these losses including: poor germination, pests such as crows and vermin, physical issues such as waterlogging and wind damage, crop destruction in times of glut and of course the petal spotting issue.
- No two businesses seem to use the same production and marketing system yet all have issues with flower spotting to some extent or another.
- All businesses seem to agree that the problem is worst later in the year, especially during September and onwards.
- Most businesses have tried to undertake some form of mitigating action at one stage or another and nothing has so far eliminated (or arguably even reduced) the levels of petal spotting experienced.
- Flowers left in the field in autumn that open naturally do not tend to show the same symptoms as those harvested tight and then sent through the supply chain.
- Flowers harvested direct from the field in mid-October and placed directly in the authors home did not show any signs of petal spotting at a time when most supermarkets had already cancelled the line owing to large losses as a result of the spotting issue.
- Neither the author nor any of the businesses monitoring product observed any issues with imported sunflowers even when British product was looking poor in store.
- Unfortunately, unlike the previous column stocks survey, at this stage it was not possible to identify any specific causes of the problem except that it is worse during back end of the season usually from September onwards.
- Owing to the season ending two to three weeks early in 2016, not all of the resource allocated to this project was used in 2016. Further work will therefore be undertaken in 2017.
- The 2017 work will include further discussions with key businesses, additional in store monitoring of temperature and humidity, further laboratory analysis of the lesions and an attempt to find out more about the supply chain of foreign cut sunflower product.

Photographic record

Product rejected and returned from the packer

Stems rejected at source by the business prior to packing

Example of the tight cropping stage of one business

Compared to the more open stage of another business

Example of the petal spotting on a bloom graded out prior to packing

Example of severe petal spotting seen in most supermarkets in September 2016