Novel Developments for the New Zealand Floriculture Industry into the Next Century

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Pioneering New Zealand growers and researchers have successfully developed exotic crops such as summer-flowering *Zantedeschia* and *Sandersonia.* The New Zealand floriculture industry requires an ongoing supply of new products that can command premium prices on international markets. This will require the ongoing introduction of new germplasm and the development of new crops, as well as breeding existing crops to introduce new forms and colours. Most new flower cultivars in New Zealand have been produced by conventional breeding techniques. In future, in vitro breeding techniques will increasingly support conventional breeding approaches. Many of the cultivars produced will need to be vegetatively propagated and so improved tissue culture techniques will be required to ensure that New Zealand's floriculture industry remains competitive.

INTRODUCTION

The value of New Zealand's floriculture exports (flowers, tubers, and bulbs) has grown dramatically over the last 18 years from $1.3 million in 1980 to $60-70 million per annum. Although this value is small in relation to the $50 billion of floriculture products traded annually worldwide, it is significant on a national scale.

International trade is dominated by a few standard crops (e.g. roses, carnations) that are high volume, low value, and very price sensitive. The New Zealand industry is not well placed to compete for a market share of these crops due to our high labour and transport costs compared to countries such as Colombia and Kenya. Most New Zealand exports are "exotic" crops or crops produced for niche markets in which we can receive premium prices (e.g., *Zantedeschia, Sandersonia*). The growth in New Zealand exports has been in cut flowers and foliage (now $50 million) and tubers and bulbs ($10 to 20 million). Bulb/tuber exports are expanding rapidly due to increased demand for *Zantedeschia* tubers and the production of tulip bulbs for Northern Hemisphere markets.

NEW PRODUCTS

Pioneering New Zealand growers and researchers have developed summer-flowering *Zantedeschia, Sandersonia aurantiaca*, and *Nerine sarniensis* as cut flower crops. Tuber storage systems have been developed along with dormancy breaking treatments and methods to extend the production season and reduce tuber disorders (Clark, 1995; Clark and Burge, 1997a,b; Dennis et al., 1994; Funnell, 1993). Our understanding of crop environmental and nutritional requirements has also improved (Brooking et al., 1997; Warrington et al., 1989). New crops under development in New Zealand (e.g., *Cyrtanthus elatus*) also require the development of production systems for high quality stems and to extend the production season. The

New Zealand industry requires an ongoing supply of new products so that premium export prices can be received. New cut flower products can be developed by:

- Developing crops from wild flora;
- Developing postharvest techniques to extend the postharvest life of possible new crops to an acceptable level;
- Developing production systems for potential crops;
- Breeding new cultivars.

BREEDING

Conventional breeding techniques have been used in New Zealand to produce a wide range of *Cymbidium* orchid and *Zantedeschia* cultivars (Funnell, 1993). Currently a breeding programme is developing *Leptospermum* cultivars with longer vase life. The native species, *L. scoparium*, has a short vase life but good flower characteristics and so this species was hybridised with two other species to introduce the long-vase-life characteristic (Bicknell, 1995).

Large increases in flower colour range, time of flowering, and quality have been achieved using conventional breeding techniques. However, a major limitation of these techniques is that the pool of genetic variation available within a species is limited. Often characteristics that are perceived as being valuable are seen in other species but it is not possible to transfer these characteristics into the crop of interest by conventional means.

In recent years a range of novel breeding technologies has been developed. These novel breeding technologies can complement conventional breeding programmes by extending the range of genetic material that can be used in breeding programmes as well as determining more rapidly whether the characteristic has been incorporated. The techniques available for enhancing conventional breeding programmes include mutation breeding, wide crosses using sexual or somatic methods, and transformation. Mutation breeding provides a tool for increasing the observed variation within a population. Selection of plants with desirable characteristics can then be carried out. Wide crosses involve combining the characteristics of plant species, which may or may not be related. Progeny can be expected to exhibit traits characteristic of both parent species. Transformation is the process of inserting new genes into plant cells. Wide crosses and transformation rely on inserting new genetic material into the species of interest, whereas mutation simply changes the expression of characteristics that are already present.

Mutation Breeding. Mutations occur naturally and horticulturalists have selected mutants with commercially valuable traits (e.g., new flower colours, dwarf, or prostrate forms). Mutagenic agents, either physical or chemical, can be applied to plant material to increase the frequency at which mutations occur. A range of chemicals is known to have more direct and specific effects on DNA, for example, ethyl methanesulphonate (EMS) is thought to cause random mutations at individual nucleotides. However, these chemicals can also be dangerous to handle and so we use gamma irradiation in our mutation breeding research because it is cleaner and there are no residual chemicals to dispose of. The physical mutagens cause breakages and deletions in the chromosomes. Reported phenotypic changes observed after irradiation of plant material include colour changes and dwarfing.

Spindle toxins (e.g., colchicine) block cell division and produce tetraploids. Tetraploid *Zantedeschia* plants have been produced with this technique (Cohen and Yao, 1996). Triploids can be produced by crossing tetraploids with diploids. Triploids have several potential advantages including enhanced vigor and sterility. Sterility is common in triploids and can be used as part of a breeding strategy to prevent other breeders from quickly producing new cultivars from our cultivar releases.

Wide Crosses. The genetic improvement of crop plants is achieved conventionally by hybridisation and selection within the gene pool of the crop species. New cultivars can be developed by producing interspecific and intergeneric hybrids. A greater understanding of the barriers to producing wide crosses is being gained and techniques are being developed to overcome them. These include pollination and post-zygotic barriers (van Tuyl, 1997). A common postzygotic barrier is abortion of the embryo due to poor development of the endosperm. A number of in vitro techniques are used to rescue the abortive embryo (e.g., ovule culture and embryo culture).

Sandersonia is the third most important export flower crop from New Zealand. However, until recently there were few opportunities to breed new cultivars as little variation occurs in this monospecific genus. Application of wide crossing technology has allowed the development of intergeneric hybrids between *Sandersonia, Gloriosa,* and *Littonia*. These hybrids (taxonomically *Sandersonia* spp.) have new flower colours and forms. Similarly, techniques have been developed that bypass the barriers to the production of *Limonium* hybrids. Two new interspecific *Limonium* hybrids have consequently been developed (Morgan et al., 1994). Many of the existing *Zantedeschia* cultivars are natural hybrids between the summer flowering species. Hybrids have been produced between the summer- and winter-flowering species but only with great difficulty as there are a number of incompatibility problems that mean the hybrids are difficult to grow (Yao et al., 1995).

An alternative approach to bypassing breeding barriers involves protoplast fusion where plant cells from different species are induced to fuse in vitro. Protoplasts are plant cells without their cell walls, the cell walls having been removed by enzymatic degradation using a "cocktail" containing enzymes such as cellulase, pectinase, and often macerozyme. Protoplast fusion has been applied successfully to a small range of plants that are in commercial use but the technique has not yet been widely utilised by plant breeders, despite the fact that it is applicable to a wide range of plant species. Over recent years we have developed protoplast regeneration protocols for a number of species including *Cyclamen*, some members of the Gentianaceae, and a number of *Solanum* species (Morgan and Burge, 1995). Present protoplast work in the lab involves further developing regeneration skills, developing electroporation techniques, and learning electro-fusion techniques.

Transformation. Molecular breeding techniques are being used to introduce new characteristics into crops. This technology enables us to insert known DNA sequences (genes) into plant cells. The genes carry codes for the production of specific enzymes that can catalyse reactions that would otherwise not occur in the plant. As DNA has the same basic structure in all plants, genes can be transferred across species barriers.

Molecular breeding techniques are very specific but can introduce only 1 to 3 genes and, therefore, can only be used to introduce characteristics that are controlled by

a few genes (e.g., flower colour, dwarfism). The Plant Pigments Group at Levin has been studying the use of molecular breeding techniques to produce new flower colours in a number of flower crops. This research includes an understanding of the plant pigments (flavonoids and carotenoids) present in the petals of these crops, the development of strategies to produce new flower colours, and transformation techniques to introduce genes (Davies and Schwinn, 1997).

The most commonly used and most efficient techniques for genetic transformation of cells of dicotyledon plants have been based on *Agrobacterium tumefaciens*. "Foreign" genes are hitched onto this natural plant gene vector and are transferred into the plant cell where they become integrated into the plant chromosomal DNA. However, the success of *Agrobacterium*-mediated DNA uptake by monocotyledon cells (e.g., *Zantedeschia, Sandersonia*) has been limited. This stimulated the development of direct DNA transfer methods which include microprojectile bombardment or so-called "biolistic transformation". The principles of microprojectile bombardment are quite simple. Literally, small particles (approx. 1 μm diameter) of gold or tungsten, onto which DNA has been precipitated, are accelerated to high speed and fused into plant cells or tissues. In some cells the DNA may be stably incorporated into the nuclear DNA. The presence of the introduced DNA can be demonstrated by testing for expression of the appropriate marker genes some weeks or months after the shooting event.

The Plant Pigments Group at Levin has successfully introduced flavonoid genes from species such as *Antirrhinum* to produce new flower or foliage colours in petunia and lisianthus. Scientists have also used antisense techniques to "turn-off" genes and produce white lisianthus and patterned flower colours.

TISSUE CULTURE

Two large commercial tissue culture laboratories in New Zealand each produce several million plantlets per year and a number of smaller laboratories produce smaller quantities. These laboratories produce about 2 million *Zantedeschia* plantlets per year plus a wide range of ornamental, berryfruit, forestry, and vegetable crops. They face competition from overseas laboratories with cheaper labour costs, especially for plants produced in large quantities (e.g., *Zantedeschia*). New Zealand laboratories export tissue culture plantlets to Australia, North America, and Europe. New Zealand laboratories retain their business by (1) supplying a wide range of species, (2) producing high quality plantlets, and (3) introducing new technologies. An example of a new technology is the development of in vitro tuberisation techniques for some crops. Other new technologies include somatic embryogenesis. Somatic embryogenesis systems are being developed internationally for important crops (e.g., conifer species, *Cyclamen*) as these systems have the potential to greatly reduce costs. Somatic embryogenesis systems have been developed in New Zealand for *Pinus radiata* (Aitken-Christie et al., 1994) and a system is currently being developed for asparagus. Research is required on the development of systems for crops relevant to the New Zealand ornamental industry.

LITERATURE CITED

Aitken-Christie, J., K. Gough, D. Maddocks, M. Sigley, F. Burger, and **P.C.S. Carter**. 1994. Towards commercialisation of conifer embryogenesis. Second international symposium on the application of biotechnology to tree culture, protection, and utilization. Bloomington, Minnesota, October 2-6, pp. 181-190.

Bicknell, R.A 1995 Breeding cut flower cultivars of *Leptospermum* using interspecific hybridization N Z J Crop and Hort Sci 23 415-421

Brooking, I.R., L.J. Davies, J.L. Catley, and **E.A. Halligan.** 1997 Temperature and irradiance effects on tuber growth of *Sandersonia aurantiaca* Acta Hort 430 55-61

Clark, G.E. 1995 Effects of storage temperature and duration on the dormancy of *Sandersonia aurantiaca* tubers N Z J Crop and Hort Sci 23 455-460

Clark, G.E. and **G.K. Burge.** 1997a Effects of growing environments, planting date, and stem treatments on sandersonia tuber weight and secondary tuber development N Z J Crop and Hort Sci 25 67-72

Clark, G.E. and **G.K. Burge.** 1997b Effects of planting density, stem cutting treatments, and shade on secondary tuber development in *Sandersonia aurantiaca* N Z J Crop and Hort Sci 25 73-78

Cohen, D. and J-L. Yao. 1996 In vitro chromosome doubling of nine *Zantedeschia* cultivars Plant Cell, Tissue and Organ Culture 47 43-49

Davies, K.M. and **K.E. Schwinn.** 1997 Flower colour pp 259-294 In R Geneve, J E Preece, and S A Merkle (eds) Biotechnology of ornamental plants CAB International, Wallingford

Dennis, D.J., J. Doreen, and **T. Ohteki.** 1994 Effect of a gibberellic acid "quick-dip" and storage on the yield and quality of blooms from hybrid *Zantedeschia* tubers Sci Hortic 57 133-142

Funnell, K.A. 1993 Zantedeschia pp 683-704 In A de Hertogh and M Le Nard (eds) The Physiology of Flower Bulbs Elsevier Science Publishers B V , The Netherlands

Morgan, E.R. and **G.K. Burge.** 1995 Shoot regeneration from protoplast derived calli of *Cyclamen persicum* Mill (Abstr N Z Branch IAPTC Conf , Pakatoa Island)

Morgan, E.R., G.K. Burge, J.F. Seelye, J.E. Grant, and **M.E. Hopping.** 1994 Interspecific hybridisation between *Limonium perigrinum* (Bergius) and *Limonium purpuratum* L Euphyt 83(3) 215-224

Van Tuyl, J.M. 1997 Interspecific hybridization of flower bulbs A review Acta Hort 430 465-476

Warrington, J.J., N.G. Seager, and **A.M. Armitage.** 1989 Environmental requirements for flowering and growth in *Nerine sarniensis* Herbertia 45 74-80

Yao, J.L., D. Cohen, and **R.E. Rowland.** 1995 Interspecific albino and variegated hybrids in the genus *Zantedeschia* Plant Sci 109 199-206