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Review

Overview of the Dynamic Role of Specialty Cut Flowers in the International Cut Flower Market

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Abstract: The global cut flower industry has faced serious challenges over the years, but still remains an important sector of agriculture. Floriculture businesses seek new, innovative trends and niches to help increase product sales. Specialty cut flower (SCF) production has increased in the past 20 years in the US, Australia, Africa, and Europe. SCF production and sales could increase further if these new products were supported by dynamic marketing campaigns that focus on their strengths compared to the traditional cut flowers (TCF) such as roses, carnations, gerberas, and chrysanthemums. The major strength of SCF is the eco-friendly profile, which is associated to low CO_2 footprints and environmental outputs. This contrasts TCF cultivation, which is associated to high energy inputs, especially at the traditional production centres (e.g., The Netherlands). It is suggested that environmental legislations, production costs, and customer demand for eco-friendly products will positively affect future SCF cultivation and sale.

Keywords: roses; gerberas; chrysanthemums; sustainability; floriculture; environmental impact; CO_2 footprint

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1. Introduction

Global cut flower production and consumption has overcome serious challenges in the past 20 years, especially those related to global economic recessions. The EU holds the first place in cut flower and ornamental potted plants sales with 31.0% of the global value, with China and the USA in second and third place, holding 18.6% and 12.5%, respectively [1]. Within the EU, in 2016, the Netherlands had the most sales of cut flowers and ornamental plants, with France and Italy in second and third places, respectively [1]. Cut flower and ornamental plant sales in the EU increased by 7% (approx. 1.4 billion euro) from 2006 to 2016, indicating a slow, but steady increase, despite the elaborate global economic status [1]. On the contrary, the number of cut flower producers in the USA declined significantly from 2007 to 2015 [2], with many of them forced out from the floriculture industry during the 2008–2009 recessionary shakeout period [3]. Cut flower production in the USA showed a modest increase from 2015 to 2018 [4,5]. The reductions recorded by the USDA between 2007 and 2015 reached 30%, indicating that cut flower production has shifted to new worldwide players such as China, Colombia, and Ecuador [6]. In 2017, China came first in sales of cut flowers and first in cut flower exports to the EU.

The aim of this review was to analyse the dynamic role of specialty cut flowers (SCF) in a market overwhelmed by traditional cut flowers (TCF) holding the majority of sales. A critical analysis provides evidence that SCFs might serve as the environmentally friendly alternatives to TCFs and claim future higher production volumes and market shares globally.

2. Exploitation of the Endemic Flora by the Floriculture Sector

New specialty ornamental crops and cut flowers are often introduced from the endemic flora. Native species leaving their natural environment may become global market trends. More than 6000 species native to Asia, Europe, North America, South America, Australia, Africa, and New Zealand were found in gardens in the USA [7]. The migration of ornamental plants has a deep historic background (18th century) and is still active to the present day.

Many South African native plants such as agapanthus (*Agapanthus africanus*), gerbera (*Gerbera jamesonii*), gladiolus (*Gladiolus* hybrids), gloriosa (*Gloriosa rothschildiana*), freesia (*Freesia hybrida*), leucadendron (*Leucadendron* sp.), leucospermum (*Leucospermum* sp.), ornithogalum (*Ornithogalum arabicum*), and protea (*Protea* sp.), were among the best-selling cut flower species during the previous decades [8]. Most of them are now considered as TCFs of great commercial success and are cultivated globally all-year round. They have been crossed or hybridised to produce numerous cultivars which gained commercial success [8]. The modern-day interest for South African native species lies on the breeding programs and/or on adaptations to various growing conditions. South Africa is regarded as a "hotspot" of diversity and an important source of new ornamental plants with the potential for commercial exploitation [8].

Cunningham et al. [9] presented many vital steps as part of a strategy to address and overcome serious challenges in the production of endemic cut flowers in Australia. Issues addressed were: (a) The implementation of existing national and international protocols for genetic resources protection, (b) the development of cultural branding and certification as marketing tools, (c) building business expertise and producer associations, and (d) increasing the reliability of supply chain of species such as *Geraldton waxflower*, *Anigozanthos* sp. *Boronia heterophylla*, *Leptospermum* sp., and *Grevillea* sp. [9]. In order to increase the economic and social impact of the native Australian SCF production and sale, local growers must improve their business and marketing skills, induce collaboration, exploit communication technologies, and increase product reliability and branding, while ensuring governmental support on protection of the initial genetic material. Similar challenges should be addressed by the South African floriculture markets [10]. The political isolation, the lack of complete distribution channels, the reduced quality compared to high grade European products, and the lack of export orientation were considered as the main barriers to valorisation of the South African native SCF. Although there is a dynamic increase in SCF production in the African continent, the labour organisations need to set labour standards for workers in production facilities [11].

3. Cultivation of TCF and SCF in a Globalised Market

The definition of SCF cannot be clear and precise, although scientists have tried to introduce a terminology that includes the following:

(a) SCF are annual or perennial species. Ornamental brunches from shrubs and trees are also included in the SCF group;
(b) they are categorized as species. Only a few of them have been hybridised to produce new varieties;
(c) they are seasonally produced in small quantities;
(d) they are mainly sold in local flower markets;
(e) they can be stored only for short periods of time;
(f) the majority of species is produced outdoors.

All-year round, intensive greenhouse cultivation of cut flowering stems may separate SCF from TCF. Species such as roses, gerberas, carnations, chrysanthemums, freesias, gypsophylla, eustoma, alstroemeria, phalaenopsis, anthurium etc. all fall into the TCF group (Table 1). The main differences between TCF vs. SCF could be related to:

(a) All year round vs. seasonally grown;
(b) numerous hybrids vs. original species;
(c) large stem numbers vs. small quantities;
(d) global sales vs. local markets;
(e) longer storage periods vs. short-period or no storage;
(f) greenhouse grown vs. outdoor cultivation.

Table 1. List of selected annual, perennial, and bulb specialty cut flowers (SCF) grown mainly outdoors at certain times of the year and traditional cut flowers (TCF) cultivated all-year round mainly inside greenhouses at different parts of the world [8,12–14].

		SCF		TCF
Acacia L. species	*Campanula* L. species	*Forsythia x intermedia* Zab.	*Paeonia lactiflora* hybrids	*Alstroemeria* L. hybrids
Achillea L. species	*Capsicum annuum* L.	*Gaillardia x grandiflora* Van Houtte.	*Physalis alkekengi* L.	*Anthurium andraeanum* Andre
Agapanthus praecox Willd.	*Caryopteris x clandonensis* A. Simmonds	*Gomphrena globosa* L.	*Physostegia virginiana* (L.) Benth.	*Antirrhinum majus* L.
Ageratum houstonianum Mill.	*Centaurea cyanus* L.	*Helianthus annuus* L.	*Polyanthes tuberosa* L.	*Aster novi-belgii* L.
Allium L. species	*Chamelaucium uncinatum* Schauer	*Helichrysum bracteatum* Vent.	*Protea* R. Br.	*Celosia argentea* L.
Amaranthus caudatus L.	*Chimonanthus praecox* (L.) Link.	*Heliconia* angusta Vell., *H. aurantica* Ghiesbr.	*Ranunculus asiaticus* L.	*Dahlia* Kav. hybrids
Amaryllis belladonna L.	*Clematis lanuginosa* Lindl.	*Helleborus niger* L.	*Rudbeckia hirta* L.	*Dedranthema x grandiflorum* Kitam.
Ammi majus L.	*Cirsium japonicum* DC.	*Hippeastrum* Herb. hybrids	*Salix* sp.	*Delphinium x cultorum* Voss.
Anemone coronaria L.	*Consolida ambigua* L. P.W. Ball & Hey W.	*Hyacinthus orientalis* L.	*Salvia splendens* Sell & Roem. & Schult., *S. viridis* L.	*Dianthus caryophyllus* L.
Anigozanthos Labill. hybrids	*Convalaria majalis* L.	*Hydrangea macrophyla* Thunb.	*Scabiosa atropurpurea* L.	*Eustoma grandiflorum* Shinn
Aquilegia L. hybrids	*Cornus alba* L.	*Iris hollandica* Hort.	*Schinus molle* L.	*Freesia x hybrida* Bailey
Argeranthemum frutescens L. Schultz-Bip.	*Cosmos bipinnatus* Cav.	*Kniphofia uvaria* (L.) Oken.	*Scilla sibirica* L.	*Gerbera jamesonii* Bol.
Artemisia abrotanum L.	*Cotinus coggygria* Scop.	*Lathyrus odoratus* L.	*Skimmia* sp. L.	*Gladiolus* L. hybrids
Asclepias tuberosa L.	*Craspedia globosa* Benth.	*Lavatera trimestris* L.	*Strelitzia reginae* Banks.	*Gypsophila paniculata* L., *G. elegans* Bieb.
Astilbe x arendsii Arends.	*Crocosmia x crocosmiflora* Burb. & Dean	*Leucandedron* R. Br	*Syringa vulgaris* L.	*Lilium* L. hybrids (asiatic and oriental)
Astrantia major L.	*Cytisus canariensis* L.	*Leucospermum* R. Br.	*Telopea speciosissima* R. Br.	Orchidaceae (*Cattleya* Lindl., *Cymbidium* Sw., *Dendrobium* Sw.a dn *Phalaenopsis* Pfitz.)
Atriplex lumex	*Cynara scolymus* L.	*Liatris spicata* L. Wild.	*Trachelium caeruleum* Graham.	*Rosa* L. hybrids
Banksia sp. L.	*Digitalis purpurea* L.	*Limonium sinuatum* L. Mill.	*Tulipa gesneriana* L.	*Solidago* L. species
Boronia heterophylla L.	*Echinacea angustifolia* L. Moench.	*Lobelia* L. species	*Verbena bonariensis* L.	
Bouvardia sp.	*Echinops banaticus* Rochel.	*Matthiola incana* L. R. Br.	*Veronica longifolia* L.	
Brassica oleracea L.	*Eremurus* Bieb. species	*Nigela damascena* L.	*Veronicastrum virginicum* (L.) Farw.	
Buddleia davidii Franch., *B. globosa* L.	*Eryngium planum* L.	*Narcissus tazetta* L.	*Zantedeschia aethiopica* (L.) Spreng.	
Calendula officinalis L.	*Eucaris amazonica* Linden.	*Nerine bowdenii* (L.) Watson	*Zinnia elegans* Jacq.	
Callistephus chinensis L. Nees.	*Eucalyptus* L. species	*Ornithogalum arabicum* L.		

The above mentioned lists of SCF and TCF are dynamic and change over the years as a result of changing worldwide production and marketing strategies by companies in the floriculture sector. In this view, SCF cultivated all-year round due to their increased market demands may be considered as TCF. In a globalised market increased popularity may define the crop as SCF or TCF. Growers may cultivate SCF and TCF simultaneously to satisfy local and/or international market demands.

Cultivation of SCF may increase local growers' income [14–18]. Growers located in North America found great potential in growing "alternative forest crops" such as salix species (i.e., *Salix matsudana*, *S. caprea*, *S. purpurea*), cornus (i.e., *Cornus sericea*), forsythias (*Forsythia* sp.), and various other flowering bunches [17]. In the North America wholesale markets, more than 1 million bunches of curly and pussy willow were sold in 2001. An additional 152,000 forsythia stems and more than 140,000 *Cornus* sp. bunches were also sold [17]. Willow cut stem growers in North America had great experience on cultivation, but they were not aware or informed about fertilization, pest management, and postharvest handling [19]. More research is required on SCF production and postharvest handling to provide solutions to growers and sellers [4,19].

In Australia, SCF production involved a wide range of native species dominated by the waxflower (*Chamelaucium uncinatum*), the kangaroo paw (*Anigozanthos* spp.), and the thryptomene (*Thryptomene* spp.) [9]. At least 64 other countries produce endemic Australian cut flowers with Israel, USA (California), South Africa, Ecuador, and Colombia being among them. *C. uncinatum* is a fast growing, evergreen shrub cultivated outdoors that produces flowering stems during winter after going through the short-day autumn period [20]. Australian native acacia species such as *A. dealbata*, *A. retinodes*, and *A. baileyana* are grown commercially in Australia and in the Mediterranean (i.e., Italy, Israel) for their impressive inflorescences [9,21]. Many SCF such as *Antirrhinum majus*, *Echinacea purpurea*, *Helianthus annuus*, *Limonium sinuatum*, *Matthiola incana*, *Scabiosa atropurpurea*, *Zinnia elegans*, and many more have increased their share in the US market [14,15]. According to the study presented by Starman et al. [15], 16 out of the 19 field grown SCF crops were profitable for commercial cultivation. Grower's income from *Achillea filipedulina*, *Liatris spicata*, *Veronica spicata*, and *Centranthus ruber* production increased linearly with increasing price/bunch sales. Stem prices varied during the year, and generally peaked around major holidays [15]. Among those species, *Cosmos bippinatus* cut flowering stems gave the highest income to growers (e.g., \$10.63–\$13.62). *Zinnia elegans*, *Scabiosa atropurpurea*, and *Antirrhinum majus* were also profitable for growers with incomes ranging from \$3.36 to \$4.51 [15]. Byczynski [22] stated that SCF growers could profit \$25,000 to \$35,000 per year, per ha of cultivation. Locally cultivated *Helianthus annuus* "Firecracker" plants would potentially be sold to wholesalers, retailers, and consumers in prices similar to those of the imported *H. annuus* flowering stems [18].

Although there is great potential in SCF cultivation, TCF hold the major part of sales in the local and international markets. In FloraHolland, the largest market of floricultural products worldwide, roses and chrysanthemums are the first and second best-selling cut flowers, respectively. The tulips, the gerberas, and the liliums came 3rd, 4th, and 5th in the top-5 list of cut flowers sold in 2019 [23]. Tulips may be considered as the best-selling SCF in the world, produced mainly in the Netherlands and presented as their national species.

The SWOT analysis shown in Table 2 provides useful comparisons between SCF and TCF. Although, growers' and sellers' decisions on cultivation and trade are complex and are often related to several factors and idiosyncrasies such as social and environmental legislations, infrastructures, environmental conditions, labour, and transportation costs. In a constantly changing global market, the TCF cultivation is the assured solution for growers and sellers, which, however, shows weaknesses associated with environmental legislations, CO_2 footprints, pesticide residues, and increased energy demands (Table 2). On the contrary, production of SCF could serve as the new alternative choices for retailers and florists who always seek niche markets to sell their products [16]. This was the case for Oklahoma (US) ornamental-horticulture and cut flower retailers that indicated the positive outcome in retail by using a greater variety of species [16]. Local production for domestic markets could be another strength of SCF (Table 2). In the US, production of local SCF increased the past 20 years and challenged imports of TCF grown in South America or other locaters [4,24]. Consumers who bought locally grown products had the perception of benefiting the local economy [25].

Table 2. Strengths, weaknesses, opportunities, and threats (SWOT) of SCF and TCF cultivated worldwide.

Species	Strengths	Weaknesses	Opportunities	Threats
SCF	a. Low cost, mainly outdoor b. Environmental friendly cultivation with low inputs c. Sustainable and low outputs d. Local production e. Variety of aesthetic features f. Many SCF have low longevity	a. Lack of identification and recognition by the customers b. Low commercial value c. Postharvest characteristics (low vase life, short storage period etc)	a. Sustainable production, reduction of CO_2 footprint, minimum phytochemicals b. New trends for floriculture industry and for the retail c. Partial replacement of TCF	a. Quality and vase life b. Customer confusion by the large number of species
TCF	a. Recognizable worldwide b. Varieties with high postharvest longevity c. Most appropriate for postharvest handling and storage d. Associated with symbolic meanings and social events e. Many different varieties provide various aesthetic features f. New varieties are associated with new marketing trends g. New varieties can be cultivated in different environments	a. High production costs due to greenhouse construction and automations and energy inputs b. High environmental outputs and CO_2 footprints c. Pesticide residues	a. Production of new, less energy demanding varieties b. Use of renewable energy sources at cultivation	a. New environmental legislations may put restrictions to traditional cultivations

4. Sustainable Production of SCF vs. TCF

As the green industry continues to mature, differentiation is an increasingly important business strategy [26]. One way to accomplish this is by adopting environmentally friendly behaviours that will attract consumers with environmental awareness [27–29]. These potential consumers are more likely to purchase environmental friendly products with reduced CO_2 footprints [3,26]. There is a small, but considerable, percentage of people who were willing to pay more money for agricultural products associated with sustainable, eco-friendly cultivation procedures [25,30]. Mainstream consumers were willing to buy eco-friendly products, but only at a modest price difference. Special attention should be given to consumer education and other promotion-related programs based on partnership between universities and private bodies (i.e., Texas Superstar®) to increase sales of new cut ornamental products [31]. Growers were also willing to adopt eco-friendly practices in cultivation, although they were sceptical on the implementation within their current cultivation system [32]. Back in 2010, Dennis et al. [32] reported that none of the grower respondents in their survey were certified as sustainable.

The recognition of floricultural products as "sustainable" is complex and demanding. Sustainable production is achieved via the implementation of strict environmental and social protocols as defined by the national and international directives [11,33]. Restrictions on CO_2 footprints and global warming potential (GWP) may affect production of cut flowers in the future [33,34]. Over a public demand for cleaner agricultural products, the sustainable SCF cultivation may serve as the environmental friendly alternative option. This can be a major strength of SCF compared to TCF (Table 2). Wandl and Haberl [35] showed that summer and spring SCF grown outdoors had <0.1 kg $CO_{2\,eq}$, while rose cultivation produced up to 13-fold more kg CO_2. The main differences in CO_2 production between the SCF and TCF were associated with excessive heating and electricity use "off-season" (i.e., the cold days of the year). Life cycle assessments (LCA) showed that increased CO_2 outputs for the production of roses, chrysanthemums, and gerberas were profound in Central and Northern European countries such as the Netherlands, Germany, and Austria [35–38]. Significant differences in CO_2 footprints, acidification, global warming, human toxicity, marine ecotoxicity, terrestrial ecotoxicity, and phytochemical oxidation were reported for roses produced in Dutch greenhouses compared to those produced in Ecuadorian facilities [33,38]. While CO_2 for roses produced in Kenya and Ethiopia ranged between 0.4 and 3.7 kg $CO_{2\,eq}$, the Dutch roses released 16–29 kg $CO_{2\,eq}$ [37]. In Greece, the cultivation of carnations in non-heated greenhouses produced only 0.316 kg $CO_{2\,eq}$ [39], indicating that heating during winter is the single most important factor contributing to greenhouse gas (GHG) emissions. As a result, future environmental legislations will apply limitations to TCF cultivation at traditional production centres, or may help in shifting production of TCF to countries in the African continent or at South America [33,34,40–42].

Fertilization and agrochemical use both contribute to the environmental outputs during cultivation. Growers of TCF support the integrated nutrition management (INM) and integrated pest and disease management (IPDM) programs to reduce their environmental footprints [33]. However, pesticide residue levels in roses, gerberas, and chrysanthemums highly concerned authorities and consumers in the EU in the past decade. In a study conducted in Belgium, 107 active ingredients were detected in harvested rose, gerbera, and chrysanthemum bunches [43]. Among them, roses were the most contaminated flowers with 14 distinct substances detected per sample and a total concentration of 26 mg kg^{-1} for a single rose sample. Substances such as acephate, methiocarb, monocrotophos, methomyl, deltamethrin, etc., could generate direct toxic effects to the nervous system of florists and consumers [43]. No research was found on pesticide residues detected on SCF. Generally, SCF suffer fewer fungal and pest contaminations during production, and therefore require minimal amounts of phytochemicals. SCF crop rotation and seasonal production might be the key to less infections and herbivore attacks. In every case, the implementation of IPDM to ornamental crop production may eventually reduce pesticide residues and improve the profile of the floricultural products.

5. Postharvest Performance and Quality

Vase life (VL) of cut flowers is considered as the single most important factor affecting consumers' buying choices. The shorter the VL of flowers purchased, the lower the possibility for a repeated buying [44,45]. While TCF hybrids show exceptional VL, the SCF show shorter longevities [14]. Environment conditions and genotype were the most important preharvest factors that contributed to inflorescence VL [46]. For example, increased RH levels inside the greenhouse decreased stomatal conductance of rose plants during the day. It was shown that stomatal responsiveness could be improved by adjusting the humidity levels either during the day or at night. Mortensen and Gislerød [47] showed that severe drought stress during growth of roses at high RH increased their VL. Longevity of vars. "Akito" and "First Red" roses decreased in winter as a result of higher humidity levels inside the greenhouses [48].

Harvest time and stage of development significantly affected VL of TCF and SCF [49]. Harvest procedures vary among species. For example, species of the Asteraceae family (i.e., chrysanthemums, gerberas, zinnias, etc.) should be in full maturity, whereas inflorescences with multiple buds are harvested at 25–50% open flowers [12,14]. Harvesting the SCF inflorescences *Eremurus* "Line Dance" and "Tap Dance" at the stage of 0-florets open resulted in significantly longer VL compared to inflorescences harvested at 1–2 and at 3–5 floret rows open [50]. VL of cut *Capsicum* "Rio Light Orange" stems was affected by harvest stage with "partly mature fruit stage" being the best for harvest [51]. Both *Celosia argentea* and *Antirrhinum majus* inflorescences had maximum VL at early harvest stage of short head diameter and 0-florets open, respectively [52]. On the contrary, VL of *Leucocoryne coquimbensis* [53], *Viburnum tinus* [54], and *Spartium junceum* [55] inflorescences were not affected by the harvest stage, indicating that different responses are recorded among different genotypes. Stem length, leaf number, and harvest time significantly affected VL of various cut flower species [46]. Leaf number and stem length affected transpiration, water balance of cells, and water transport in xylem vessels, respectively. These were identified as the most crucial factors of flower wilting. Day-light and temperature during cultivation may also affect VL in response to stem hydraulic conductivity and carbohydrate storage [56,57].

Short-period storage and handling significantly affect VL of TCF and SCF [49]. Many SCF may respond well to low temperature storage [14]. SCF responded differently to postharvest handling (i.e., storage time and temperature, wet or dry storage). For example, wet or dry storage of *Eremurus* [50], *Matthiola incana* [58], *Capsicum* ornamental peppers [51], *Celosia argentea*, and *Antirrhinum majus* [52] was effective for up to 2 weeks. *Achillea filipendulina*, *Buddleia davidii*, *Cercis canadensis*, *Cosmos bipinnatus*, *Echinacea purpurea*, *Helianthus maximilianii*, *Penstemon digitalis*, and *Weigela* sp. were all positively affected by 1–2 week storage at temperatures ranging from 2.0 to 7.0 °C [59]. *S. junceum* inflorescences were successfully stored for 30 d at 3 °C, without any loss in VL [55]. Likewise, *Curcuma alismatifolia* was stored for 6 d at 7 °C without any loss in VL [60]. *Anigozanthos* spp. could be stored for up to 2 weeks at 4 °C without showing symptoms of wilt or petal discolouration [61].

The presence of ethylene inside storage facilities during handling or transport may severely reduce VL and quality of climacteric TCF and SCF. The SCF *Achillea filipendulina*, *Celosia argentea*, *Helianthus maximilianii*, *Penstemon digitalis*, and *Weigela* sp. were negatively affected by the presence of <1 $\mu L\ L^{-1}$ ethylene inside the storage rooms [59]. Exposure of *Boronia heterophylla* flowers to 10 μL ethylene L^{-1} significantly reduced VL by 2.6 d compared to the un-exposed flowers [62]. *Curcuma alismatifolia* showed significant reductions in VL and bud opening after exposure to 0.5 - 2.0 $\mu L\ L^{-1}$ ethylene [60]. *Spartium junceum* inflorescences suffered a detrimental flower and organ fall when exposed to 5 or 10 $\mu L\ L^{-1}$ ethylene [55]. Treatments with 1-MCP, STS, Ag^{+}, and α-aminoisobutyric acid alleviated ethylene suffering and reduced aging symptoms. 1-MCP was found to be effective in various SCF including *Boronia heterophylla* [62], *Curcuma alismatifolia* [60], *Viburnum tinus* [54], *Celosia argentea, Antirrhinum majus* [52,63], *Eremurus* [50], and *Spartium junceum* [55]. 1-MCP increased the VL in ethylene-present or ethylene-free environments and delayed the aging process. Likewise, STS or Ag^{+} blocked ethylene-induced flower abscission and wilt and facilitated VL increases in most of the ethylene-sensitive SCF (i.e., *V. tinus, A. majus, B. heterophylla*).

6. Conclusions

Analysing the strengths and weaknesses of SCF and TCF, there are arguments over sustainability, marketing, and promotion of those cut flower groups. TCF are highly recognizable floricultural products, and biotechnology centres back-up their development with new varieties. On the contrary, SCF may be the eco-friendly alternative species to provide sustainable solutions to growers and consumers. SCF cultivation and sales have gained volumes over the last 15 years. SCF production can be sustainable with minimum energy and agrochemical inputs, although more research is required on VL extension and postharvest quality care.

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