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# Proteaceae Floral Crops: Cultivar Development and Underexploited Uses*

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The Proteaceae apparently originated on the southern supercontinent Gondwana long before it divided and began drifting apart during the Mesozoic era, accounting for the presence of the Proteaceae on all of the southern continents (Brits 1984a). The Protea family comprises about 1400 species in over 60 genera, of which over 800 species in 45 genera are from Australia. Africa claims about 400 species, including 330 species in 14 genera from the western Cape. About 90 species occur in Central and South America, 80 on islands east of New Guinea, and 45 in New Caledonia. Madagascar, New Guinea, New Zealand, and Southeast Asia host small numbers of species (Rebelo 1995).

Proteas are neither herbaceous nor annual, and they are always woody. Their structural habit is variable from groundcover forms with creeping stems, and those with underground stems, to vertical to spreading shrubs, to tree forms. The leaves are generally large, lignified, hard, and leathery. A mature leaf will generally snap rather than fold when bent. The leaf anatomy is specially adapted for water conservation and drought resistance. These characteristics and the high leaf carbon to nitrogen ratio render the leaves indigestible to most insect pests (Rebelo 1995), accounting for the relatively pest-free status of most commercial protea plantings.

The distribution of the family is linked to the occurrence of soils that are extremely deficient in plant nutrients (Brits 1984a). An accommodating characteristic of the family is the presence of proteoid roots. These are dense clusters of hairy rootlets that form a 2–5 cm thick mat at the soil surface which enhances nutrient uptake from the nutrient-sparse soils on which the Proteaceae evolved. All species examined so far, in at least ten genera, possess proteoid roots (Lamont 1986).

The capitulum, in which the flowers are borne on a flat or pointed receptacle, is the most common type of flowerhead. Involucral bracts surround the receptacle and may be prominent, as in *Protea*, or inconspicuous, as in *Leucospermum*. Involucral bracts in *Leucadendron* are also inconspicuous, but the floral bracts of female plants are large and develop into woody cones. An important taxonomic feature of the family is that its flowers do not have separate sepals and petals. The perianth is made up of a single set of four segments called tepals. As a bud opens, the perianth segments curl back to expose the style which extends from the superior ovary to the stigma. In some species, small floral nectaries at the base of the ovary secrete nectar to attract pollinators (Rebelo 1995). Another adaptation of evolution that has become important in the utilization of *Leucospermum* and *Protea* as cutflowers is bird pollination. The large, usually solitary, terminal flowers of these genera, and their predominant colors of creamy white, and blends of yellow, orange, and red, colors birds are attracted to, are probably adaptations to pollination by the Cape Sugarbird, *Promerops cafer*, and other nectar eating native birds. This is thought to be the prime reason why the South African species, and perhaps particularly *Leucospermum* and *Protea*, are the most attractive of the family and have excellent potential as cutflowers (Brits 1984a).

The floral biology of proteas is protandrous, with anthesis occurring prior to the stigma becoming receptive; a mechanism to help insure cross pollination. Most *Protea* seem incapable of self-pollination, although certain *Leucospermum* and *Serruria* species will produce seed when self pollinated. There are four types of pollinators, or pollen delivery; rodents, birds, insects, and wind. The flowerheads of certain *Leucospermum* and *Protea* species are visited by several species of gerbils, mice, rats, and shrews. Many *Leucospermum*, *Mimetes*, and *Protea* species are pollinated by birds. Since birds do not rely on smell, bird-pollinated species have little if any scent. The small species of *Leucospermum* and *Protea* are pollinated by bees and wasps and a few other insects; *Leucadendron* are pollinated by several beetle species, and most small-flowered genera are visited by a number of beetle, fly, and wasp species. Ten *Leucadendron* species are the only wind-pollinated proteas in southern Africa (Rebelo 1995).

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The hermaphrodite species of protea are extremely low seed producers, with only one to 30% of flowers resulting in seed. It is surmised that a large percentage of hermaphrodite flowers function only as males. Another reason for low seed production may be the plant's need to produce nutrient rich seeds to reduce seedling mortality in a nutrient-poor environment. However, dioecious species generally have a high seed set, possibly because all flowers on a female plant are reproductively functional (Rebelo 1995).

**HISTORICAL**

In 1771, the great Swedish botanist Carl Linnaeus wrote a colleague in Amsterdam, "*Inexhaustum credo Cap. B. spei esse plantarum speciebus; certe nulla Flora ditior erit*." Freely translated this reads, "I believe the Cape of Good Hope is by no means exhausted of plant species; surely no other flora could be richer..." The Australian Proteaceae contain more genera, but it is the South African ones that have attracted the interest of the world, commencing with the attempts by Joseph Knight to cultivate them under artificial conditions in the late 1700s. They proved to be difficult subjects, but the first flowers produced outside of South Africa were shown at the Royal Botanical Gardens at Kew in 1774 and 21 species had bloomed there by 1810. In the 18th and 19th centuries they became a "patrician indulgence" as collections were found in the royal conservatories from St. Petersburg to Paris (Parvin 1984).

Although there has been much exploration of the Cape Floral Kingdom over the past 400 years, new species are still being found, many of them in the Proteaceae. The interest in this family began with the 1605 description by botanist Carolus Clusius of the flowerhead of *Protea neriifolia* as thistle-like, graceful, and unique. The Proteaceae are often the most prominent elements of the Cape fynbos with large, stiffly erect flowerheads. A cut flower industry developed around flowers harvested from the fynbos (Brits 1984b). A far-sighted Stellenbosch farmer, Mr. Frank Batchelor pioneered the development of the commercial protea industry in South Africa as he retired from deciduous fruit production. From wild-collected materials, he moved into selection, hybridization, and vegetative propagation, recognizing that superior quality was required for the marketplace (Soutter 1984).

Contemporaneously, Marie Vogts took up the challenge to learn more about the habits and production of proteas. Wild plants in their natural habitat were her reference books as she established cultivated plantings which could be studied and compared. By the late 1950s, she had acquired enough knowledge to conclude that proteas could be cultivated, and her book "Proteas: Know them and grow them" (1958) was published. The book focused attention on the economic possibilities of proteas. Continuing her work, she sought out the natural variants that occurred in the mountains and brought them into cultivation. Seeing horticultural potential as well as marketability in these variants, she recognized the variations in flowering times at different sites as important to extending the marketing season (Vogts 1984). She was instrumental in founding the Protea Research Unit of the South African Department of Agriculture and focusing its attention on the genetic variability of wild populations and interspecific hybrids, and initiating a research program to improve their adaptability to cultivation (Brits 1984b). Her four decades of research and investigation laid a foundation for an industry that benefits not only South Africa's landed establishment, but also their rural peoples, and that has reached beyond the Cape Floral Kingdom to Australia, New Zealand, Israel, California and Hawaii, Zimbabwe, El Salvador, Chile, the Canary Islands, France, and other distant lands. Thus, this "alternative crop/new crop" has a long and honorable history predating the 1990s interest.

The University of Hawaii became involved in 1964 when a visiting professor of Horticulture, Dr. Sam McFadden, imported seed of various Proteaceae for trial in Honolulu. The next year additional seed were planted at the Maui Agricultural Research Center, 1000 m up the slope of Haleakala crater, where they flourished. Evaluations were made in 1969 separating 34 species into those suitable for cutflowers, for landscaping, and those unsuitable for either purpose. In 1970, 63 species of nine genera were imported, and a research program with emphasis on propagation and nutrition began to take form (Parvin et al. 1973). It was soon recognized that *Leucospermum* flowered on Maui as much as two months earlier than in California, suggesting the potential for a competitive advantage for a Hawaii export industry (Parvin 1984) if early flowering cultivars of horticultural merit could be obtained or created. The first pollinations in a new breeding program were made in 1972. The current research program emphasizes breeding for improved cultivars for cutflower production, the physiology of flowering, disease management, and postharvest handling and storage for *Leucospermum* and *Protea*.

The results from protea research programs in South Africa and Hawaii, and to an extent, Israel, have helped to stimulate protea cultivation in those and several other countries around the world, primarily for the international cutflower trade. Europe has been the traditional market for protea, but the United States and Japan have significantly expanded floral consumption and increased purchases of protea in recent years. Israeli market research recently reported that the world-wide cutflower markets can still absorb large quantities of proteas without lowering prices, but that the market is in need of new cultivars to refresh existing selections (Danziger 1997).

The emphasis on cultivar development is put into perspective by Soutter (1984); "It is generally said that a horticultural industry is only as good as its cultivars, and certainly in the case of floriculture, one can add the rate at which new cultivars are placed on the market." Numerous cultivars have been introduced by scientists and commercial breeders, hobbyists, and plant and flower collectors gathering from the native fynbos. *The International Protea Register*, Stellenbosch, South Africa, now in its fourth edition, keeps track of named cultivars along with their origin and brief descriptions to the extent it can obtain the information. This valuable resource allows researchers and producers to exchange plant materials and communications about known cultivars and their adaptability and performance in cultivated situations around the world. Table 1 summarizes the registered cultivars, and cultivars recognized but not yet registered, of four protea genera.

The register also lists cultivars of unknown origin, including 14 *Leucadendron*, 14 *Leucospermum*, and 24 *Protea*. It lists only one intergeneric hybrid, (*Mimetes* × *Leucospermum*) 'Splendidus'. The 86 registered cultivars are authored by 20 registrants from five countries; Australia, New Zealand, South Africa, United States, and Zimbabwe (Sadie 1997).

The International Protea Association (IPA) supports the promotion and commercial production of protea as well as scientific research and conservation of native germplasm (Mathews 1984). The IPA held its 9th biennial conference in Cape Town, South Africa, in August 1998 with representatives from 12 nations participating. Regional production and marketing reports were made by industry leaders, while academics and graduate students gave oral and poster presentations on research progress in areas of conservation, pest and disease management, cultivar development, propagation, pruning, irrigation, nutrition, and postharvest physiology.

Economically, the most important protea species is *Macadamia integrifolia*, the only native food plant in Australia to achieve international status as a commercial nut crop. Macadamia breeding and selection work was initiated in 1934 by the University of Hawaii, and over the next 50 years 13 cultivars were introduced from 120,000 seedlings evaluated. Commercial development of this crop began in Hawaii in the 1940s (Hamilton and Ito 1984). Hawaii was the world's leading producer until Australia recently claimed that spot. Today, this gourmet dessert nut is cultivated commercially in Australia, Brazil, Costa Rica, Guatemala, Hawaii, Kenya, Malawi, South Africa, and Zimbabwe. Recently, China established commercial plantings on Hainan island.

Selected Proteaceae floral crops were analyzed for their potential profitability, on a hypothetical 4 ha farm, and determined to be profitable, given adequate farm management and marketing. A computerized spreadsheet model of protea production in Hawaii enables one to estimate profitability over a wide range of conditions (Fleming et al. 1991, 1994). The computerized program is available free by contacting fleming@hawaii.edu.

**Table 1.** Summary of cultivars in The International Protea Register (the number of interspecific hybrids is in parentheses).

| Genus | Named cultivars: Registered | Recognized but not registered | Total |
|---|---|---|---|
| *Leucadendron* | 12 (5) | 101 (18) | 113 (23) |
| *Leucospermum* | 30 (19) | 58 (15) | 88 (34) |
| *Protea* | 42 (24) | 139 (29) | 181 (53) |
| *Serruria* | 2 (2) | 4 (1) | 6 (3) |
| Total (4 genera) | 86 (50) | 302 (63) | 388 (113) |

A variety of protea species have uses within or near their habitat. The seeds of *Brabeium stellatifolium* of South Africa are roasted and eaten or used as a coffee substitute. The seeds of *Finschia chloraxantha* from New Guinea and *Gevuina avellana* from South America are eaten by natives. The timbers of the Australian silky oaks *Cardwellia sublimis, Orites excelsa*, and *Grevillea robusta* are used in furniture and panelling. The Australian *Oreocallis wickhami* and *Banksia serrata* are used for yokes and boat knees, and the wood of *B. verticillata* for railway carriages and furniture. *Hakea leucopteris* and *H. vittata* wood is used for smoking pipes. The barks of *Faurea saligna* and *Leucospermum conocarpum* are used for tanning leather in South Africa. Species reported to have medicinal uses are *Faurea speciosa* for ear drops (root and leaf extract), and *F. saligna* to treat dysentery and diarrhea (root extract). Most protea flowers are of value to apiarists for their abundant nectar production (Rao 1971).

**PROTEA**

*Protea* is a large genus with 136 species of which 70 are distributed in the southern hemisphere temperate zones and the balance distributed in southern hemisphere sub-tropical to tropical zones, with 3 extending above the equator into the northern tropics (Rao 1971). Of the 117 species native to the African continent, 82 are from South Africa (Vogts 1982). A recent account of *Protea* species in Southern Africa lists 90 species and numerous subspecies (Robelo 1995). Linnaeus named the genus *Protea* in 1735 after the Greek god Proteus, who, according to legend, was able to transform his shape and appearance into numerous animate and inanimate forms at will (Robelo 1995). It was from the name *Protea* that the family name Proteaceae was assigned by the French botanist Jussieu (Rousseau 1970).

The natural habitat of *Protea* ranges in elevation from sea level to over 2000 m. In South Africa a rich diversity of species inhabit the well-drained, moderately-acid, low fertility, granite soils from Cape Town to the Table Mountain areas up to 1300 m (Parvin et al. 1973).

The genus is characterized by large bracts, often brightly colored, surrounding a composite type flower. The bracts are smooth or pubescent, with many species having bracts fringed with a dark “fur” lending a tactile as well as visual appeal. The range of colors includes red, pink, yellow, white, and occasionally green (Watson and Parvin 1973). The most widely recognized species in the genus is *Protea cynaroides*, the King Protea, the national flower of South Africa. It has flower heads up to 30 cm across, with widely spaced bracts arranged around a peak of flowers that vary in color from near white to soft silvery-pink to deep rose pink to crimson, in a few selected cultivars.

Many natural variants of *P. cynaroides* can be placed into three South African ecotypes. Those from the eastern cape and southern coastal plain have long leaves on long stems that terminate with relatively small but wide-open flower heads. They are very attractive but difficult to pack. The plants are vigorous and bear 10 to 20 heads per plant. Variants from the Outeniqua mountains region bear large bowl-shaped rose colored flower heads on thick stems. The heads are more easily packed because the bracts do not flare out. Average flower head yield is five to eight per plant. The variants from the Western Cape region are slow growing and average only about four heads per plant, but are described by Vogts (1980) as beautifully goblet-shaped. A miniature form of *P. cynaroides*, with flower heads the size of a typical pincushion protea, offers much promise for expanded florist use of this species. *Protea cynaroides* generally show good resistance to *Phytophthora* root rot (von Broembsen and Brits 1986).

Several clonal selections of *P. neriifolia* are grown commercially for their prolific production of fall and winter blooms. The plant becomes a large shrub with foliage resembling that of oleander. Flower heads range in color from light pink to rose to dark red, with some white selections known. Some selections have silvery hairs subtending tufts of black hairs at the bract tips. Plants of 20 years age have been reported to bear commercial quality flowers (Vogts 1980). This species also shows good resistance to *Phytophthora* root rot (von Broembsen and Brits 1986).

The grey-leaf sugarbush, *P. laurifolia* (formerly *P. marginata*), is similar to *P. neriifolia* for many characteristics, although their natural distributions do not overlap and natural hybrids between the two do not occur. To the non-taxonomist, foliage characteristics may be the most distinguishing feature between the two species. The leaves of *P. laurifolia* are grey-green to blue-green, elliptic and broader than the bright green leaves of *P. neriifolia* (Vogts 1982). If left unmanaged, *P. neriifolia* will grow to become an erect shrub 3 m tall while *P. laurifolia* will become an 8 m tall tree ( Robelo 1995).

*Protea magnifica*, the Queen protea, is somewhat susceptible to *Phytophthora* (von Broembsen and Brits 1986) but is still grown for its large 15 to 20 cm flower heads of white to rose pink to salmon colors. Many cultivars have black-and-blond tufts of hair on the bract margins (Vogts 1980) and are sometimes referred to as woolly-beard protea.

The rose-spoon protea, *P. eximia*, gets its common name from the long spathulate inner bracts that are widely splayed and easily distinguish this large flowered species from others (Vogts 1982). These bracts range in color from pink to orange-brown. Awns extending from the perianth have purple-black velvety hairs. Plants generally range in height from 2 to 5 m, are sparsely branched, and flower from early winter through late spring (Robelo 1995). A tall tree-like variant reaches peak flowering in summer (Vogts 1982).

Long, narrow leaves, and flower heads with pointed bracts characterize *P. longifolia*. Bract color is variable from white to pink and green. Plant stature and growth habit are also variable in its native stands, where many natural hybrids with other *Protea* species overlapping its range have been found.

*Protea grandiceps*, also somewhat susceptible to *Phytophthora* (von Broembsen and Brits 1986) comes from high elevation mountainous regions that are snow-covered in winter. It is a slow growing long-lived plant that bears up to 40 salmon-colored flower heads of 10 to 15 cm. Plants can be cultivated for more than 20 years (Vogts 1980).

The sugar bush, *P. repens*, is widely grown commercially for its white to pink to deep red colors and long flowering season (Vogts 1980). It is another species with good resistance to *Phytophthora* root rot and can be used to replant *Phytophthora* infested fields (von Broembsen and Brits 1986).

*Protea compacta* has lanky flower stems on a stiffly upright, sparsely branched shrub that grows to 3.5 m tall. The rich pink bracts, with their light-reflecting fine-hair-fringed margins are longer than the cup-shaped flower heads. The prominent flower heads, unobscured by foliage, make fine winter cutflowers (Vogts 1982).

Numerous selections of these and other species, and of naturally occurring hybrids that have been identified from the South African fynbos, are cultivated by commercial growers. Cuttings of 22 named selections of *Protea* of South African origin were imported by the University of Hawaii in 1988, propagated, field planted, and evaluated for adaptability and plant growth characteristics at its Kula Agricultural Research Center on Maui. Yield, seasonality of bloom, and keeping quality were recorded from 1989 to 1993. The yield and seasonality over a 12 month period (August 1992 through July 1993) of the seven cultivars that produced 30 flowers or more are reported in Table 2. By careful evaluation of seasonality in localized climates, it is possible to select cultivars to cover a large portion of the year, although some months may not be well represented (Criley et al. 1996).

Protea can be propagated from seed, with the resulting variation expected of cross-pollinated heterozygous materials. Given the availability of clonal selections, the method of choice among progressive com-

**Table 2.** Yields and seasonality on Maui for selected South African *Protea* accessions.

| | Yield | Months of flowering | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Cultivar | (12 mo) | Aug. | Sept. | Oct. | Nov. | Dec. | Jan. | Feb. | Mar. | Apr. | May | Jun. | Jul. |
| Annette | 37 | | | | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | |
| Brenda | 210 | | | ✓ | ✓ | ✓ | ✓ | | | | | | |
| Cardinal | 31 | ✓ | | | | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Guerna | 86 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Heibrech | 45 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | ✓ | ✓ | |
| Red Baron | 86 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | ✓ | | |
| Sylvia | 66 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |

mercial growers is to propagate from cuttings. Terminal and sub-terminal cuttings are made from the current season's mature growth. Robust cuttings of 20 to 25 cm in length root readily, for most cultivars. Longer cuttings may be taken if the grower desires to have lower branches well above ground level. Removing half of each leaf of long leaf cultivars is a common practice. An IBA auxin treatment of 4000 to 8000 ppm is beneficial. The rooting medium should be very well aerated but not allowed to dry. Mixtures of 25% to 50% peat with the balance being polystyrene or perlite has given good results. Rooting is generally done under standard mistbed conditions. An approved fungicide sprayed over the cuttings following planting can prevent infections. Rooting time is variable among species, with *P. cynaroides* rooting quickly and *P. neriifolia* often taking many weeks (Mathews 1981).

When selecting a production site, good soil drainage is the most important requirement for protea production. Deep soils that allow expanded root development and can store a good supply of water and nutrients are preferred, but shallow soils can be suitable if drainage is rapid and frequent irrigation can be provided (Claassens 1981).

Relatively low concentrations of nutrients are required for normal growth of proteas. Most species react favorably to nitrogen, particularly in the ammonium form, while most are intolerant of amounts of phosphorus that would be considered moderate for non-proteaceous plants. Protea plants seem to have a very effective mechanism to scavenge phosphorous from soils with low phosphorus status (Claassens 1981, 1986).

Cresswell (1991) produced a tissue analysis standard for assessing the appropriate phosphorus status for two *Protea* cultivars. Only the desirable ranges are reported in Table 3. Values lower or higher than those reported here were considered low to deficient or high to toxic, respectively.

The recommended developmental stage for harvesting most *Protea*, to insure market quality and acceptable postharvest life, is the so-called soft-tip stage when bracts have lost their firmness and begin to loosen but still cohere (Meynhardt 1976). At this stage, few insects are present because anthesis has not yet occurred, so there is little to attract them. However, flowers picked too early will not open (Coetzee and Wright 1991). A serious problem with marketing several species of *Protea* is the undesirable discoloration of leaves soon after harvesting. The problem is most pronounced in *P. eximia* and *P. neriifolia*, and their hybrids, and to a lesser extent with *P. compacta* and its hybrids (Ferreira 1986; Paull 1988).

Leaf blackening, or browning as it is sometimes called, in *Protea* is caused by carbohydrate depletion due primarily to the sugar demand by the inflorescence for nectar production (Dai and Paull 1995). Low availability of mobile carbohydrates in the leaves, combined with the high respiratory demand of the inflorescence, resulted in a 70% decline in mobile leaf carbohydrate levels in *P. neriifolia* within 24 hours of harvest (Jones et al. 1995). Warm temperatures and low light in postharvest storage have been correlated with increased rates of leaf blackening (Ferreira 1986). Refrigeration, especially during postharvest storage, packaging, and shipping periods, has a most significant effect on delaying the onset of leaf blackening (Paull 1988). Refrigeration will slow respiration, reduce water stress, and slow nectar production by the inflorescence, thereby conserving carbohydrate reserves in the stem and foliage. A storage and transport temperature of 2° to 5°C will help ensure bloom quality and postharvest life (Coetzee and Wright 1991). Pulsing cut *Protea* stems in a 1% sucrose solution, or a floral preservative solution, before packing and especially post-unpacking is an effective treatment to delay the onset of leaf blackening (Brink and de Swardt 1986; Paull 1988). Another form of leaf browning results from fumigation with methyl bromide (Coetzee and Wright 1991), which imported shipments are often subjected to if insects are present. Growers should practice good field sanitation and appropriate postharvest disinfestation practices prior to packing, so that agriculture inspectors at the receiving end will not fumigate the shipment.

**Table 3.** Desirable ranges of phosphorus in tissues of two *Protea* cultivars.

| | Desirable phosphorus (ppm) | | |
|---|---|---|---|
| Cultivar | Stems | Recently matured leaves | Old leaves |
| Satin Pink | 0.19–0.35 | 0.19–0.29 | 0.21–0.44 |
| Pink Ice | 0.06–0.29 | 0.06–0.27 | 0.16–0.46 |

Natural hybrids within the genus *Protea* are not an uncommon occurrence where the geographic ranges of two or more species overlap. Scientists at the Fynbos Research Unit, Elsenburg, South Africa, have made a collection of such natural hybrids and in most cases have been able to determine their parentage (Table 4). Some of these meet standards of commercial horticulturists and have been released to South Africa's protea industry. Dr. Littlejohn, the protea breeder at Elsenburg, recently initiated a program to produce controlled hybrids in the genus *Protea* to further benefit the protea industry.

**LEUCOSPERMUM**

*Leucospermum* species are evergreen woody perennials with growth habits that range from small trees to spreading shrubs to prostrate ground covers. The most widely grown species are floriferous, spreading shrubs on which relatively short-stemmed inflorescences are borne in the spring. Horticulturists have had to develop management practices to improve stem length and straightness for their use as cut flowers.

Rourke (1972) and Jacobs (1985) describe the inflorescence as a capitulum that develops from an axillary rather than a terminal bud, but that appears to arise distally. Inflorescences may be solitary, as in *L. cordifolium*, *L. lineare*, and *L. vestitum*, or in clusters (conflorescences), as in *L. oleifolium*, *L. tottum*, and *L. mundii*. The individual florets consist of a perianth formed by four fused perianth segments, one of which separates from the other three as the flower opens. The perianth curls back to display a prominent style; the striking appearance of the whole inflorescence of open flowers resembles a pincushion—thus one of the common names is pincushion protea. The styles, perianth, and involucral bracts may be white, yellow, pink, orange, or red and the combinations are responsible for the popularity of the pincushion proteas as cutflowers.

Although most of the *Leucospermums* are indigenous to nutrient-poor, coarse, acidic, sandstone-derived soils, they seem adaptable to a variety of soil types within a narrow range of pH and fertility levels. This is evidenced by their culture in several regions of southern Africa, southern California, Israel, Australia, and in the volcanic soils of Hawaii and the Canary Islands (Criley 1998).

Propagation of the commercial cultivars of *Leucospermum* is by cuttings, of which most root readily. While cuttings can be rooted at almost any physiological stage of development, a preferred cutting is the recently matured new growth, known as a semi-hardwood cutting (Malan 1992). This type of material is gathered in autumn after shoot growth terminates.

A tissue culture protocol for *Leucospermum* was developed using axillary bud explants induced to proliferate on a basal medium of half-strength Murashige and Skoog inorganic salts supplemented with sucrose and benzyl adenine (Kunisaki 1989, 1990). *Leucospermum* Hawaii Gold, propagated from tissue cultures, is flowering at the Kula Agriculture Research Center and appear identical to the type cultivar from which the explants were taken.

Grafting is often viewed as a solution to problems of root system adaptation to low or high pH soils, or soil-borne diseases. The selection of rootstock plays a significant role in improving adaptability and yield of *Leucospermum* (Van der Merwe 1985). Grafting onto lime-tolerant rootstocks, such as *L. patersonii*, has been recommended as an approach to problems of protea production on soils of neutral to slightly basic pH (Brits 1984b). The standard grafting technique is wedge-grafting of leafy semi-hardwood scions onto selected rootstocks (Rousseau 1966; Vogts et al. 1976). Cutting grafts, where the graft union develops while the cutting roots, is also recommended (Brits 1990b). Brits (1990c), in screening 19 species and several hybrids for their potential as rootstocks, determined that *L.* 'Spider' (a primary hybrid of *L. formosum* × *L. tottum*) has a degree of tolerance to *Phytophthora cinnamomi*. *Leucospermum* 'Spider' is pres-

**Table 4.** Recent *Protea* hybrids of South African origin.

| | |
|---|---|
| Sheila | (*P. magnifica* × *P. burchelli*) |
| Venetia | (*P. magnifica* × *P. neriifolia*) |
| Pink Duke | (*P. compacta* × *P. susannae*) |
| Candida | (*P. magnifica* × *P. obtusifolia*) |
| Valentine | (*P. cynaroides* × *P. compacta*) |
| King Grand | (*P. cynaroides* × *P. grandiceps*) |
| Venus | (*P. repens* × *P. aristata*) |
| Liebencherry | (*P. repens* × *P. longifoli*) |
| unnamed | (*P. cynaroides* × *P. nitida*) |
| unnamed | (*P. cynaroides* × *P. repens*) |

ently being used as a rootstock by several commercial producers in South Africa. *Leucospermum saxosum* has also been determined to have low susceptibility to *Phytophthora* (Moffat and Turnbull 1994), and a selection of *L. patersonii*, designated ‘Nemastrong’, has tolerance to nematodes (Ackerman et al. 1995). Such rootstocks may have the potential to expand and increase yields of plantings where *Phytophthora* and nematodes are a problem.

The production period for *Leucospermum* is late winter to late spring. Parvin (1974) reported that 65% to 75% of the total crop of *L. cordifolium* ‘Hawaiian Sunburst’ was harvested from Dec. through Feb. in Hawaii. They are also high yielding. During a three-year study, beginning with 6-year-old plants, the per plant yields averaged 600 to 650 flowers.

Research on postharvest handling practices has shown that the pincushion protea will tolerate cool, dry, long-term storage and still provide a useful vaselife. *L. cordifolium* flowers that were cooled and hydrated at 1°C in water, wrapped in newsprint and bagged in plastic film withstood periods of three and four weeks at 1°C storage, and after rehydration, possessed an average vaselife of 8 days (Jones and Faragher 1990). Downs and Reihana (1986) found significant varietal differences in vaselife following a period of simulated transport, with the New Zealand cultivar ‘Harry Chittick’ at 35.5 days, a Hawaii hybrid of *L. lineare* × *L. cordifolium* at 29.7 days, and ‘Veldfire’, a South African hybrid at 16.9 days.

Parvin (1978) improved vaselife with 2% to 4% sucrose plus 200 to 600 ppm hydroxyquinoline citrate solutions. Silver nitrate at 1000 ppm did not benefit cultivars of *L. cordifolium* but improved vaselife for the hybrid *L.* ‘Hawaii Gold’ (Parvin and Leonhardt 1982). Criley investigated revival of wilted flowers with extruded styles, in order to increase packing densities for export shipments. Flowers pulsed with a preservative prior to partial dehydration (20% loss of FW) and storage (24 h at 13°C) could be revived, although vaselife was not as long as with fresh cut flowers (Criley et al. 1978a,b). Flowers cut in bud (7 cm diam.) offered better promise, with full development and less loss of vaselife than flowers cut at a younger stage (Criley et al. 1978a; Parvin and Leonhardt 1982).

While a number of Proteaceae may be grown as potted plants, the *Leucospermums*, with their relative ease of rooting and attractive floral display, have the greatest potential (Sacks and Resendiz 1996). Criley (1998) reported that budded cuttings flowered soon after rooting, adding confirmation to their potential as potted plants, and proposed that stock plants be manipulated to achieve stronger branches for this use.

Research on photoperiod responsiveness of *Leucospermum* (Wallerstein 1989; Malan and Jacobs 1990) indicates that daylength manipulation may have implications for potted flowering plant production. High light intensity was shown to be necessary for flowering (Jacobs and Minnaar 1980; Napier and Jacobs 1989; Ackerman et al. 1995) and to promote rapid rooting of cuttings.

*Leucospermum* species suitable for potted plants are of two types: those having a single large inflorescence, such as *L. cordifolium*, *L. lineare*, and *L. tottum*; and those with small multiple inflorescences (conflorescences) such as *L. oleifolium*, *L. muirii*, and *L. mundii* (Brits et al. 1992; Ackerman et al. 1995; Brits 1995a). It is important to select material that will root rapidly and support flower initiation and development on a young root system (Ackermen and Brits 1991; Brits et al. 1992).

Although the genus *Leucospermum* consists of 48 species (Rourke 1972), little genetic improvement through hybridization has taken place until relatively recently. Jacobs (1985) reported that only a few species were utilized as cut flowers (*L. cordifolium*, *L. patersonii*, *L. lineare*, *L. conocarpodendron*, *L. vestitum*), but that natural and man-made interspecific hybrids exist as clonal selections. Collection and introduction of natural interspecific hybrids has occurred (Brits and van den Berg 1991), and controlled crosses were made between species in efforts to produce later flowering, improve color and shape, and to introduce tolerance to *Phytophthora cinniamomi* (Brits 1992a). Today, active breeding programs are being conducted at the Fynbos Research Station, Elsenburg, South Africa (Brits 1992a,b; Littlejohn et al. 1995) and at the Maui Agricultural Research Station of the University of Hawaii (Ito et al. 1978, 1979, 1990; Leonhardt et al. 1995), and in Israel (Shchori et al. 1995).

As of the fourth edition of the *International Protea Register* (*International Registration Authority: Proteas 1997*), 30 cultivar names have been registered and another 58 have been noted but not registered for selections and interspecific hybrids (Criley 1998). Among the hybrids registered, only three are advanced hybrids (having more than two species in their genealogy). These hybrids, developed and registered by the University of Hawaii, are:

*L*. 'Rachel', with parentage (*L. lineare* × *L. vestitum*) × *L. glabrum*

*L*. 'Hawaii Moon', with parentage (*L. lineare* × *L. cordifolium*) × *L. conocarpodendron*

*L*. 'Kathryn', with parentage (*L. lineare* × *L. cordifolium*) × *L. conocarpodendron*

The criteria for developing new *Leucospermum* cultivars must consider the needs of growers, handlers, retailers, and consumers. The criteria developed for the Hawaii breeding program includes disease resistance, earliness to flower, an extended flowering season, long slender and straight stems, slender leaves, reduced leaf pubescence, ease of propagation, high yields, good postharvest characteristics, new and improved colors, and market acceptance (Leonhardt et al. 1995). Leaf and stem characteristics, and disease resistance are given emphasis.

Many commercial *Leucospermum* cultivars are bulky, heavy, and cumbersome to pack due to large stem diameters and large heavy-textured leaves. These are undesirable characteristics, particularly to exporters, because freight charges are based on a formula that considers cubic dimensions and weight of the box. A densely packed, light-weight box reduces the per-bloom freight charge and allows exporters to compete more favorably in overseas markets. The species *L. lineare*, and particularly the selection *L. lineare* 'Starlight', has slender, light-weight yet strong stems with narrow, nearly needle-like foliage. Breeding has demonstrated that these characteristics are heritable and that *L. lineare* hybrids have improved leaf and stem characteristics. *Leucospermum lineare* is also free of foliar pubescence. Foliar pubescence attracts and retains moisture, which provides an environment for fungal spore germination and infection (Leonhardt et al. 1995).

The most important diseases occurring on protea in Hawaii are root and collar rots caused by *Phytophthora cinnamomi*, *P. nicotianae*, and *Cylindrocladium* sp., stem and leaf scab caused by *Sphaceloma* (Elsinoe) sp., leaf spots and blights caused by *Drechslera biseptata* and *D. dematioidea*, leaf spec caused by *Alternaria alternata*, and root knot galls caused by *Meloidogyne incognita*, the root-knot nematode (Nagata and Ferreira 1993). Root-knot nematodes can severely limit growth and productivity of *Leucospermum*. Heavily infected plants show stunting and chlorosis, followed by death of the plant (Cho et al. 1976; Cho and Apt 1977). Wu reported that this nematode can reduce cut flower yields by at least 25% in infected fields compared to fumigated fields (Wu et al. 1978).

The Hawaii breeding program has utilized ten species and numerous $F_1$, $F_2$, and $F_3$ hybrids to produce seedling populations that are evaluated for disease resistance and other horticultural characteristics (Leonhardt et al. 1995). Some of the parental materials are used for very specific purposes. A selection of *L. saxosum* for example, was determined to be immune to *Sphaceloma* (Elsinoe scab disease) (Nagata et al. 1995) and has been used to impart resistance into commercial hybrids. Among hybrids, *L*. 'Rachel' has demonstrated a good level of resistance to *Sphaceloma*, and has also shown a good level of resistance to two isolates causing *Botrytis* blight and moderate resistance to two isolates causing *Drechslera* blight. The hybrid *L.* 'Ka Hoku Hawaii' (Hawaii Star), *L. cordifolium* × (*L. lineare* × *L. vestitum*), and the unnamed hybrids No. 36, *L. lineare* × [*L. conocarpodendron* × (*L. lineare* × *L. cordifolium*)], and No. 49, [*L. conocarpodendron* × (*L. lineare* × *L. cordifolium*)] × *L. cordifolium* 'Sweet Lemon', have shown a good level of resistance to both *Drechslera* isolates. The hybrids *L*. 'Pohaka La Hawaii' (Hawaii Sunbeam), (*L. lineare* × *L. glabrum*), and No. 36 have shown a good level of resistance to *Botrytis* isolates (Nagata et al. 1995; Leonhardt et al. 1995).

Commercial producers in Hawaii compete in North American markets with California producers. The flowering season for *Leucospermum* begins several weeks earlier in Hawaii than in California. Producers in Hawaii could enjoy this advantage for a longer period if earlier flowering cultivars could be developed. The species *L. patersonii* and *L. pluridens* are among the earliest-flowering, and are being used in breeding for that quality. Two accessions of *L. pluridens* × (*L. lineare* × *L. cordifolium*) flower earlier at the Maui Agriculture Research Station than the hybrid parent (Leonhardt et al. 1995).

***LEUCADENDRON***

The South African genus *Leucadendron* contains about 60 species, collectively referred to as the conebushes. They are easily identified since they are dioecious, having plants of separate male and female sexes. Both sexes have terminal flowerheads. Female plants produce woody cones containing fruits and seeds while male plants do not produce cones. The cones on female plants consist of spirally arranged floral bracts which partially cover the cone. Male plants are often larger and more heavily branched and may have smaller leaves than female plants (Robelo 1995).

As with most Proteaceae, the *Leucadendrons* grow best in areas with light, well-drained soils with low concentrations of dissolved salts, an adequate supply of fresh water, temperatures in the range of 7°C to 27°C, and frequent if not regular light winds. *Leucadendrons* require an acid soil with a pH not exceeding 5.0. Sandy soils with some humus provide the best growing medium (Vogts 1980).

Several species are cultivated commercially for their decorative foliage, including *L. argenteum, L. discolor, L. galpinii, L. laureolum, L. salicifolium, L. salignum, L. tinctum,* and *L. uliginosum. Leucadendron argenteum*, the 'Silver Tree', can grow to a 8 m tall tree if left unmanaged. Its leaves are grey-green with abundant fine satiny silver hairs that glisten in sunlight. It is grown for its long-lasting cut foliage, and also makes an attractive landscape plant. Its natural habitat is arid, and in cultivation it will succumb to overwatering, soil fungi, and nematodes. *Leucadendron discolor*, harvested in winter and spring, ranges in color from light to dark green to yellow to red, and is a spreading bush up to 1.5 m high. *Leucadendron laureolum* is chartreuse to bright yellow when flowering in winter and spring while *L. salignum* (formerly *L. adscendens*) is bright red, becoming more intensely colored as temperatures decrease. A particularly outstanding cultivar is the female selection *L. salignum* 'Safari Sunset'. *Leucadendron uliginosum* has elegant, slender shoots covered with numerous shiny, silvery leaves (Vogts 1980, Kepler 1988).

The genetic variation in *Leucadendron* is vast and largely untapped for breeding purposes (Littlejohn et al. 1995), although a few hybrids have been introduced to the commercial trade, mostly from South Africa. Hybrids cultivated by commercial growers include *L.* 'Silvan Red' and *L.* 'Inca Gold', both (*L. laureolum* × *L. salignum*), *L.* 'Kam-ee-lion' (*L. salignum* × *L. eucalyptifolium*), and the recent South African introduction *L.* 'Rosette' (*L. laureolum* × *L. elimense* ssp. *salterii*), which can be harvested as a green, yellow, or red-brown product, depending on the season (Littlejohn et al. 1998).

In addition to their highly colorful, easily packaged, long and long-lasting cut stems, a characteristic of many *Leucadendrons* that makes them commercially important is their potential for very high yields. Pruned and managed *L.* 'Silvan Red', in a 3 year study at 3 locations averaged 265 marketable stems per plant per year (Barth et al. 1996). This cultivar can be harvested in the fall as a red-foliaged stem, and in the winter as a tricolor stem with yellow, red, and green foliar bracts. *Leucadendron* 'Safari Sunset', a selection of New Zealand origin, is probably the most widely grown commercial cultivar, with extensive plantings in Australia, New Zealand, South Africa, and Israel. The erect bushy plant is vigorous and fast growing. Its deep wine-colored bracts have excellent keeping quality, lasting up to 60 days (Tija 1986). Dr. Ben-Jaacov, in his presentation at the International Protea Association Conference in Cape Town in 1998 reported that 'Safari Sunset', under intensive management in Israel, has given yields in excess of 600,000 marketable stems per hectare per year. Recent research in South Africa compared *L.* 'Rosette' with *L.* 'Safari Sunset' for yield and stem length. In the third harvest year *L.* 'Rosette' yielded 44.5 stems per plant with 20 stems 80 cm or longer while *L.* 'Safari Sunset' yielded 37.0 stems per plant with 10 stems 80 cm or longer (Littlejohn et al. 1998). Both cultivars are exceptional commercial materials.

Although more widely known as commercial cut foliages and landscape plants, *Leucadendrons* can be grown as colorful potted "flowering" plants. The male *L. discolor* 'Sunset' naturally flowers profusely in early spring with colorful flower-heads. Israeli research has demonstrated that flowering potted plants of 'Sunset' can be produced in 3–5 months by rooting large branched cuttings with initiated flowers. The basal stems of branched 15 cm long cuttings were dipped in a 4,000 ppm IBA solution prior to sticking in a styrofoam/peat medium under intermittent mist and 25% reduced natural light. Rooting began in 4 weeks. The stage of development of the flower-head at rooting was critical for the cutting's further development into a flowering potted plant. If not fully initiated as floral buds, the meristem aborted or reverted to the vegetative state. However, when cuttings were taken at the right stage of floral initiation, colorful flowering potted plants were produced in 3–5 months. Conventional technology for producing potted flowering plants of *L. discolor* by rooting small unbranched vegetative cuttings, growing them to the appropriate size, retarding them chemically, and bringing them to flower, would take 2 years or longer (Ben-Jaacov et al., 1986). The potential for using this technology to produce attractive *Leucadendron* flowering potted plants for the commercial nursery trade is significant.

***BANKSIA***

The fourth largest export wildflower crop of Australia (Sedgley 1996), the genus *Banksia* is named for the famous botanist, Sir Joseph Banks. Seventy-six taxa have been described under 2 sub-genera, 3 sections, and 13 series (Sedgley 1998). *Banksia* are evergreen, woody perennials with growth habits that range from prostrate ground-huggers to trees. Most of the species are found in the south-west with the remainder along the southern and eastern coasts and tablelands. Nearly all have ornamental features that confer horticultural potential, whether as fresh or dried cut flowers, cut foliages, or in the landscape (Elliott and Jones 1982; Joyce 1998; Parvin et al. 1973; Sedgley 1998; Wrigley and Fagg 1996).

Species widely grown for cut flowers and foliages are shown in Table 5. The most popular cut flower types bear their cylindrical flower spikes terminally, but a few terminal-flowering selections have been made of axillary bearers (Sedgely 1998). Some species produce attractive flowerheads upright on horizontal branches and would need considerable management to be suitable for the commercial markets. Although many commercial plantings are produced from seed and show considerable variability, progress has been made in cultivar development (Fuss and Sedgley 1991; Sedgley et al. 1991; Sedgley 1991, 1995a,b,c,d).

Concurrent with these developments is a need to improve the vegetative propagation systems, as cutting propagation often results in development of a large knob of callus (Hocking 1976). Cutting propagation yields variable results, but the use of intermittent mist (allowing some drying between cycles) and auxin stimulates better root development on semi-hardwood terminal cuttings (Bennell and Barth 1986; Sedgley 1995c). Grafting onto various disease resistant species such as *B. robur* and *B. spinulosa* offers some promise, but additional research is needed to establish successful techniques and timing and to determine compatibility relationships and tolerance to stresses. It is necessary to avoid rootstocks that form lignotubers as these may sucker and compete with the scion (Elliott and Jones 1982). Cutting grafts have been successful with a few species (Elliot and Jones 1982).

Seed germination is reliable, but not for the hybrids, and seed supplies are limited. *Banksia* seed is produced in a hard follicle that often requires heat or heat followed by immersion in water to cause it to open. Seedlings are susceptible to damping off and should be germinated in a sterile well-drained medium. Germination requires 21 to 90 days at 20°–25°C (Elliot and Jones 1982). The optimum medium temperature can range from a constant 10° to 25°C or fluctuate by 10° to 15°C (Bennell and Barth 1986). Transplanting is done as soon as the seedling is large enough to handle.

All species grow best in light, sandy soils of acid pH. They are adapted to soils of low fertility, but benefit from a supply of calcium and application of nitrogen, potassium and iron (Sedgley 1996, 1998). Like other Proteaceae, banksias tend to be intolerant to high levels of phosphorus which interfere with iron uptake (Handreck 1991). In cultivation, pruning is necessary to remove shoots that will not flower and to encourage development of

**Table 5.** Some Banksia species suitable for cut flower or cut foliage production. Sources: Parvin et al. 1973; Elliot and Jones 1982; Salinger 1985; Sedgley 1998.

| *Banksia* species | Cut flower | Cut foliage |
|---|---|---|
| *ashbyi* | ✓ | |
| *baxteri* | ✓ | ✓ |
| *burdettii* | ✓ | |
| *coccinea* | ✓ | |
| *ericifolia* | | ✓ |
| *grandis* | ✓ | ✓ |
| *hookeriana* | ✓ | |
| *integrifolia* | | ✓ |
| *menziesii* | ✓ | |
| *occidentalis* | | ✓ |
| *prionotes* | ✓ | |
| *speciosa* | ✓ | ✓ |
| *victoriae* | ✓ | |

shoots with sufficient diameter to initiate the inflorescence (Fuss et al. 1992; Sedgley and Fuss 1992; Rohl et al. 1994; Sedgely 1996).

Sedgley (1996, 1998) notes that there has been little published research on postharvest care of cut *Banksia*. Sucrose pulses did not improve the 15 days vase life of *B. coccinea* (Delaporte et al. 1997), and anti-bacterials such as 0.01% chlorine, acidifiers such as 0.01% citric acid, and 0.02% aluminum sulfate have been recommended as a matter of course, but without verified results (Sedgely 1996).

***GREVILLEA***

A large genus (more than 340 species) of shrubs and trees from dry sclerophyll forests and heaths in Australia (5 species are found in New Caledonia, Sulewesi, and Papua New Guinea), grevilleas have many ornamental uses, especially in landscapes. Growth habits of the most popular species range from prostrate ground covers to mounded shrubs. Some have unusual, asymmetric, or layered habits. A tree form, *Grevillea robusta*, flourishes in sub-tropic climates and has potential as an invasive species because of its abundant seed production.

*Grevillea* have been in cultivation outside of Australia for over 200 years, with the earliest record of introduction of 3 species to England in 1791 and another 15 species in the 1820s (Elliot and Jones 1990). Nurseries in New Zealand and California also grow a wide range of species for landscape uses. As these locations and their native habitats suggest, many grevillea are frost and cold tolerant to –4°C (Elliot and Jones 1990). Drought tolerance is another quality to recommend many species in areas with dry summers.

*Grevillea* inflorescences are mostly toothbrush-like clusters, about 5 to 12 cm in length, and running the color gamut from white and greenish through yellow, orange, purplish, and red, and include some multi-colored forms. Other inflorescence categories include upright spider-like, pendant, or terminal cylindrical clusters. Some have very strong aromas while others are pleasant and sweet. Flowering tends to be seasonal, depending upon moisture, temperature, and daylength. Flowering is strongest in sunny locations and diminished in shade (Wrigley and Fagg 1996). There are also reports of skin irritation and rash from handling some prickly as well as non-prickly species.

While a number of hybrid grevilleas and more tropical species have been selected for large colorful inflorescences (Tully 1977), they are not widely marketed as cut flowers because of short vaselife and a tendency for floret abscission. Although the best can achieve a vase life of 7 to 10 days following cutting, production is said to be low (Olde and Marriott 1995). They are also alleged to be difficult to pack. The potential for their use is good if the problems can be overcome through the use of postharvest treatments, improved packaging, and breeding and selection (Joyce et al. 1996). A sugar, 2% citric acid, and bleach mixture has been recommended for home use, together with maintaining turgor by placing the cut stems in water.

*Grevillea* foliage displays a wide range of textures, colors, and shapes. The textures and shapes range from deeply divided, fern-like and fishbone-like leaves to entire or broadly-lobed shapes and pinnately-divided and regularly toothed and holly-like foliage. Colors range from silver-grey to dark glossy green. Many species have attractive undersurface of silver or bronze indumentum. These elements contribute to their value as landscape plantings, but also to their use as cut foliages. Cut as a growth flush matures, the foliage may last 30 days in water or commercial floral preservatives (Parvin 1991; Criley and Parvin 1993). It is this use that has potential in the floriculture trade. Management practices for cut foliage production need to be developed.

Potted grevillea plants have wide acceptance for patio and garden use both because of their foliage and flowers. They are easily rooted and managed, both by pruning and with growth regulators (Ben-Jaacov et al. 1989). The development of tissue culture techniques enables greater availability of attractive, but difficult-to-root cultivars such as 'Robyn Gordon' (Gorst et al. 1978, Watad et al. 1992). Several potted grevilleas have been introduced into the trade by Israel producers (Ben-Jaacov et al. 1989).

*Grevillea* may be propagated by seed, cuttings, layers, grafting, and tissue culture. Propagation by cuttings is said to be easy with mid to late summer matured growth (Wrigley and Fagg 1996). A Hawaii study indicated that quick dips in liquid auxin formulations (2000 to 4000 ppm) applied to terminal or immediately sub-terminal growth gave satisfactory results in 5 to 6 weeks (Groesbeck and Rauch 1985). Commercial liquid and powder auxin formulations provided good rooting for a number of species. Bottom heat of 29°C with no auxin stimulated 90% take on older wood of *G.* 'Robyn Gordon' (Dupee and Clemens 1981). Interesting landscape forms have been produced by approach-grafting weeping or prostrate forms onto rootstocks of *G. robusta* (Crossen 1990) or *G. banksii* or *G.* 'Poorinda Royal Mantle'(Wrigley and Fagg 1996). The cleft graft was reported successful as well (Dupee and Clemens 1981). However, it is recommended that a healthy top bud be left near the cut to prevent dieback below the graft (Elliot and Jones 1990). Air layering is reported as regularly successful (Tully 1977). Seed germination is enhanced by a presoak in 0.2% potassium nitrate for 12–24 hours, sowing in a sandy medium, and subjecting the seed to alternating warm (25°–33°C) temperatures (Heslehurst 1977). Germination required 4 to 5 weeks. Scarification or seedcoat removal also improves germination (Dupee and Clemens 1981).

More than one-half of the species have been tried in horticulture because of their wide adaptability to a range of soil conditions (Molyneux 1978). Many of the Western Australia species are found on infertile, non-calcareous soils, sands, and leached lateritic soils. Many of the eastern species can be found in clay or clay-loam soils. A few inhabit deserts or rainforests, and some tolerate slightly saline or alkaline soils (Elliot and Jones 1990; Olde and Marriott 1995). Many of the Western Australian species are not demanding of substrate as long as it is well-drained, although there are a few that will even tolerate poor drainage (Olde and Marriott 1995). While they respond to good fertility, high nutrient levels, especially phosphorus, are not required. Controlled release fertilization with careful attention to the form provided is recommended (Bowden 1987).

Longevity under well-fertilized conditions appears to be a problem, especially where the plants are also well-watered (Specht 1978). However healthy 10 to 15 year old plants can be found. These have generally benefited from regular pruning (Elliot and Jones 1990). *Phytophthora cinnamomi* is very devastating to *grevilleas* (Molyneux 1978).

***ISOPOGON***

*Isopogon* is native to temperate Australian regions, with the main distribution in southwestern Australia. Many are coastal or near-coastal in habitat and grow in well-drained, highly-leached sandy or lateritic soils and gravels or clay loams. They range from sea level to moderate altitudes and cope with a wide temperature range down to –7°C, where damage occurs. Full sun is the preferred light environment, but some tolerate semi-shade (Elliot and Jones 1990).

They offer some interesting, hardy plant materials for the landscape, and possibly for the cutflower trade. Most of the 35 described species are temperate zone shrubs of 1 to 2.5 m tall, but a few can grow into small trees (Foreman 1997). Most species are small to medium-sized shrubs while others are dwarf, spreading undershrubs. A number of species are adapted to container culture.

Cone- or drumstick-shaped flower clusters, of white to yellow to pink to mauve, are borne terminally or in the upper leaf axils. Flowering is chiefly in the spring months. A few species have good vase life and are grown commercially in Australia. Among species with cutflower potential are the winter-flowering *I. cuneatus*, and spring-flowering *I. latifolius* and *I. formosus* (Salinger 1985; Elliot and Jones 1990; Foreman 1997). While their cones are decorative, the scales are often shed with the seed.

Seed is not plentiful because it is often lost when the scales dehisce from the cone. Fresh seed, sown shallowly in a moist medium, germinates in 20 to 90 days. One pregermination recommendation is to lightly singe the seed with a flame (Elliot and Jones 1990). Cutting propagation is usually successful when aided by hormone rooting powders.

In culture, controlled release fertilizers with a low phosphorus content are recommended. Established plants are fairly drought tolerant, and over-watering contributes to loss of plants because the wet conditions favor *Phytophthora cinnamomi* infection. Tip pruning following flowering stimulates bushy growth. Species with lignotubers tolerate severe pruning.

***DRYANDRA***

These Australian natives (120 species) have a variable growth habit, ranging from prostrate shrubs to small trees. Foliage characteristics range from soft and needlelike to tough and prickly. The flowerhead resembles a shaving brush surrounded by basal bracts. Flower colors are mainly in the yellow to orange to bronze shades. Their potential as cutflowers needs further evaluation, but some species, such as *D. formosa*, dry nicely and could be added to this niche market (Joyce 1998). Among the recommended cut flower species are *D. formosa*, *D. praemorsa*, and *D. quercifolia* (Elliot and Jones 1984). Many species have foliage so spiny that they are not suitable for floral purposes (Salinger 1985).

Propagation is generally by sowing fresh or stored seed into a well-drained, loose medium; however, seed-feeding insects often render viable seed scarce (Elliot and Jones 1984). Pregermination treatments do not seem necessary (Cavanaugh 1994). Germination times range from 3 weeks to 3 months with an average of 5 to 8 weeks. Transplanting can be done fairly early, when seedlings have attained 50–75 mm in height. Cutting and grafting propagation successes have been reported for some species (Cavanaugh 1994), but neither practice is widely used. Softwood cuttings taken during winter and treated with rooting hormones have yielded some success (Elliot and Jones 1984).

Their native habitats include lateritic gravel, sandy, or granitic soils, always well-drained (Elliot and Jones 1984). Once established, they are said to be more drought tolerant than *Banksia* species (Elliot and Jones, 1984). Many species are fairly cold tolerant, tolerating light frosts or short-lived snowfalls. Cultural conditions for success include full sun, good drainage, and good air circulation. As with other Proteaceae, low fertility is adequate and high phosphorus levels are to be avoided. Chlorosis is a problem on some soils and may be countered with weak iron chelate drenches. A few species are recommended as container plants: *D. ferruginea*, *D. polycephala*, and *D. speciosa* (Elliot and Jones 1984).

***TELOPEA***

Five species of *Telopea* have been described, and a number of hybrids have been released (Dennis 1991; Nixon and Payne 1996; Wrigley and Fagg 1996). They are native to acid, infertile, well-drained soils in New South Wales, Victoria, and Tasmania. As small trees or managed shrubs, they have both landscape value and commercial cutflower use. All species produce terminal, brilliant to rose red (occasional pink, white or yellow) inflorescences up to 15 cm in diameter on stems of up to 1 m length. The florets are arranged spirally on elongated cones subtended by an involucre of similarly colored bracts. *Telopea speciosissima* and *T. oreades* are the principal species for commercial flower production. Unlike other proteas, there is little by-pass by lower shoots. Plants tend to be upright and vigorous.

The most important species, *T. speciosissima* is known as the waratah and is the floral emblem of New South Wales, Australia. Although blooms were originally wild-collected, commercial production has increased in Australia as well as in New Zealand, US (Hawaii), Israel, and South Africa (Offord 1996). Australian production has been reported at 20,000 to 50,000 stems/ha five years after establishment in high density plantings (Worrall 1994), with annual production estimated at 0.6 to 1.7 million stems (Worrall, cited in Offord 1996). The plants are long-lived and capable of production for many years with good management.

While telopeas occur in woodland situations, they flower best in full sun or light shade. Flowering occurs in spring to early summer, but the bloom period is only 4 to 5 weeks duration. Choice of location can influence flowering time as can selection of hybrids (Matthews 1993; Offord 1996). Floral display life is about 7 to 13 days (Dennis 1991) and browning of the bracts can be a problem. The inflorescence is usually harvested before all florets have matured, and is discarded when one-third have turned blue-red (Faragher 1986). Vase life could be extended 3 to 5 days by harvesting when only the first cycle of flowers has matured, by the use of 5% sucrose and a germicidal compound in the water, and by refrigerating the cut flowers at 2°C after hydration (Lill and Dennis 1986). Ethylene does not appear to be a critical factor in senescence (Faragher 1986). Selection for lack of bract browning and low nectar production is a consideration in developing commercial types (Salinger 1981).

*Telopea* are readily propagated from fresh seed with germination occurring in 2.5–4 weeks at 25°C (Worrall 1994; Wrigley and Fagg 1996). Seed can be stored at room temperature for 6 months and for at least 2 years at 5°C (Worrall 1994; Offord 1996).

Semi-hardwood terminal cuttings (20 cm length with 5–6 leaves) of *T. speciosissima*, treated with 2000 to 4000 ppm IBA as a quick basal dip rooted with success rates of 50 to 75% after 8 weeks (Worrall 1976). A talc dust of 0.3% IBA is also satisfactory. Bottom heat of 24°C enhances rooting as does intermittent mist (Worrall 1994). Response varied with season, and cuttings from actively growing mother plants responded better to the low levels of IBA than to cuttings taken in winter from dormant plants. Leaf bud cuttings have been used to increase selected plants when propagative material is limited (Ellyard and Butler 1985). Tissue culture has been successful as well (Seelye et al. 1986; Offord and Campbell 1992; Offord et al. 1992).

*Telopea* culture requires well-drained soils, full sun, and freedom from frost. While their native soils are deep sands, they also thrive on well-drained basaltic clays (Offord 1996). Water requirements are high during summer flower bud initiation. Established plants tolerate a temperature range from 3° to 24°C. Plants are spaced at 1.5 to 3 m in rows with 3 m between rows (Dennis 1991). Pruning at or soon after harvest is practiced to encourage new stems of suitable length for cutflowers in the next season. Rejuvenation pruning is practiced periodically to reduce plant height and encourage production of longer stems (Worral 1994). Pot culture is also possible, but the lignotuber produced by the plants requires a fairly large container (Offord 1996). Potting media need to be well-drained with a pH of 5.5 and low phosphorus content.

### *SERRURIA*

Like many other South African proteas, the genus *Serruria* (50 species) occur in well-drained nutrient-poor soils of the winter-rainfall area (1000 mm) of the Cape Floral Kingdom of South Africa. Their distribution is limited to small, specific localities within this region (Rebelo 1995), and many are endangered because of loss of habitat (Worth and van Wilgen 1988).

The serrurias are small shrubs (prostrate habit to 2 m tall) with fine, feathery foliage and prominent, white to pink bracts subtending the individual flowers borne multiply on one to 11 capitula. Commonly called spiderheads in their native South Africa, serruria inflorescences may be solitary or consist of clusters of small flowerheads. The principal species in commercial culture are *S. florida* (Blushing Bride) and *S. rosea* and their hybrids.

The cutflower serrurias tend to be upright growers. The globose flowerheads range from 3 to 5.5 cm in diameter but appear larger because of the bracts. Flowering occurs in the late winter to early spring, and is known to be stimulated by the long days of the preceding summer and fall (Malan and Brits 1990). Initiation and early development required about 6 weeks and another 10 weeks was required to reach anthesis. Little work has been reported on improving vase life, which is about 7 to 10 days following cutting. The flowers also dry well (Matthews and Carter 1993).

*Serruria* potted plants have good floral display qualities and can be produced in less than one year (Malan and Brits 1990). Cuttings should be taken during the high light, long days of early spring and summer as induced cuttings taken in the fall had low rooting percentages (Ackerman et al. 1995). The flowering period ranges from 30 to 55 days under outdoor conditions. Short durations of darkness as in shipping are not damaging to the post-harvest life of potted plants. Growth retardants such as paclobutrazol inhibit shoot elongation, while ethephon increases branching and branch angle (Brits 1995).

Propagation of serrurias to establish desirable clones is by mainly by cuttings. Ten weeks is required for acceptable rooting, but up to 20 weeks may be required if cuttings are taken during late fall or winter. Cutting bases are dipped for 10 seconds into a potassium salt formulation of IBA at the rate of 4000 mg/L (Ackerman et al. 1995). Techniques to establish and proliferate *Serruria* in vitro have been reported, but the rooting of plantlets from such cultures was not described (Ben-Jaacov and Jacobs 1995). Seed is reportedly long-lived and germinates in response to soil temperature fluctuations following clearing of the understory by fire (Brits 1986a; Worth and Wilgen 1988), but soaking in 1% hydrogen peroxide has been shown to stimulate germination in the laboratory (Brits 1986b).

### *MIMETES*

Known as the Pagoda flowers in their native South Africa, *Mimetes* species bear large terminal flowerheads containing smaller headlets (capitula) bearing few to many flowers. Leaves and bracts subtending these headlets are often brightly colored and may curl around to clasp the flowers. Some species in the Silver Pagoda group bear silvery hairs, making them attractive for this character rather than for colored bracts.

Most of the 13 species of *Mimetes* are rare and found in isolated habitats of the south and southwestern Cape (Rourke 1984), frequently at high elevations in low to moderate rainfall areas. Most are found on sandstone-derived soils, but a few are found in moist peaty soils along marshes and swamps (Rebelo 1995). Coastal species such as *M. cucullatus* also withstand salt winds. Repeated burning maintains the shrub in a rounded form with numerous upright unbranched stems arising from a woody, persistent lignotuber (Rourke 1984). Flowering is most profuse on the vigorous young growth, suggesting that commercial flower production will be dependent upon efficient pruning.

*Mimetes cucullatus* is one of the more widely distributed species. It flowers year around but most heavily during the fall and winter months and offers potential as a cutflower as it produces 30 cm stems tipped with scarlet red and yellow bracts. It is said to have good vase life as a cutflower (Matthews and Carter 1993). It is a long-lived shrub once established and tolerates heavy pruning. Other *Mimetes* species with attractive flowerheads are reportedly short-lived although the seed remains viable for many years, ready to germinate when the natural habitat is cleared by fire (Rebelo 1995).

Cultivation of *Mimetes* requires well-drained, acid soils with some organic matter. Studies of plant management are still needed. Propagation is by seed or semi-hardwood cuttings taken in the fall (Matthews and Carter 1993).

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Ornamental members of the family Proteaceae are now well established in the cut flower and amenity industries of many countries around the world. As with all ornamentals, however, it is imperative that we continue the development of new lines and products to keep pace with the ever-changing market. The most important features of any new cultivar are novelty, quality, yield and reliability.Â  These problems are discussed in terms of cultivar registration and evaluation, and illustrated using Banksia breeding as an example. The Banksia selection program is currently focused on the cut flower species B. coccinea, B. menziesii, B. hookeriana and B. prionotes, and two superior cultivars have so far been identified. The Department of Primary Industries and Regional Development provides: biosecurity/quarantine measures at the WA border to prevent the entry of pest insects where relevant post border biosecurity measures advice on widespread pest insects present in the state. For advice on pest insects search our website, the Western Australian Organism List or contact our Pest and Disease Information Service (PaDIS).Â  Pest insects can have adverse and damaging impacts on agricultural production and market access, the natural environment, and our lifestyle. Pest insects may cause problems by damaging crops and food production, parasitising livestock, or being a nuisance and health hazard to humans. Western Australia is free from some of the world's major pest insects. Pesticides used to ensure better crop health, but can be extremely detrimental to surrounding environments.Â  Organic crops have gathered popularity due to fear of the possible harm of pesticides. What Are Pesticides? Pesticides are chemicals that deter and eliminate certain pest populations including insects, rodents, fungi, weeds, and other animals. The agricultural industry relies heavily on the application of pesticides to protect crop yields from damage. They are also commonly used to exterminate mosquitoes to prevent the spread of malaria, West Nile virus, and yellow fever. Pesticides are known by various names, depending on their target. These include insecticide, fungicide, and herbicide (to n This may affect crop growth and development in the field and potentially affect tuber yield and yield distribution for different cultivars. The hypothesis to do this is; if seed potato physiological age is an important source of yield variation it must impact on at least one of the parameters of yield; i.e. cumulative amount of radiation intercepted by the canopy (Rcum), radiation use efficiency (RUE) or partitioning (harvest index; HI).Â  Yield differences among cultivars were explained by differences in radiation use efficiency (RUE), because the spatial and temporal patterns of canopy development were similar for all cultivars.Â  Soil test were performed using a Ministry of Agriculture and Fisheries Quick Test (MAF QT) procedures. . 46. Proteaceae floral crops: Cultivar development. and underexploited uses. p.410-430. In: J. Janick (ed.), Perspectives on new crops and. new uses, ASHS Press, Alexandria, VA. Malan, D.G. and Jacobs, G. 1990.Â  The use of ambient air led to manage frosting problem. The intermediate two phase fluid with a controlled evaporating pressure, recovering heat from the air, is used to avoid the direct contact of humid air with very cold heat exchanger surface in order to limit the frost formation.