

A proposal for consideration: Establish a northern Australia cooperative tree improvement program (NACTIP), initially with African mahogany (*Khaya senegalensis*).

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Summary

Conservation and domestication of *Khaya senegalensis* in northern Australia commenced very recently. It has involved: planting a provenance seedling seed orchard at Walkamin, Queensland (2001); mild selection in provenance trials and relatively small, unimproved stands in the Northern Territory (NT) (2001) and at Weipa, Queensland (2003); the planting of grafted seed orchards in the NT (2002), at Walkamin (2003) and Weipa (2004); and work that will lead to clone tests being planted in the NT and at Weipa early in 2005.

There is interest from Managed Investment Schemes and others in starting commercial plantings in Queensland and perhaps elsewhere soon. It results from the success of first trial plantings of *K. senegalensis* more than 30 years ago near Darwin and Weipa and subsequently elsewhere in northern Australia. Logs with high value timber have been made into excellent furniture. However, because the early and current plantings derive from genetically unimproved seed, they contain many trees with short and crooked boles. Improved breeds would increase returns on plantation investment.

The species is also emerging as of considerable interest in some countries in Asia and elsewhere. No tree improvement programs are known to be in place nor planned outside northern Australia. Therefore, the products of tree improvement in northern Australia could be used there and, potentially, in overseas plantings.

It is suggested that the work done already, and the good prospects for the species in commercial plantings, provide stakeholders with an opportunity for formal cooperation (with its many advantages) not to be missed. Provided all interested parties pool resources and plan concerted efforts, there could be rapid progress in genetic improvement of the species. It is suggested that stakeholders in a potential plantation forestry industry in northern Australia should form a cooperative and undertake tree improvement with *K. senegalensis* initially, preferably in parallel with the other R and D needed to underpin such an industry, and to do so with a minimum of delay.

The case for a Northern Australia Cooperative Tree Improvement Program (NACTIP), proposed to be based on *K. senegalensis* initially, is strong because: breeding has begun; there must be great genetic variation in *K. senegalensis*; traits most in need of rapid improvement have been identified; the reproductive biology of the species is favourable; it seems likely there will be a substantial, annual plantation program beginning in the near future; and the few resources available to each of the separate programs are limiting their development.

There are many good precedents for tree improvement cooperatives, with university-based programs being especially advantageous. Opportunities exist for establishing such a cooperative, or one based on another of the successful models, customised to suit the circum.

Introduction

The Workshop on “Prospects for high-value hardwood timber plantations in the ‘dry’ tropics of northern Australia”, held at Mareeba, Queensland during 19-21 October, 2004, attracted 20 Working Papers and two, broader-focus Keynote Working Papers (Bevege et al. 2004). More than a half of the former papers addressed *Khaya senegalensis* Desr. (A. Juss.) (African mahogany), either directly or in association with other species. Those papers reporting on results of species trials or other aspects related to the domestication of *K. senegalensis* (adaptability, growth, gene conservation and tree improvement, sawlog recovery, timber quality, value of products and market prospects) were unanimous in the view that *K. senegalensis* is the commercially most promising high-value hardwood (HVH) timber species that has been or is being tested in the ‘dry’ tropics of northern Australia. Moreover, industrial and agroforestry plantings with *K. senegalensis* are starting or are proposed for north Queensland in the Burdekin, Cooktown and Lakeland regions (Dickinson et al. 2004, Jago 2004; pers. comms M. Bell 2004, G. Sexton 2004 and E. Wiles 2004). As well, the Northern Territory (NT) government has an African mahogany timber industry strategy (Whitbread 2003), and it seeks to encourage commercial planting of the species in the NT (Speech, by Hon. Kon Vatskalis, MLA, NT Minister for Primary Industries and Fisheries, at the launch of the NT’s African mahogany industry strategy, Darwin, 23 June 2004).

Some other Workshop papers demonstrated that a few other HVH species are either in early stages of commercialisation in northern Australia with little or no tree improvement in place (eg. sandalwood – Done et al. 2004), or show some promise for future commercialisation [eg. teak (*Tectona grandis*) – Reilly et al. 2004, Robertson and Reilly 2004]; and *Chukrasia velutina* – Gunn et al. 2004, who also mentioned the uncertainties regarding taxonomy and authorities for species epithets in the genus. Pilot plantings of teak have been made in two areas in north Queensland, and these may lead to commercial plantations of the species there or elsewhere in northern Australia. Additional species, from among the numerous under test (Bristow 2004), or others yet to be tested, may be commercialised in the future.

Since tree improvement with *K. senegalensis* in northern Australia, though only commenced in 2001, is more advanced than with any other HVH species suitable for the ‘dry tropics’ there, commercialisation of this species seems closer, and for other reasons given in this paper, it proposes establishment of a cooperative tree improvement program with this species initially. However, this does not preclude the addition of other species either soon or some time later.

The paper also:

- looks briefly at how the development and dispersal of new varieties of crop plants is undertaken (with a view to gaining insights that might be useful in the context of the present paper),
- reviews the status of domestication of *K. senegalensis* in northern Australia,
- gives examples of existing tree improvement cooperatives,
- outlines a case for establishment of a northern Australia cooperative tree improvement program (NACTIP), and
- suggests means by which a NACTIP might be initiated.

Prospects for *K. senegalensis* to underpin a plantation industry in northern Australia

Nikles et al. 2004a showed that stands of *K. senegalensis* planted in the early 1970s totalling around 7 ha have survived and grown well near Gunn Point and near Howard Springs in the Darwin region, with tallest trees at 30 years of age being 28 m and 25 m respectively. Remarkably, one small stand of 0.4 ha, planted in 1970 near Howard Springs at 4 440 spha and never thinned, averaged 91% survival at just over 34.5 years of age. Reilly et al. 2004 reported 4.5- and 5.5-year growth, stem straightness,

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bole length and other aspects of tree performance in trials of mostly HVH species established on a wide range of sites (6) around Adelaide River, Darwin, Katherine and Marrakai in 1998-99 and 1999-00. They found that “African mahogany showed the best growth across a number of sites (actually 6 sites - DGN) and appeared more adaptable to site (soil) variability than some other species evaluated such as *Swietenia humulis* Zucc. and *T. grandis*”. [However, African mahogany was generally inferior to *T. grandis* in stem straightness and bole length, and to *S. humulis* (Pacific mahogany) in stem straightness. These traits particularly are being targeted for genetic improvement in the breeding program with *K. senegalensis* in the NT – Nikles et al. 2004a].

Several other papers presented at the Workshop provide additional evidence of the adaptability and favourable silvicultural features of the species over a wide range of conditions in northern Australia. Bragg et al. 2004 reported on the best of many stands established at Weipa, Queensland in the 1970s in rehabilitation of mined areas, and unmanaged subsequently. In 2004, the best 90 trees per ha (out of an original 667 per ha), had an average diameter at breast height (dbh) of 31.7 cm, or an impressive mean annual increment in dbh of 1.2 cm. Survival at 27 years of age was almost 100% and the stand had large numbers of merchantable trees (pers. comm., A. Bragg, 2004). Dickinson et al. 2004 state “At present, the long-term results (to 15 years) confirm that *Khaya senegalensis* is undoubtedly the high-value plantation species with greatest promise for plantation establishment in the dry tropics of Queensland”.

Armstrong et al. 2004 reported on aspects of a study of sawn timber recovery and timber and product quality from logs obtained from 38 trees selected in the unimproved NT stands that were planted at 3 m x 3 m spacings, with no subsequent management. Several of these 30-32-years-old trees (rotation age or older) gave high green-off-saw recoveries, timber with good properties for high-value products, and award-winning, specialty furniture. The species also produces timber of high quality at Weipa, Queensland (Bragg et al. 2004), and from amenity trees grown around Darwin, Katherine and some other places in the NT (Whitbread, 2003). Arnold 2004 briefly reviewed the world supply and timber trade situation with respect to *K. senegalensis* and some other high-value hardwoods. He concluded that the demand, scarcity, increasing prices and international conservation pressures “seem certain to create good markets for quality, plantation grown timbers of species such as *K. senegalensis*.” Furthermore, Arnold et al. 2004, using climate and growth data, predicted a vast homoclimate for *K. senegalensis* in northern Australia. This indicates its likely suitability for planting in places additional to those where it has been planted so far.

The foregoing information augurs well for the emerging plans for commercial plantings of the species in northern Australia. With good planning and management, and attention to all the requisite strategic underpinning described by Bevege 2004, it should be possible to create a viable HVH plantation industry in northern Australia, based initially on *K. senegalensis*. Like all other wild plant species that have been domesticated, ie. modified genetically by breeding in concert with the development of cultivation, harvesting and re-establishment technologies that enable the species to be cropped sustainably, this species will require such attention in order for its full potential to be realised.

The early plantings, which were all of genetically-unimproved planting stock, contain many trees with short, crooked boles (Nikles et al. 2004a). This is also the case in the young trials in which the stock derives from seed of the old stands or amenity trees without any effective selection (Dickinson et al. 2004, Reilly et al. 2004). Accordingly, Nikles et al. 2004a identified the unavailability of genetically-improved planting stock as one potential constraint on the optimal development of a forestry industry in northern Australia based on future plantings of *K. senegalensis*. They described the program of conservation and genetic improvement of the species that commenced by mild selection of trees in the NT in 2001 and detailed its impressive progress, noted that improvement work had started in Queensland at Walkamin in 2001 and Weipa in 2003, mentioned the informal collaboration that exists between workers with *K. senegalensis* in the NT and Queensland, and suggested “the likely most efficient means for addressing the imperatives and research needs identified ..., would be the

establishment of a cooperative genetic improvement program with *K. senegalensis* across northern Australia”.

How is the development and dispersal of new plant varieties undertaken?

Plant industries based on grain crops, pastures, turf grasses and horticultural species have evolved much further than forest tree crops in the development and marketing of genetically-improved, named and even branded varieties. The production and marketing (sometimes involving licensing) of bred seed or other propagules of many of these crops constitutes a large part of agribusiness activities, sometimes involving global distribution of specific crop varieties. This is associated with a trend towards “much greater private involvement in Australian plant breedingby a very small number of multi-national firms...” (Lindner 2002, p 593).

Though forest tree breeding is less advanced in general, it is useful to briefly consider variety development and release in agricultural and some forest tree crops via a few examples, with a view to gaining insights that might be useful in the context of the present paper (Appendix 1). It may be concluded from the review in Appendix 1 plus further information below, that more attention is now being given to the development, commercialisation and protection of superior varieties of forest trees, and that experience with other crop plants can be instructive.

Forest tree improvement in Australia was conducted initially by State Forest Services or their equivalents and started mainly in the 1950s (Nikles 1985). These agencies were the prime or only users of the products (commonly bulked seedlots from seed orchards) of their own tree improvement programs. There has been little pressure or desire, until recently, for the external commercialisation of the genetically-improved material developed. However, there is increasing recognition in plantation forestry of the slogan, long accepted in agriculture, “good seed does not cost – it pays!”

Historically, genetic improvement programs with forest tree species targeted local demand in the region of production. However, in recent years, there has been increasing trade in bulked seed orchard seed, family seedlots and clones selected for superior performance, at least in the local target environments of the program under which they were developed. For example, the State Forestry authority in Queensland [Department of Primary Industries and Fisheries - Forestry (DPI-Forestry)] has a long history of arranging collaborative tests of its improved material on forest sites of collaborators and potential clients (Nikles 1996, 2000). It markets seed orchard bulked seed and other forms of improved material of the indigenous, rainforest conifer (*Araucaria cunninghamii* Ait.) and several *Pinus* species and interspecific hybrids. In some cases, DPI-Forestry reproduces seed of families proven superior in tests on clients' land, or of families predicted to be excellent, and provides seed of such for mass propagation by the clients (pers. comm., I. Last 2004). Recently it licensed the equivalent agency in NSW to make use of certain of its pine hybrid clones that perform best there. Some other agencies and companies in Australia and overseas are marketing genetically-improved forest tree propagation material (sometimes with little or no proving of performance outside the region of development).

Verryn and Hettasch 2002 also exemplified the trend towards the use of ‘outsourcing of improved material’ in forest tree breeding ‘to improve time to market’. They stated (p 36): “In recent times companies around the globe are outsourcing their germplasm by accessing other tree improvement programmes (such as that of CSIR) as a means to ‘fast-track’ the deployment of improved germplasm”. (By ‘CSIR’ is meant the South African Council for Scientific and Industrial Research).

Though more attention is now being given to the development, commercialisation and protection of superior varieties of forest trees, it is still rare for tree breeders to acquire Plant Breeders Rights. It was suggested by Bevege 2004 that acquiring such rights will become much more important in the future.

Tree improvement programs associated with large-scale plantations for a single species involve the following broad activities, integrated in various sequences or with some conducted simultaneously, depending on circumstances:

- a) species and provenance selection,
- b) accumulation of a broad base of seedlots of the better provenances,
- c) establishment of substantial plantings of these seedlots for individual tree selection,
- d) selection of superior trees by certain criteria to form a breeding population,
- e) breeding by recurrent selection with infusions,
- f) mass propagation of superior material (also recurrently), and
- g) implementation of a deployment strategy in commercial plantings.

Programs delivering superior, inter-specific hybrids are even more complex (Nikles 1992, 1993, 2000; Potts and Dungey 2004). Both kinds of programs require skilful, integrated planning and execution, as well as periodic updatings of the strategies and implementation plans. Therefore, in domesticating a forest tree species by single-species or interspecific hybrid breeding, careful consideration needs to be given to how it may be undertaken most effectively. In particular, with species for which germplasm needs to be accessed from countries of origin, cognisance must be taken of the Convention on Biodiversity (CBD) (Bevege 2004).

The efficacy of cooperative tree improvement, at different levels as appropriate (local, regional, national or international), has been recognised (Nikles 1985), and is further illustrated and advocated in this paper. Just one example of the importance of being associated with an international cooperative tree breeding program, with a species that is of pan-tropical distribution and significance, is provided by the work of CAMCORE on the genetics of *Gmelina arborea* in international trials (CAMCORE 2003). Furthermore, the success, and essentiality, of international breeding programs with staple food crops and animals, coordinated by the global Consultative Group on International Agricultural Research, is widely accepted and supported (CGIAR 2003),

Status of domestication of *K. senegalensis* in northern Australia

Genetic domestication of *K. senegalensis*, in the sense of conducting an integrated conservation and genetic improvement program, started in the NT in 2001 employing a strategy that has two-overlapping phases:

- 1) a simple, first phase aimed at delivering somewhat-improved planting stock (superior clones propagated as rooted cuttings) as quickly as possible (from first open-pollinated progeny of first selections in the available, unimproved stands), that is linked to
- 2) a long-term phase of population improvement involving recurrent selection in large, improving and diverse base populations that 'spins off' new varieties into the operational planting program.

See Nikles et al. 2004a,b for details of the program. Flow charts depicting the facilities and activities involved in establishing and implementing the strategy, along with anticipated times when improved material might be available, were presented. It was forecast that untested then partially-tested clones (based on 5th year test results), should be available from 2005 and 2012 respectively, fully-tested clones from the first hedge garden and partially-tested clones from a planned second series of clone tests after 2017 and 2016 respectively, and seed from the uncultured then the culled gene recombination orchard (GRO) by 2007 and 2018 respectively.

The above outcomes are, of course, dependent on continued support of the NT program, which currently is not guaranteed. It is the most advanced domestication program with *K. senegalensis* in Australia and, considering Arnold 2004, most likely in the world. However, it is beginning to experience several constraints to its full potential for development (identified as a number of A proposal for consideration: Establish a northern Australia cooperative tree improvement program (NACTIP), with African mahogany (*Khaya senegalensis*) initially - D. Garth Nikles

imperatives and R and D needs in Nikles et al. 2004a), largely because it has 'grown like Topsy', without adequate long-term provision of the resources needed to fully sustain its growth. Moreover, it may not be possible for the NT government to continue to provide the resources required as the program develops (pers. comm., D. Reilly 2004).

In Queensland, tree improvement facility plantings have been made at the Department of Primary Industries and Fisheries (DPI and F) Research Station at Walkamin, and by several collaborators at Weipa. The former comprise:

- a small clonal seed orchard (CSO) of 0.60 ha (94 grafts) containing a subset of 68 of the NT clones, planted in 2003, primarily to further safeguard these clones, and
- a small provenance seedling seed orchard (PSSO) of 0.72 ha (1 111 trees per ha) of 9 provenances (6 of Burkina Faso, one each of Uganda, New Caledonia and 'Darwin street trees') planted in March 2001. Four of these provenances (all from Burkina Faso) are not present in the NT, and represent new germplasm in terms of the diversity of the species in Australia. (However, other provenances of Burkina Faso are represented in the current NT breeding population).

Currently, the work at Walkamin is a low-cost project, primarily establishing genetic resources that become available in opportunistic ways. For example, recently some 300 excess, open-pollinated seedlings from several NT breeding trees, and some 70 rooted cuttings from a sub-set of siblings of the 300 plants, were transferred there from Darwin.

At Weipa, the species is the one preferred, from among 34 planted in tests during 1967-1970, for mined-land rehabilitation and subsequently for commercial timber purposes (Bragg et al. 2004). A start was made in 2003 on a tree improvement program (Bragg et al. 2004) on similar lines to those described above for the program that commenced in the NT in 2001. The facilities established so far comprise plantings of early 2004 as follows:

- a CSO section of 0.46 ha including 128 grafted ramets from 36 selected trees of 2 provenances, that may be extended by adding grafts of any new select trees;
- an 'extensive seedling seed orchard' (ESSO) of approximately 1 ha of plants from bulked seed from somewhat more than 20 selected trees of one provenance; and
- an irrigated hedge garden of some 490 seedlings from the same parents represented in the ESSO, plus identified open-pollinated progeny (some 60) of an additional, exceptionally-superior tree.

The hedge garden, on the Napranum Aboriginal Council's farm site (Bragg et al. 2004), is being managed to provide cuttings. The first setting of cuttings is scheduled for late 2004 with the intention of planting a small test of rooted cuttings clones early in 2005 (pers. comm., A. Bragg 2004). Although the program at Weipa is being undertaken via collaboration between the mine owner (COMALCO – the Commonwealth Aluminium Corporation), the Napranum Aboriginal Council and the Queensland Departments of State Development and Innovation, and Primary Industries and Fisheries, currently it is a low-input operation.

At present, it is not known whether the provenances, of the 36 trees selected (in 2 stands of 2 provenances planted in 1977) for the Weipa CSO, are also among the 24 provenances established a few years earlier in the 1970s in the NT. At least one of the provenances used in early trials at Weipa (Uganda S9368) is also represented in the NT. In view of the several provenances used in some early trials at Weipa (some details of 5 such were provided to the author by Dr Ian Bevege in October 2004), it seems likely that there could be some provenances of *K. senegalensis*, additional to the 24 in the NT, within stands at Weipa. It is desirable to ascertain whether this is so, and what other

provenances are represented in plantings at Weipa that might provide additional breeding material in the future.

The overall pool of genetic resources accumulating in Australia is being further enhanced via seed importations by interested groups or individuals (pers. comms to the author 2004). These include recent accessions from Burkina Faso, Ghana and a secondary source in Honduras. It will be desirable to document the origins, mark and map the field destinations of plants obtained and benchmark their relationships, diversity and performance against material in the existing improvement programs.

Information presented in the sections above suggests that *K. senegalensis* warrants well-planned and supported, accelerated domestication in northern Australia.

A critical look at the situation

The situation is that we have a technically-soundly-based, interim tree improvement program with *K. senegalensis* established in the NT, but there are no immediate and, currently, only limited short-term demands there for the program's anticipated products. On the other hand, there is emerging what could be a strong demand for genetically-improved planting stock in Queensland because of the start of and plans for plantings mentioned above. However, it is likely that outputs of improved seed and clones from the Queensland programs will be realised some years later and less abundantly than from the NT program. The small CSO at Walkamin may produce limited seed from about 2009 (3 or more years later than the GRO in the NT), and the small PSSO may not produce much useful seed until about 2012. (Nikles et al. 2004a reported that the species can flower from 10 to 12 years after planting). Presently, the small program at Weipa is gearing primarily for local needs (pers. comm., A. Bragg 2004). This current miss-match of tree improvement and plantation establishment activities by public and private sectors respectively in the two jurisdictions could be resolved by linking the imminent 'supply' from the NT and Queensland tree improvement programs with the forecast 'demand' in Queensland, and supplying future NT demand, through a cooperative venture between the NT and Queensland programs and the 'potentially-needy', private-sector planters right across northern Australia.

As the tree improvement programs outlined above develop, additional resources will be required to maintain the several, important facilities already established, and to cope with the new work that will be generated as current and future clonal conservation banks (CCBs), GROs, hedge gardens, clone and progeny tests mature, and CSOs come into being, all requiring cycling. Yet funds and other resources for ongoing genetic improvement of *K. senegalensis* in northern Australia are currently scarce or non-existent. Thus, the pooling of stakeholder resources and leveraging more would be a logical tactic.

In terms of the future supply of hedge garden cuttings and GRO seed, the clone and progeny testing aspects of the NT program could be extended advantageously to sites in Queensland, provided collaborators could be found. Such extended testing on multi-sites would enable estimation of the extent of genotype-by-environment (G x E) interaction, more accurate selection of superior material, and the targeting of clones to commercial planting areas.

Obvious locations for such extended tests would be the lands obtained for planting by the promoters of Managed Investment Schemes (MISs), agroforestry sites and, as suggested by D I. Bevege (pers. comm., 2004), one or more 'stress sites' that could simulate conditions in prime sites during extended drought, for example. This is provided there was reasonable certainty of the protection, maintenance and accessibility of such tests for measurement and assessment.

The tree improvement work started at Walkamin in 2001 and Weipa in 2003 could also be linked to the NT program. For example, intensified exchanges of information on strategies, technical knowledge and germplasm, plus reciprocal visits by personnel, could be mutually beneficial, as the current A proposal for consideration: Establish a northern Australia cooperative tree improvement program (NACTIP), with African mahogany (*Khaya senegalensis*) initially - D. Garth Nikles

exchanges of some of these kinds appear to be. As well, all programs could contribute rooted cuttings clones to a future cooperative, multi-location clone test designed to estimate G x E interaction. (The rationale for this is given later).

Equally important is the fact that each of the other groups mentioned has something that could be contributed advantageously to the NT program and, in time, receive inputs in return. For example, the programs at Walkamin and Weipa could contribute clones to the GRO in the NT thereby enhancing its diversity. This would result in greater diversity within the progeny tests *cum* second-cycle base population which might be planted there. The promoters of MIS (all of whom have imported seed, either from Africa or a secondary source in Central America) could contribute samples of seed so that seedlings and/or rooted cuttings could be included in clone tests for benchmarking. Such samples could also be used to determine via molecular studies whether the new accessions are related to the germplasm already established in the NT and Weipa conservation and breeding populations. These examples of potential, collaborative activities are not exhaustive.

Inclusion of new collaborators, and intensification of existing collaboration, could be mutually advantageous. Potentially, the best means for achieving and efficiently integrating such a development, and the practical work outlined above, would be via a cooperative tree improvement program. This is further demonstrated in the next section.

An important point to make is that a well-planned and implemented cooperative improvement program in northern Australia could create demand for its products from many of the countries identified by Arnold 2004 as beginning to plant *K. senegalensis*, none of which has commenced nor could easily start such an improvement program. Thus, there is opportunity to produce improved material in northern Australia, use it there and develop markets for it in other countries as well.

Cooperative tree improvement programs

Often the formation of a cooperative is driven by a realisation of the large benefits that can stem from the pooling of resources. For example, the founding members of ALRTIG (Australian Low Rainfall Tree Improvement Group) representing 7 major and many other stakeholders “agreed that inter-agency cooperation is the key to the rapid and efficient improvement of Australia’s tree genetic resources for low rainfall plantation forestry” (Harwood and Bush 2002, p 4). It is widely appreciated that, for an industry group to succeed in securing funds/grants from funding bodies, it needs among other things, to demonstrate that there is stakeholder unity in the application.

In southern Australia, where *Pinus radiata* is grown extensively in all 5 states and the ACT, and where independent (but collaborative) tree improvement programs commenced in the 1950s, it became evident in time that cooperative breeding would be more efficient (Nikles 1985). As well, there were well-trying examples of tree improvement cooperatives in the United States from which to derive a locally-adapted model (see below). A consequence was the establishment of the Southern Tree Breeding Association (STBA) (a cooperative) in 1983 (Nikles 1985, Table 1). These and some other cooperative tree breeding programs are described briefly below.

The university-based and other tree improvement cooperatives in the USA

The ‘classical’ cooperative forest tree improvement (TI) programs are the three, on-going, University-based programs with *Pinus* species, each established approaching or more than 50 years ago, in the SE and SW USA. Background on the formation of these cooperatives is given in Zobel and Sprague 1993, and current accounts of their membership, activities, etc. can be found in their annual reports.

These, cooperatives, with base locations and years of establishment, are:

- a) the Cooperative Forest Genetics Research Program, Gainesville, Florida, 1959;

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- b) the North Carolina State University – Industry Cooperative TI Program, Raleigh, NC, 1957;
- c) the Western Gulf/Texas Forest Service Cooperative Forest TI Program, College Station, Texas, 1951.

Outside the SE and SW USA, there are other cooperatives such as the Inland Empire Tree Improvement Cooperative based at Moscow, Idaho, established in 1968; and that in the Pacific North West with Douglas fir, also with a long history.

Clearly, these cooperatives are long-lived; each is on-going with stable funding.

Some other common features of the intra-national, university-based cooperatives, are:

- a) Diverse membership within their regions of operation, with core partners commonly being corporate owners of forest lands (with or without processing mills of various kinds), State Forest Services (which require improved seed for their nurseries supplying stock to mainly small growers), with the university providing infra-structure and other important services. In some cases, members include seed companies and/or nurseries.
- b) Management commonly is via an Advisory Board and Executive Committee, and Technical Committees function to progress operational areas or disciplines. The Director is a university Professor, supported by other faculty, technicians and students.
- c) Budgets comprise member fees, grants and University-provided salaries for some staff.

It should be noted that membership of the well-established, large TI cooperatives, including the STBA, includes not only some of the largest forest products companies in the world, but also some much smaller organisations. Often these companies are strong competitors in the market place for their end products, but they recognise the benefits of cooperation at the pre-plantation establishment and management end of the supply chain.

Also based at NC State University is CAMCORE, the International Tree Conservation and Domestication Cooperative which was established in 1980 and continues to grow (CAMCORE 2003). It has a similar structural and operational model to those of the other university-based cooperatives, but with an international sphere of activity with a tropics/sub-tropics focus. Currently it has 19 active company and 7 honorary (host country) members across 10 and 6 countries respectively. This international character assists it to gain access to germplasm in a wide variety of countries, in full consultation with local authorities and meeting CBD obligations. For more information about CAMCORE and its programs, see Dvorak and Donahue 1992, Dvorak 2000 and the organisation's annual reports.

Benefits of cooperatives

Some specific benefits of TI cooperatives, particularly those that are university-based, include:

- a) program continuity (note the USA cooperatives that have continued for approaching or more than 50 years; CAMCORE and the STBA for more than 20 years, and both are on-going; this is very important in a long-term enterprise like tree improvement);
- b) better buffered against short-term changes in government and other support;
- c) higher genetic gain can be realised (more trees in tests, more intense and more accurate selection);
- d) more information is available via pooling;
- e) a cooperative has greater 'clout' when, eg., seeking funds;
- f) intellectual capital is enhanced;
- g) synergies are generated, and 'critical mass' can be attained more readily;
- h) the pooling of resources enables access to better facilities;
- i) staff stability throughout is generally higher;

- j) cooperatives often attract greater talent for all positions, especially the very important leadership role, and capable students; and
- k) much of the research required by the industries in the cooperative can be done rather economically by post-graduate students.

Some Australian cooperative tree improvement programs

A summary of aspects of several tree improvement cooperatives in Australia is given in Table 1. Currently, the STBA is the only formally-established forest tree improvement cooperative in Australia. It has New Zealand members. A similar, New Zealand cooperative has Australian members.

Note that all the cooperatives listed in Table 1 involve the private and public sectors, though the STBA is predominantly a private sector association. Each has an age or period of funding exceeding 6 years (some considerably longer). Not shown in the table is the fact that the principle of operation is that intellectual property and other benefits generated are apportioned in relation to member contributions.

Thus, good models of forest tree improvement cooperatives exist, both in Australia and overseas. Nevertheless, it would be essential to customise a scheme appropriate to the local circumstances in northern Australia.

Developing a northern Australia cooperative tree improvement program (NACTIP)

Considerations in establishing a NACTIP

Possibly the most important issue would be how to develop among stakeholders the will to cooperate, and secure agreement that the most effective way forward is via cooperation, the point that had to be reached by, for example, the stakeholders who were able to go on and form ALRTIG, as mentioned above. The WIFM principle (What's In It For Me) is important.

Involved in this is the often considerable disparity of resources of various kinds that individual stakeholders may be able to bring to a cooperative. Clearly, this would need resolution, possibly as in the ALRTIG case via an Establishment Workshop (Harwood and Bush 2002). The fact that so many successful cooperatives have been able to resolve such issues should be encouraging to potential stakeholders in the proposed NACTIP.

Potential members of a cooperative might make their respective contributions in different ways – cash, kind, access to and management of field sites, intellectual capacity via R & D, etc. Accepting this can be important in getting started. The value of such disparate contributions must be recognised in apportioning Intellectual Property (IP), and the intent to do this must be made clear 'up front', and needs to be explained. (I am indebted to Dr D. I. Bevege for bringing these points to my notice).

It should be noted that:

- a) Many akin programs are run as partnerships of industry and public agencies (see Table 1, for example).
- b) There is a trend towards total or almost total industry self reliance in some akin programs elsewhere (Lindner 2002, pers. comm., D.I. Bevege 2004).
- c) A NACTIP must, surely, build on the existing, good platforms that have been constructed in the NT and at Walkamin, Queensland by public sector agencies, and at Weipa in collaboration between such latter agencies, the Napranum Aboriginal Council and COMALCO.

- d) A NACTIP has the potential to produce 'public goods', eg. contribute to development on some aboriginal lands; and the sharing of benefits with the wider community and/or overcoming market failure (pers. comm., D. I. Bevege 2004).
- e) A recent precedent for a public-private sectors partnership in tree improvement is ALRTIG.
- f) There could be some possibilities for establishment of a NACTIP via venture capital – perhaps unlikely in view of anticipated limited demand for products, at least initially; though this could change, eg. via development of overseas markets.

Once stakeholder agreement to proceed has been reached, aspects that would require definition for NACTIP would include:

- a) goals
- b) objectives
- c) business plan
- d) securing members and funding
- e) modus operandi
- f) securing personnel
- g) defining the tree improvement strategy
- h) developing projects required to achieve the goals
- i) implementation plans with milestones and performance indicators.

What could be the potential constraints?

Perhaps the most obvious, potential constraint is that a *K. senegalensis* industry does not yet exist in northern Australia, so there are no revenues from such a potential source that could be tapped to assist in establishing a NACTIP. However, when ALRTIG was mooted in southern Australia in the late 1990s, there was a very limited industry based on the 9 eucalypt and 2 pine species now involved. Another possible constraint is availability of start-up funds. However, a cooperative often has considerable 'clout', and provides an efficient means for assembling a critical mass of funds via membership fees, other sources and the leverage of extra funds.

Another potential constraint to a northern-Australia-wide cooperative tree improvement program is the possibility of there being such strong family-by or clone-by-environment interaction (generalised to genotype- by- environment – G x E interaction) that 'regionalisation' of the program or other tactics become necessary. Biologically-important interaction could be expected in suites of seed families and, even more so, clones established in different climatic, edaphic, soil drainage and biological environments that would exist across such diverse target regions such as Katherine, Darwin, Cooktown, Lakeland, Weipa, the Burdekin, etc. This would mean that, for optimal performance at individual sites, the superior families or clones could be different at all or some sites. Clearly, this phenomenon would need to be investigated to determine the importance of G x E interaction, and should be accorded high priority in cooperative research with *K. senegalensis* in northern Australia.

A number of existing tree improvement cooperatives operate across environmentally-diverse regions successfully via appropriate coping strategies, eg. regionalisation, or deployment of stable, high-performing material. Such programs include the North Carolina- and Texas-based cooperatives, CAMCORE and the STBA (*P. radiata* and *E. globulus* across diverse environments in southern Australia).

What platform could be used as a base?

Logically, a NACTIP would be built up from the platform of facilities and plans of the existing program in the NT and those of the collaborators and potential co-operators in Queensland. It could be instructive, then, to consider the 'imperatives' and 'more urgent research needs' identified for the NT program and its collaborators. These are restated from Nikles et al. 2004a below.

What research and development work would need to be done?

“Imperatives critical to the success of the program will include:

- a) Ensuring adequate funding is provided for ongoing support of the NT work;
- b) Ensuring the protection and rapid development of the GRO and CCB so that seed then seedlings will be available with minimal delays for: ‘fuelling’ the series of clone tests; the regeneration of diversity for future cycles of selection (especially for stem straightness and bole length); and for the provision of seed to planting programs;
- c) Enhancing genetic diversity by infusing new germplasm from natural stands, especially those in regions poorly or not at all represented in Australia eg. the Central African Republic, Cameroon; and
- d) Eliminating or minimising the threat of shoot borer.”

The shoot borer is *Hypsipyla robusta* Moore; its presently low level of threat to *K. senegalensis* is outlined in Griffiths et al. 2004 and Nikles et al. 2004a.

“The following appear to be the more urgent research needs:

- a) Estimating G x E interaction at the clone level across many sites;
- b) Documenting the periods of flowering of the clones in the CCB and GRO;
- c) Improving protocols for rooting cuttings of both hedged seedlings and superior trees available in young stands (firstly for clone tests, and later for mass production of superior clones held in hedge gardens), and check that rooted cuttings are not inferior to seedlings;
- d) Checking that rooted cuttings are not inferior to seedlings’
- e) Undertaking molecular studies of diversity, co-ancestry and levels of inbreeding in the several, current working populations: the first-cycle breeding population of 142 selected trees, the 2 000 trees in the trials described by Reilly et al. 2004, the first hedge garden, progeny of the CCB and GRO, the Queensland stands at Weipa and of the trials in the Bowen to Townsville region described by Dickinson et al. 2004, and seedlots recently introduced by various stakeholders;
- f) Investigate provenance and other genetic variation including genetic parameters; and
- g) Finding means for reducing the generation interval to less than the 12-14 years currently anticipated.”

To these lists could be added: standardise the marking and mapping of seed sources in all experimental and commercial plantings. This is best practice, needed to ensure that there is knowledge of the seed source in all future plantings.

Suggested projects for a NACTIP with K. senegalensis

It would be desirable to prepare a plan defining essential projects with a specific, initial implementation period of, say, 5 years in order for the proposal to appeal strongly to potential sources of supporting funds. Based largely on findings of Nikles et al. 2004a, it is suggested that the NACTIP planners would need to consider the following in relation to *K. senegalensis*:

- a) Document an appropriate TI strategy and implementation plan.
- b) Manage the GRO, CSOs (including new) and CCB in the NT, and similar facilities in Queensland in concert.
- c) Clone test local and ‘benchmark’ recently-imported sources of germ plasm via CGTs (cooperative genetic tests) across a wide range of environments; plan clone releases.
- d) Contract /encourage development of ‘rooted cuttings’ technology – for young seedlings and ‘selection-age’(6-10-year-old?) trees – and test rooted cuttings against seedlings.
- e) Characterise provenances, identify origins and estimate inbreeding of key populations in the NT and Queensland programs via molecular studies.

- f) Monitor shoot borer activity and watch for resistance; collaborate closely with quarantine authorities and entomological R & D agencies.
- g) Establish and manage Series 2, multi-site CGTs (clonal).
- h) Source seed, establish and manage Cycle 2 base populations (seed from uncultured GRO/CSO and infusions of new provenances) on multi-sites.
- i) Investigate provenance variation, identify sources of germplasm needed and import seed.
- j) Publicise the benefits and overcome any criticisms of a well-planned and executed *K. senegalensis*-based industry.
- k) Plan preliminary work on 1 or 2 additional species to extend the scope for future plantings and provide insurance against pests and diseases.

What would be the over-riding benefits of a NACTIP?

Perhaps the over-riding, potential benefit, especially pertinent at the current beginning of domestication of *K. senegalensis* in northern Australia when resources available to any one stakeholder or group are very limited, is the opportunity to pool those limited resources and so gain a critical mass with which much greater progress could be made.

Depending on how a NACTIP were constructed and based, most or all the benefits of cooperatives given above would apply.

Potential co-operators could link in to the more advanced NT and Queensland program in a number of ways, e.g.:

- a) those with imported seedlots could have them benchmarked against what is most likely the best material on the near horizon, viz. clones from the first hedge gardens (the first clone tests are scheduled to be planted in the NT and at Weipa in 2004-05).
- b) some could provide seeds for the next series hedge garden and clone tests, and have tests of all the clones established on their lands by agreements.
- c) some could contribute clones to the proposed clonal seed orchard; and, more distantly in time, contribute germplasm to and participate in progeny testing from the GRO and CSOs.
- d) some might make 'in kind' contributions of various kinds, eg. provide secure test sites for clone tests.

These and other joint activities would strengthen and improve on the present NT and Queensland programs, and feed back higher genetic gains that would accrue to all members.

Interested/potentially interested parties (stakeholders)

Governments have a vested interest in industry development within their jurisdictions. In Australia, all states and territories have agencies charged with attracting industry. In many cases, the Commonwealth government favourably considers contributions to an enterprise that crosses the boundaries of States and Territories, eg. the mitigating of salinity. Actual examples of Commonwealth involvement in tree breeding cooperatives are provided by 4 of the 5 cases given in Table 1. (The mandarin breeding project, Queensland based and oriented at this time, is the one exception). Thus government agencies are likely to be supportive of a NACTIP.

In view of the vast homoclimate of *K. senegalensis* across northern Australia (Arnold et al. 2004), there will be many areas suitable for commercial planting of the species on aboriginal lands. Bragg et al. 2004 indicate that the Napranum community near Weipa is positive about the development of commercial plantings on their land – the first hedge garden has been established on land of the Napranum Aboriginal Council. There could be other such communities elsewhere in the northern Australia, which might benefit from planting *K. senegalensis* commercially and participating in a NACTIP.

Other stakeholders could include promoters of Managed Investment Schemes (various kinds), and “small” private growers and/ or their representatives, e.g. Australian Forest Growers and other groups.

In summary, a tentative listing of stakeholders might include:

- a) NT government (various agencies)
- b) Queensland government (various agencies)
- c) Commonwealth government (various agencies)
- d) Napranum community (Napranum Aboriginal Council) – COMALCO and, potentially, other such aboriginal communities across northern Australia
- e) promoters of Managed Investment Schemes (various kinds)
- f) “small” private growers and/ or their representatives, eg. Australian Forest Growers (AFG), and the Plantation Forestry Regional Development Committees in Queensland (Plantation Forestry North Queensland, Plantation Forestry Central Queensland), and the NT Forestry and Timber Products Network.

Some potential sources of funding support

Background on the Australian plantation forestry industry, including investment opportunities, support mechanisms and challenges, is given by Roberts 2004. It is clear from her exposition, the examples given above of existing cooperatives, and the status of tree improvement with *K. senegalensis* in northern Australia outlined in this paper, that the funding sources for starting a NACTIP would almost certainly have to include public and private sectors.

Potential sources of support to be mentioned here are based on an incomplete consideration of some existing programs somewhat akin to the proposed NACTIP, and are merely a sample of the possibilities that may exist. We can consider 1) sources that might fund more operational-type R & D work, and 2) potential supporters of more basic research.

Under 1) could be mentioned:

- a) DAFF (Australian Department of Agriculture, Fisheries and Forestry),
- b) RIRDC and partners’ JVAP (Rural Industries Research & Development Corporation and partners’ Joint Venture Agroforestry Program),
- c) Cooperative Venture for Capacity Building (CVCB), administered by RIRDC,
- d) TSKIA (Tropical Science, Knowledge and Innovation Alliance),
- e) Potentially, a new CRC (Cooperative Research Centre); or, a NACTIP might be linked to any extension of the CRC for Tropical Savannas, and
- f) Managed Investment Services.

DAFF funding for forestry activities in general would require investigation, for example the New Industries Development Program (NIDP) would appear relevant. It is of interest that DAFF funds much of CSIRO’s work on salinity amelioration in the Goulburn River catchment in Victoria.

The RIRDC and partners’ JVAP provided ‘seed’ funding to enable the development of ALRTIG (Harwood and Bush 2002). It provided partial funding to two *K. senegalensis* - related projects with the NT and Queensland (the start of the conservation and tree improvement program, and the wood study – Reilly et al. in press, Armstrong 2004). It also contributed some funds for the Mareeba Workshop (Bevege et al. 2004). As well, aspects of the work proposed for a NACTIP seem relevant to the RIRDC/JVAP’s mission.

The CVCB was established in 2001 by 9 R & D corporations and DAFF as partners, to enhance capacity building in rural industries in Australia. It is administered by RIRDC. Details contained in its calls for submission of proposals for funding (www.rirdc.gov.au/capacitybuilding/funding-proposals.html) suggest that its mission is relevant to aspects of the proposed NACTIP.

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The TSKIA, formed in 2003, embraces the tropics of the NT, W Australia and Queensland, via leadership from the governments of those jurisdictions, and the Commonwealth, in joint endeavours to enhance development in northern Australia. Thus it could be a very appropriate body to approach for assistance in establishing a NACTIP. Its Tropical Futures Forum was held in Darwin early in 2004. Progress on tree improvement with *K. senegalensis* has been made known to the Alliance, along with the suggestion that it consider supporting the work.

Managed Investment Services secure funds for investment in various ventures. Those investing in HVH plantation establishment could have direct or indirect, vested interests in the development of genetically-improved planting stock.

Under 2), potential sources of funding for specific research projects (for example, the molecular study of key populations suggested by Nikles et al. 2004a), the following could be mentioned: ACIAR (Australian Centre for International Agricultural Research), ARC (Australian Research Council), and FWPRDC (Forest and Wood Products Research and Development Corporation). Each of these agencies has specific requirements that would have to be fulfilled.

It is possible that international agencies such as CAMCORE and ITTO (International Tropical Timber Organisation) might consider approaches for expressions of interest in participating in appropriate ways.

Potential consortia by which a NACTIP might be established

- a) Consortia could comprise one or more of the following, or some other arrangement:
- b) incorporation in the next phase of CRC for Tropical Savannas,
- c) a potentially-new 'CRC for Agroforestry', with partners such as:
 - DBIRD (NT),
 - DPI&F (Qld)
 - CDU (Charles Darwin Univ., NT)
 - JCU (James Cook Univ., Qld)
 - CQU (C. Qld Univ.)
 - 'Industrials'
 - AFG and/or other representatives of "small growers",
- d) a consortium of interested public agencies, eg, DBIRD, NT plus DPI&F and DSD & I, Queensland ,
- e) a private-sector based consortium or Managed Investment Scheme,
- f) a mixed model (public agencies and private sector entities), eg, akin to ALRTIG; or akin to the macadamia, mandarin or mango models (Table 1), or
- g) a cooperative on the US, university-based model (currently governments are making alliances and building partnerships with universities, eg. Queensland).

The latter model (f) has many potential advantages, eg. demonstrated successes and longevity, minimal effect of government changes, insulation (partly?) from "vagaries of science funding" and, potentially, all the benefits of such cooperatives detailed under 'Benefits of cooperatives' above.

Potential challenges for stakeholders and action needed to initiate a NACTIP

*Some challenges for stakeholders in the embryonic *K. senegalensis* industry*

Is the incipient northern Australia HVH plantation industry at the point where the subsequent 'ALRTIG' partners were in 1998?

Is there a consensus in vision, and a desire to explore for a way forward?

If so, how might a 'movement' be started?

Should an 'exploration committee' be formed?

What would be its terms of reference (TOR)?

Would the TOR include: surveying potential stakeholders, developing a unified plan, surveying possible sources of 'start up' funds, exploring the university-based and other models?

Is there a consensus on the 'imperatives' and essential R & D for a NACTIP to address?

This question could be addressed in relation to the items proposed above under the sub-heading: What research and development work would need to be done?

What initiative is required?

Many of the potential member stakeholders of the proposed NACTIP were represented at the Mareeba Workshop. If there were a positive consensus among them, it might be possible to form an interim Task Force to begin planning for a fully representative 'Establishment Workshop'.

Conclusions

More than 30 years ago the first trial plantings of *K. senegalensis* were made in the NT and at Weipa, Queensland. These plantings have grown well and produced some HVH timber already, but they and subsequent plantings contain high proportions of trees with crooked, short boles. Very recently, intensive domestication of the species has commenced by a few groups with: the planting of grafted orchards in the NT in 2002, at Walkamin, Queensland in 2003 and at Weipa in 2004; the initiation of work that will lead to clone tests being planted in the NT and at Weipa in 2005; and the assembly of some genetic resources at other places. There is interest in starting commercial plantings in Queensland soon, and encouragement to do so in the NT. Also, the species is emerging as of considerable interest in several countries in Asia. No tree improvement programs are known to be in place nor planned outside northern Australia.

These, and other relevant matters presented in this paper, highlight the opportunity, for stakeholders in a viable plantation industry in northern Australia, to pool their efforts and plan and implement an integrated strategy for domestication of *K. senegalensis*. The way forward for a potential industry based on this species initially is for all interested parties to form a cooperative and undertake tree improvement, preferably in parallel with the other R and D needed to underpin such an industry.

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Table 1. Aspects of some cooperative tree improvement programs in Australia.

Program	Members providing resources	Period	Base location	Operating areas	Aims
STBA ¹ (<i>Pinus radiata</i> and other species)	'Industrials' – 16, research providers – 5	1983 – present & beyond	Mt Gambier	Southern Australia & New Zealand ²	Increase the profits of clients via 4 main thrusts
ALRTIG ³ (eucalypts – 7 timber spp and 2 oil spp; and 2 pines)	Seven major stakeholders from 5 States, C'wealth agencies and many private growers	1999 – end of 2006	Canberra (CSIRO)	All 5 southern states	Develop superior breeds for the 400-600 mm MAR zone
Macadamia	AMS, HAL, CSIRO, NSW DPI & Qld DPI&F ⁴	1996 – end of 2007	Brisbane	SE Qld, NNSW	Increase yield/ha, size nuts, HI, ⁵ quality
Mandarin	DPI&F, QFVG, 2 DFG Associations ⁵	1993 – 2013	Bundaberg, DPI&F	SE Qld	Develop a new, super-quality variety
Mango	Agric. W Aust., CSIRO, Qld DPI & F, NT DPI	1994 – present & beyond	Darwin, Mareeba	Across northern Australia	Develop new varieties for domestic & export markets

¹ STBA – Southern Tree Breeding Association Inc. In the 1990s, *Eucalyptus globulus* was added to the portfolio of species, with similar members involved. *E. nitens* is also involved for a limited number of members.

² Most New Zealand growers and other stakeholders in the *P. radiata* industry in New Zealand are members of a local cooperative – which has at least one member in Australia.

³ Australian Low Rainfall Tree Improvement Group.

⁴ AMS – Australian Macadamia Society; HAL – Horticulture Australia.

⁵ HI – harvest index. In this case, increasing the proportion of whole kernel to total nut.

⁶ QFVG – Queensland Fruit and Vegetable Growers.

Appendix 1

How is the development and dispersal of new plant varieties undertaken?

Plant industries based on grain crops, pastures, turf grasses and horticultural species have evolved much further than forest tree crops in the development and marketing of improved, named and even branded varieties. Nevertheless, it is useful to briefly consider variety development and release in several of these crops via a few examples.

Agricultural crops and pastures. For background, a comprehensive review of the history and past achievements of plant breeding, and an outline of “ how plant breeding has changed in the course of the past century and must adapt to the needs of the present century”(p 1) by Reeves and Cassaday 2002 may be consulted.

In Australia, it is common for state government departments of primary industries (or equivalent agencies) to fund the breeding research and development, including repeated, widespread trials (often in collaboration with contributing partners), leading to the mass production of new, superior varieties. The second stage of the process of producing such varieties and bringing them into commercial use by farmers, can be a call for expressions of interest for the commercialisation of the new variety. Often it is preferred that the commercialisation be through an exclusive licence agreement with a private sector partner who can demonstrate a superior seed/clone production, distribution and marketing plan, including the capacity to ensure that seed/propagules of the new variety will be maintained free of contamination. Returns from such partnerships and enterprises are usually assigned to the partners in proportion to their contributions.

The breeding, testing and global marketing of white clover by the government agency AgResearch Grasslands in New Zealand since 1987 (Woodfield et al. 2002) provides an example of one model of the process outlined above. The authors state (p 605):”This has been accomplished by forming strategic partnerships with public agencies, universities and private seed companies to provide evaluation facilities, knowledge of market opportunities and requirements, and distribution networks in each of these (= global) markets..... The global approach to breeding has enabled us to retain a critical mass in white clover breeding despite the vagaries of science funding” (highlighting by the present author). In a personal communication in October 2002, Derek Woodfield informed the present author that “returns from breeding are based on a base royalty of 15% on wholesale seed price. The royalty can be split between partners involved in the development based on their breeding input”.

Horticultural crops. As examples, basic aspects of the breeding programs with three horticultural tree crops macadamia, mandarin and mango in Australia are outlined in Table 1 (main text). In all cases, the breeding is supported jointly by industry bodies (representing the majority of growers) and interested government agencies. The profits generated are distributed in proportion to the contributions by the partners.

In other fruit and other crops, similar arrangements hold, though the precise form of the partnerships may vary from crop to crop. In virtually all cases, however, the general principle of partnerships of industry bodies, growers and public sector agencies holds.

Forest tree plantation crops. There has been extensive trading in forest tree seed, both in large quantities for establishment of large commercial plantations, and in smaller amounts for trials and the establishment of breeding base populations. For example, the South African company Mondi Forests exported 63 t of eucalypt and pine seed to Brazil during 1973 to 1984, and large amounts of *Pinus elliottii* and *P. taeda* seed to the United States, the homeland of the two pine species (Denison 1999). (Much of the pine seed may have been re-exported elsewhere).

Other tropical tree species traded very extensively have included *Acacia* species, teak (*Tectona grandis*) and mahogany (*Swietenia macrophylla*).

With few exceptions until recently, the large volumes of forest tree seed traded have been from natural stands or other unimproved sources. Exceptions include much of the pine seed exported by Mondi Forests, and by the Forestry authority in Queensland (which came largely from clonal seed orchard surpluses).

It is concluded from this brief review plus information presented in the main text, that more attention is now being given to the development, commercialisation and protection of superior varieties of forest trees, and that experience with other crop plants can be instructive.