TOWARD THE DOMESTICATION OF KANGAROO PAWS

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Summary

Until very recently, the history of Kangaro Paws in cultivation has been one of repeated but largely unsuccessful attempts to cultivate wild species. Only one of twelve such species has provided hardy long-lived plants for cultivation in warm temperate climatic conditions. The major hazard has been "Ink Disease". Now, following research, the establishment of "in vitro" methods for routine propagation, and the first releases of improved cultivars from systematic breeding programs, Kangaroo Paws may have been set upon the path of domestication as new ornamental plants. This article summarizes the main strategies, techniques, and results of a selection, breeding and allied research program.

1. Introduction

Kangaroo Paws consist of eleven species of *Anigozanthos* and the allied monotype *Macropidia fuliginosa*, and the general popular name should extend to cultivars. They are Winter/Spring active, sometimes late Summer dormant, herbaceous perennials with persistent rhizome forming clumps of leaf fans, each fan eventually producing a flower stem 1.5 to 2.5 times the height of basal leaves. There is significant variation between, and also within, species of stature, flower stem architecture, leaf and flower colour, flowering season (normally in the range late Winter, Spring, Summer) and other characters relevant to a potential ornamental plant, and this potential has been long recognized. The coloured woolly indumentum which clothes flowers and stems is a particular feature.

However, the wild species have had a long, episodic, and problematic history in cultivation. Only the Tall Kangaroo Paw (*A.flavidus*) has provided hardy, long-lived plants relatively popular in cultivation in temperate Australia.

Flowers of several species (notably *A.manglesii*, *A.pulcherrimus*, and *M.fuliginosa*) have been cut from wild populations for both local and export cut flower consumption. Attempts have been made to at least supplement this through cultivated plantations, but have proven hazardous. Trial or moderate production for cut flowers has occurred elsewhere (Israel, California, New Zealand, Japan and Holland).

The essential point of all this earlier history is that cultivation has been solely of wild seedling arrays, or, later, of a few naively chosen, vegetatively propagated, species or hybrid clones. By and large, the problematic aspects of cultivation have persisted, with "Ink Disease" by far the most important problem, and with devastating levels in monoculture not infrequent.

However, three separate but inter-related developments over the last ten years may have set Kangaroo Paws on the path of successful domestication and application. These circumstances are:

1.1. Research

Botanical studies have clarified taxonomy, ecology, aspects of reproductive biology, biogeography and related matters (much of which has value for selection and breeding). Horticultural research has led to improved production methods and suggested the feasibility of cultivation by hydroponic methods and/or in controlled environment glasshouse conditions. Thirdly, plant pathological studies have (finally) produced a very considerable clarification of the "Ink Disease" syndrome.

1.2. "In vitro" propagation

Propagation by seed germination is problematic, and vegetative propagation by division of rhizome while quite reliable is labour intensive and therefore costly. Both facts have constituted a handicap in both research and commercial settings. Easy and cost effective clonal propagation by "in vitro" methods is now established and more or less routine. Explants of apical meristematic regions with a few leaf primordia and modified M. and S. media are more or less standard elements of such propagation, with four to five-fold multiplication every four to five weeks being typical. Rooting of shoots "in vivo" can be easily achieved in appropriate conditions.

1.3. Cultivar development and release

Selection and breeding programs have begun to release improved cultivars. Improved resistance to "Ink Disease" if not full immunity, is a feature of many of these cultivars, and with good empirical performance in monocultural settings including nursery production and cut flower plantations. Most released cultivars are inter-specific hybrids, some with relatively complex pedigrees.

Much of the activity in these three areas has been based in Australia, but trials, research, and some commercial application of these newer cultivars has begun recently elsewhere. The time may be opportune, therefore, to illustrate some of this activity. This will be attempted through a summary of the main elements of the author's selection, breeding, and allied research program.

Reference will be made to breeding system and basic breeding scheme, the controlled pollination technique, the question of inbreeding, aims of selection and breeding, parental selection, intra-specific and inter-specific hybridization, infertility and induced polyploidy, ancillary uses of "in vitro" methods, and future developments.

2. Breeding system and basic breeding scheme

All Kangaroo Paws show substantial but not absolute self-incompatibility (with A.flavidus having the greatest departure from the absolute level).

However, they are also protogynous species. Nectar flow and stigmatic receptivity are established prior to flower opening and are in decline by the time of pollen dehiscence (normally two to three days after opening).

Wind and insects are ineffective in pollen transfer. Nectar-feeding bird species are the only clearly established biotic pollination agents. An "architectural" matching of floral anatomy and shape to that of the head parts of the birds, with pollen transfer effected by head patch feathers, suggests a specific adaptation of Kangaroo Paws to bird pollination.

In these joint circumstances, it is clear that Kangaroo Paws are dominantly outbreeding species, and that individuals are genetically heterozygous.

Kangaroo Paws are also perennial species capable of vegetative propagation.

Thus, being perennial outbreeders, clonal breeding in the sense of Simmonds (Simmonds, 1979) is the appropriate basic breeding scheme. That is, selection is exercised on the families of variable heterozygotic individuals generated from heterozygotic parents. Such selection is normally practised on successive vegetative generations, with any ultimate selection also being propagated vegetatively.

It can be noted that, whatever additional breeding strategies are employed, and however many segregating stages may be planned, superior individuals may arise at any stage.

3. Controlled pollination technique

Nectar-feeding bird species (not only those indigenous to wild habitats) must be excluded from the breeding environment. (The author, in the environment of southern Victoria, has found it convenient and successful to house breeding stocks in a "walk-in" polythene-film clad tunnel with screen-mesh doors.)

Emasculation of flowers has been found to be unnecessary (except for A.flavidus) in the condition that intended pollen transfers are made on the first day of flower opening. In this condition, unintended progeny (mostly "selfs") are extremely rare.

The simplest effective means of transfer of pollen is by whole anthers held in small forceps or tweezers. A finger pressure technique on the perianth tube produces a separation in the natural contiguity of stigma and anthers in any one flower during pollen transfer.

Storage of partly dehydrated and frozen pollen has been effective and permits hybridization of parents with little, if any, overlap in flowering season. Recently dehisced anthers provide the most suitable material and items for storage.

Full reciprocal hybrids at the diploid level appear equivalent, but seed set levels are higher where the female parent has the shorter style (implicating processes of pollen tube growth). Greater efficiency results from transferring pollen of the longer-styled member of any diploid parental pair.

4. The question of inbreeding

Inbreeding is normally avoided in the breeding of perennial outbreeders, but can have a limited role provided the expected inbreeding depression is not too severe.

Selfing (or, more realistically, attempted selfing) through several generations with a sample of Kangaroo Paws of specific status, indicated severe inbreeding depression (except for A.flavidus which was more moderate).

Dwarfing, growth abnormalities, and reduction of fertility were frequent and expressed in early generations. Inbreeding appears inappropriate, and accurate pedigree records are advised to avoid inbreeding by default.

5. Aims of selection and breeding

The paramount aim has been to achieve operational resistance to "Ink Disease", involving selection and appropriate cultural conditions in interaction.

"Ink Disease" is probably best conceived as variable effects of a multiplicity of causal factors - alone or in combination. The common denominator of effects are necrotic regions, largely confined to leaves, having a deep purplish-black colour - a generalized form of response to various stresses. (It can be noted that a similarly coloured exudate in the medium occurs with most explants in aseptic "in vitro" propagation). The more severe the effect the more likely are secondary diseases; and premature death is a frequent occurrence with most species - A. flavidus being exceptional (but not immune).

"Ink Disease" can be attributed to frost action, poor root zone aeration, salinity, nutrient disorders, severe wilting and severe mechanical damage. Other conditions being equal, onset is frequently a correlate of senescence of older leaves. Such causes are in principle subject to control, and the routine provision of good cultural conditions is always to be recommended.

However, even in the best of apparent circumstances, "Ink Disease" can develop, and here is almost invariably attributable to particular air-born fungal species. Earlier reports of pathogenicity for some fungal species should be discounted, but pathogenicity is clearly involved with Alternaria alternata, one (possibly two) species of Alternaria new to science, and Puccinea haemodori (for which a typical orange-brown "rust" may initially mask purplish-black necroses). Even where some fungicidal or fungistatic agents show control effects, required spray programs are uneconomic for large monocultural settings of susceptible genotypes.

Phenotypic variation, replication across sites and seasons, and pedigree records indicate that genetically based resistance(s) exist(s) and can be inherited. Levels of heritability are as yet unknown but sufficient for practical purposes. However, with several fungi and other causes or co-factors involved, attempts at successive selections for specific resistences would be, at least, logistically daunting. Further, adaptive genetic plasticity of Alternaria species, with other horticultural subjects where specific resistances are found, is well known (the so-called "vertifolia" effect). In these circumstances the author has sought a generalized field or "horizontal" resistance by practising selection in field conditions, across sites and seasons, and in the face of at least seasonally high levels of inoculum of all fungal species. The practical criterion is of at most minor necrotic development confined to older senescent leaves and with clean new seasonal growth.

In these circumstances such cultivars in good cultural conditions, including an annual pruning and destruction of senescent materials, appear to provide a successful formula for economic cultivation.

Other aims relate at broadest level to ornamental horticultural applications with human selection of plants suited to one or more of:

- outdoor (garden or similar) cultivation
- field cut flower production
- container-grown flowering plant production
- cut flower or container-grown production in protected environments.

6. Parental selection

This refers specifically to basic breeding clones of species status. Selection occurs as indicated previously. Two relevant additional points are as follows. First, that some such clones have now been propagated through at least ten vegetative generations with no sign of "clonal degeneration" with respect to "Ink Disease". Second, that new resistant species selections are more or less constantly identified to expand basic breeding stocks to facilitate, for example, back-crossing procedures where at least several independant recurrent parents may be required to avoid inbreeding.

7. Intra-specific and inter-specific hybridization

Both classes of hybrids have been generated, but in the author's and other breeders' experience, greater progress appears achievable through inter-specific hybridization. There appear to be no insuperable barriers to the generation of F_1 inter-specific hybrids between Anigozanthos species by traditional techniques - even if seed set and germination rates are very low for some combinations. It may be noted that all Kangaroo Paws have the same basic (= haploid) chromosome number of six, that chromosomes are small, and polyploids appear unrepresented in wild populations. Intergeneric hybrids of Macropidia and Anigozanthos have, apparently, not been synthesized.

From the point of view of further breeding F_1 inter-specific hybrids vary enormously in fertility - from profoundly infertile to some which display "heterotic" seed set levels, compared to parents, against a range of independant pollen parents.

Inter-specific hybrids have been carried beyond the F_1 generation at the diploid level, and many have been synthesized, but too few as yet to comment on trends in fertility. Some tendency to "breakdown" of self-incompatibility has been observed.

While inbreeding through strict selfing or use of closely related parents has been avoided with second and later generation crosses, quite variable families of bi-specific, tri-specific, and even more parentally complex progeny have been obtained.

8. Infertility and induced polyploidy

High to profound infertility constitutes a barrier to further breeding with some F_1 inter-specific hybrids. Colchicine treatments, using various techniques, have been successful in inducing polyploidy. Where outcomes are stable, tetraploidy appears to be the usual result. In such cases, fertility is restored and, macroscopically, larger flowers, frequently with a denser indumentum, is the invariable result, but with less consistency in other characters.

Hybridization at the tetraploid level and between diploid and tetraploid parents has been achieved but insufficient evidence exists as yet on karyotypological consequences - but several putative triploids fail to show the expected profound infertility.

9. Ancillary uses of "in vitro" methods

Although the incidence is low (of the order of one plant in several thousand), atypical plants do occur in commercial "in vitro" propagation. Somaclonal variation of plants regenerated from callus cultures has been demonstrated. Such experience may become of value in generation of additional genetic variation, but traditional breeding methods have not yet exhausted existing variation.

Of more interest is the successful germination of otherwise difficult to germinate seed "in vitro", which is of value for rare seed of promising crosses. Consideration is being given to the possible applicability of embryo rescue.

10. Future developments

To date, the program can be regarded as largely exploratory and involving various contingent experiments. None-the-less, it has already yielded a range of commercially successful cultivars. The major future development will be to exploit in larger quantitative terms, those basic parents, breeding pathways and techniques identified as of greatest value or promise.

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