plants and I am sure it could be used just as successfully with rainforest species.

A large number of rainforest plants have the potential to become important ornamentals. Propagation should not present any serious problems. The main limitations are in knowledge of the species and availability of propagation material.

COMMERCIAL PRODUCTION OF KANGAROO PAWS

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INTRODUCTION

There has been a rapid expansion of interest in the development and production of Australian native plants. One genus which has received a great deal of attention is *Anigozanthos* (kangaroo paws). Kangaroo paws blooms, originally all bush-picked, are currently available from commercial plantings. Now, the potential of kangaroo paws as "potted colour" is about to be realised.

Extensive work has already been done with *Anigozanthos* in areas such as taxonomy, ecology, evolution, hybridisation, plant selection, micropropagation, field cultivation, pathology, and flower production. However, much of the horticultural information has been published for the gardening fraternity or as a result of scientific investigations into the biology of the genus. With the introduction of kangaroo paws as cultivated cutflowers, information relevant to field production has been gathered by workers in Western Australia. Other information is less easily available as it originates from the experience and observations of gardening enthusiasts, plant breeding experts, and unpublished research work.

At the University of Sydney, work is aimed at the production and utilisation of new hybrids of *Anigozanthos* as containerised plants.

PLANT IMPROVEMENT

Many species of *Anigozanthos* are not well-suited to field cropping or nursery production methods. *Anigozanthos flavidus* is the most vigorous, reliable, and long-lived of the species but produces flower stems which are up to three metres in height and are generally unspectacular. *A. manglesii*, the red

and green kangaroo paw, Western Australia's floral emblem, produces stunning single terminal inflorescences but is highly susceptible to two major fungal diseases — rust (*Puccinia haemodori*) and ink disease (leaf blackening). Other species such as *A. rufus*, *A. humilis*, *A. preissii*, and *A. onycis* produce magnificent flower colour and form, with a dwarf habit, but are relatively short-lived.

Considerable effort has been put into the hybridisation and selection of new cultivars of the popular kangaroo paws. The work by S. Hopper and K. Oliver in Western Australia, and M. Turner in Victoria is particularly noteworthy. Hopper (9) undertook studies on the evolution, ecology, and natural hybridisation of *Anigozanthos* species in Western Australia and produced many F_1 interspecific hybrids, four of which found their way into the nursery industry. These were *A. preissii* × *A. flavidus*, *A. onycis* × *A. flavidus*, *A. rufus* × *A. flavidus* and *A. manglesii* × *A. flavidus*. Selections from the first three are now widely known as 'Regal Claw', 'Dwarf Delight', and 'Red Cross', respectively. These studies provide valuable information on reproductive biology, pollination, seed set, germination rates and phenotypic heritability (10,11,12,13).

Oliver (18) initiated breeding and selection work aimed at synthesising new hybrids of significant horticultural value and has succeeded in producing a range of selections of complex parentages, over several ploidy levels, which are currently being released commercially. Turner has established an extensive and systematic breeding programme aimed at drawing on the full potential of the genus for floral characteristics, growth habit, and disease resistance. His selections for cut flower production have drawn considerable attention to the crop in the U.S.A. (19). Other cultivars are aimed at the containerised plant market (Turner, pers. comm.).

The University of Sydney has been involved in the hybridisation of kangaroo paws since 1981. Cross-pollination of selected species has resulted in a range of exciting new hybrids which are proof of the great potential of kangaroo paws as a flowering pot plant crop. However, with the impending release of these and other new cultivars for nursery production, research is concentrating on the means by which flowering can be manipulated to ensure the ability to produce a flowering crop to meet market demands.

PROPAGATION

The first area of concern is the method by which this crop can be produced in sufficient quantity for commercial production. Seed supplies are often scarce, particularly for the more

unusual species (26). Germination rates of available seed are usually low and variable for many species, although slightly improved with hot water and chemical pre-treatments. Some hybrids are sterile and do not set seed at all (10). Development of the seedling to flowering is slow, taking nine to eighteen months (10), and variability in flower quality and productivity is well-established (3). Rhizome division has been an alternative method of propagation but the rate of multiplication of material still remains low, as well as unreliable. It cannot realistically be considered for large-scale production.

The most effective means of commercial propagation of kangaroo paws is through the use of tissue culture techniques. Establishment of *A. flavidus* in culture media was first documented at Canberra Botanic Gardens (17). Ellyard (2) successfully induced the formation of multiple shoots of *A. manglesii*, *A. flavidus*, and *Macropidia fuliginosa*, and successfully re-established plantlets in soil. McComb and Newton (16) reported surprisingly high survival rates of tissue-cultured plants re-established in potting mix, and they recorded flowering in less than four months after removal from 5 cm tubes.

In recent years, micropropagation of kangaroo paws has moved from the scientific research laboratory to commercial tissue culture establishments. New plant selections can now be established in culture and rapidly multiplied to large numbers. Experience with nutrient media, culture conditions, and transplantation procedures for kangaroo paws exists in the commercial sector because of the large-scale production of the Hopper hybrids *in vitro*. This, in fact, has been a major contributing factor to the wide distribution of these hybrids as representatives of *Anigozanthos* in retail nurseries and provides evidence for the potential of this method of propagation. Despite risks of induced phenotypic variation and latent microbial contamination, of major concern to research and commercial laboratories alike, micropropagation offers the best method for the rapid multiplication of kangaroo paws.

GROWTH REQUIREMENTS

Transplantation from Tissue Culture. Little is known of the optimum conditions for growth in the early stages of crop development of kangaroo paws from tissue culture. Kangaroo paws is relatively easy to re-establish in soil in comparison to some species, for example *Grevillea* cv. Robyn Gordon (15). Survival rates of 80% were obtained by McComb and Newton (16) and increased to 95% when an anti-transpirant spray of Acropol® 1% (v/v) was applied to plantlets.

Rapid adaptation of tissue-cultured plantlets to the exter-

nal environment demands the initiation of photoautotrophic growth and development of functional roots after transplantation. Initiation of root primordia using indole-3-butyric acid (IBA) in the final stage of subculturing enhances rooting on transfer from culture to potting media (16). It is the author's experience that rooting of individual shoots in culture leads to reliable plant survival, early establishment, and uniform crop growth after transplantation. Material can also be transferred directly from multiplication media into soil but an effective means of initiating roots soon after removal from culture is essential. Hughes (14) found that 250 ppm IBA applied as a quick-dip — with mist — promoted early root initiation and development.

High humidity is an important environmental factor used to maintain plant turgidity until growth begins. However, care must be taken to ensure that over-wet conditions do not develop. Excessive wetting of the leaves and waterlogging of the growing media can cause black leaf spots, poor growth, and/or survival. It is recommended that newly transplanted material be placed in a protected environment designed to maintain high relative humidity until growth is apparent.

The growing medium should provide good drainage and aeration for young plants. A mixture used successfully at the University of Sydney is 1:1, peat:sand, moistened and drained prior to planting. This mixture retains adequate soil moisture under a humidity tent for initial root development. The nutrient requirements of newly transplanted kangaroo paws have yet to be investigated.

Even, moderate temperatures between 20°C and 27°C are generally recommended when transplanting tissue-cultured plants (1). Exposure of *A. manglesii* seedlings to low temperatures, 12° to 15°C, early in development has been reported to favour plant growth and floral initiation (7, 24). However, the vegetative growth of *A. manglesii* and *A. flavidus* plantlets from culture was found to be optimal at 24°C (day) and 19°C (night) (14).

The survival and subsequent growth of transplants may be enhanced by the initial use of low light and the gradual introduction of high light intensities. However, a 50% reduction in light showed no beneficial effect on the growth of *A. manglesii* and *A. flavidus* (14).

Growing on Potted Plants. It has been found that kangaroo paws will not tolerate very wet or alkaline soil conditions, which induce iron deficiency. They do best in well-drained, moderately acidic, sandy soils, in full sun (25,26). At the University of Sydney, mixtures of German peat and coarse quarry

sand provide adequate growing media for potted plants. However, the identification of a better mixture to decrease net weight, while maintaining good drainage, would certainly be beneficial to commercial growers.

Favourable growth responses of Kangaroo paws to high nutrient levels have been reported. In pot trials, *A. flavidus* showed increased plant height and lateral shoot production with high levels of phosphorus, potassium, and nitrogen (4). Growth of a range of *Anigozanthos* species and hybrids, under hydroponic conditions at Knoxfield in Victoria, was found to be very vigorous, and plants flowered outside their normal season (8).

Watering has been found to be critical when flower buds are developing. The combination of a limited medium volume, rapid root growth, good drainage, and warm temperatures may lead to the wilting of young flower stems. Older flower stems tend to retain their rigidity better under water stress. It is desirable to keep the foliage as dry as possible since constant wetting by overhead irrigation increases plant susceptibility to foliar fungal diseases.

CONTROL OF FLOWERING

Temperature is the single most important environmental factor affecting flower production in *Anigozanthos*. Grieve and Marchant (6) reported the work of Went (1956) in which temperatures of 17°C (day) and 11.5°C (night) were said to produce the best growth and flower colour in *A. manglesii*. No details of the experiment are available. The conclusion was drawn that flowers in this species only form under low temperatures and that this is the reason for spring flowering after flower formation in winter. This conclusion has been investigated in recent studies at the University of Sydney.

Van de Krogt and Noordegraaf (24) showed that temperatures of 15°C (day) and 12°C (night) resulted in a greater number of flower stems in the first flowering season than other temperature regimes. However, in a subsequent study (22), higher temperatures were found to induce a high flower yield in the second flowering season. These results suggest that cold temperatures favour floral initiation but that flower evocation is hastened by higher temperatures.

Hagiladi (7) found that pre-cooling *A. manglesii* seedlings at 10°C enhanced growth at 25°C and hence, lateral shoot production and flower yield were increased. The best growth of seedlings was obtained at 20°C (day) and 12°C (night). It is suggested that vegetative growth is initiated when night temperatures are 12°C to 15°C and that maximum lateral shoot

production should be obtained before night temperatures are lowered to 10°C. At this temperature, floral initiation is said to take place. Floral evocation is reported to be directly related to temperature. With increased temperatures, more flowers appear.

Work at the University of Sydney has investigated the pattern of flower development under natural conditions. It is found that floral initiation in field-grown kangaroo paws occurs in the autumn, flower bud development is slow through the winter months, and as temperatures increase in spring, the flower stems appear (Motum and Goodwin, unpub.). Thus floral initiation occurs earlier than previously suggested by Grieve and Marchant (6).

The use of micropropagation is a new strategy in kangaroo paw production. However, interesting effects have been observed. Flowering of plants from seed occurs in 9 to 18 months (10). McComb and Newton (16) reported flowering of plants from tissue culture in less than 4 months after removal from tubes. Current studies on tissue-cultured plants of *A. humilis* × *A. flavidus* at 21°/16°C indicate that floral initiation is evident soon after deflasking. The control of floral induction, synchronisation, and uniformity of flower production within a crop is now a major area of research.

Studies so far have revealed that, although transplantation from tissue culture is best done under controlled conditions, complete plant development under glasshouse conditions may prove problematic. Temperature studies indicate that high temperatures encourage flower induction but flower colour tends to fade. Temperatures of 30°/25°C produced stunted and aborted flowers without pigmentation (Motum and Goodwin, unpub.). Low temperatures maintain strong flower colour but slow flower induction (Motum and Goodwin, unpub.). Flower colour is associated with anthocyanins present in the branched hairs covering the racemes. The intensity and shade of colour of the flowers may vary with changes in pH due to their ionic character (5). Flower colour of kangaroo paws under controlled conditions may be manipulated with the use of acid or alkaline solutions, but techniques have yet to be investigated.

Photoperiodic studies suggest that responses to long and short days may be variable in Kangaroo paws. Van de Krogt (24) and Hagiladi (7) reported little or no effect of day length on flower formation. However, long days (16 hrs day/8 hrs night) have been reported to hasten flowering in *A. flavidus*, while short days (8 hrs day/16 hrs night) encourage flowering in *A. manglesii* and *A. rufus* (Motum and Goodwin, unpub.). The degree of response may depend on the species or cultivar

receiving attention.

DISEASES

The most serious problem of kangaroo paws is disease control. Kangaroo paws have been found to be susceptible to two major fungal diseases. Ink spot disease, or leaf blackening, has always been associated with field cultivated Kangaroo paws, but is particularly significant in the production of perfectly formed potted plants. It is reported to be caused by *Alternaria alternata* (21). However, the plants themselves also produce chemicals which are seen as a blue/black ink in tissue culture media and show blackening with tip senescence, even in sterile conditions, suggesting that the situation may be more complex. Harsh chemical sprays can also be instrumental in causing leaf blackening.

The second foliar disease is rust, caused by *Puccinia haemodori* (20). Until recently, this disease had only been recorded on Kangaroo paws in Western Australia. It is now known that this disease may be a threat in the eastern states. Moist conditions favour these diseases although some measure of control has been reported with the fungicide Mancozeb® (3,26). Breeding and selection of Kangaroo paws looks to be the most effective means of limiting these problems at present. Work at the University of Sydney has been undertaken to collect further information on these problems.

CONCLUSIONS

It is evident that kangaroo paws have been the subject of extensive study. In addition to their use as cut flowers, they will soon be available as containerised plants. With exciting new cultivars being produced by plant breeders, further information on propagation, growth requirements, control of flowering, and disease problems of *Anigozanthos* will be needed by commercial growers.

Micropropagation offers the most effective means of rapid multiplication of new plant selections. Problems associated with tissue culture production remain the subject of ongoing research. As Kangaroo paws is new to cultivation as containerised plants, information on optimum growth requirements in this context is limited. However, knowledge is expanding. The control of flowering remains a problem, although a practical approach to programming flowering pot plant production is being developed at the University of Sydney. The basis for the successful production of Kangaroo paws as a commercial crop is the effort put into plant improvement and selection for disease resistance. Further research is now needed in critical

areas of commercial production to do justice to these new selections.

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PROBLEMS AND OPPORTUNITIES IN TROPICAL FRUIT TREE PROPAGATION

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INTRODUCTION

Tropical fruit tree propagation as referred to in this paper is largely confined to those species of tropical or subtropical origin which are not major industries in northern Australia. However a few more established crops (e.g. mango and lychee) are included in the context of developments and problems associated with plant quarantine introduction and propagation.

There has been little innovative research in propagation of the "emerging" tropical tree fruits in terms of support from government institutions in Australia. This is perhaps justified in the order of research priorities. However, as varietal screening and market development proceed, the few fruits with sustained market prospects will be identified.

Developments in propagation techniques to date have largely arisen from the initiatives of individual nurserymen, and trial and error in quarantine facilities where problems in establishing importations have arisen.