Genetic Improvement, a *Sine Qua Non* for the Future of Koa

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Introduction

I have come to preface essentially all of my forestry talks with a reminder about the logarithmic curves of tropical deforestation and human population growth, one down and one up. By this century's end, forests will disappear at around 15 million hectares annually (15 times the size of Hawai'i), and people will appear annually around 100 million (100 times our population). No look at trees to be harvested twenty or fifty years from now can afford to ignore these damning statistics.

It is safe to state that no significant plant competes long in today's world market without significant plant breeding. Essentially no breeding has been done with *Acacia koa*, the subject of this conference. To be sure, koa has the charisma of Kona coffee, and its immediate future looks bright with no major improvements at all. How long can this last?

The studies of our team, to be reviewed by Dr. Sun, indicate a basis for optimism for impressive improvement by genetic selection in this native tree. However, these studies can as well be interpreted to indicate that most koas are very bad, indeed, thus improvement is easy. That such improvement is a *sine qua non* to koa's future is the theme of this talk.

At a recent conference on sustainable tropical forestry (Brewbaker and Sun 1996), over 200 authors from the tropics concurred in the view that genetic improvement was a *sine qua non* to every species being considered. Nature does not automatically select the best germplasm for man! It is only very rarely that the major commercial species in one location evolved there. Monterey pines are commercial in New Zealand, not in California; Caribbean pines are commercial in Australia, not the Caribbean; Australia's eucalypts are commercial in Brazil, Zaire, and soon in Hawai'i, not in Australia. No agriculturist would think of breeding any crop based solely on germplasm from his state, let alone in one county or on one island in it.

Koa evolved in Hawai'i, probably from a very limited germplasm base. It evolved in the absence of goats and pigs, that ruin it today in most of Hawai'i's ecosystems. It evolved in the absence of the hundreds of insects and pathogens worldwide that thrive on its genus, *Acacia*. We are very naive to think that koa is perfect just the way "God made it" and will thrive commercially without improvement. Genetic improvement requires dedicated, long-term support of public and private agencies to appropriate research, and at present such support is negligible in the state of Hawai'i.

Koa's evolution -- a fragile germplasm base?

Acacia koa Gray is a member of a large genus of legumes with about 1200 species, of which 800 are Australasian. It is in the section Heterophylla of the genus together with about 20 other species, trees found in the South Pacific and in the Mascarene Islands off Africa. Koa is a polyploid species, with 2n = 52 chromosomes, probably the result of species hybridization and doubling. About one forth of the acacias studied are similarly polyploid. Like koa, most of these polyploids are able to reproduce by self-fertilization, in contrast to their diploid relatives, which are self-sterile. Such polyploid species are usually isolated genetically from their diploid ancestors, forming seedless hybrids. We are exploiting similar seedless interspecific hybrids in leucaena ("koa haole") as a high-value hardwood in Hawai'i (Sorensson and Brewbaker 1995). If harvestable in six to eight years, such fast-grown hardwoods may have a more exciting future than koa. I returned yesterday from a conference on tree production in the newly thriving country of Venezuela, where *Leucaena* spp. play a major role.

It is probable that koa arrived in Hawai'i as a few seeds dropped by birds, producing trees that fortunately could reproduce by self-fertility. Even for a polyploid, this creates a narrow gene base that can ultimately cripple any species for evolution or breeding in the modern context. This context includes six million tourists a year coming to Hawai'i, many carrying fungi on their shoes or insects in their luggage. This context also includes the fact that many of these fungi and insects will have cohabited with the 1200 acacias of the Americas (200 species), Africa (200 species), or Australasia (800 species). In our careful assessment of challenges for improvement of koa (Brewbaker et al. 1991), it was stressed

that 101 insects and 94 pathogens have already been identified on koa, most of them as probable pests. To these, one must add new pathogenic strains and insect races that arrive regularly in Hawai'i, despite best quarantine efforts.

The islands of Hawai'i abound with examples of species built on a fragile germplasm base, often easily disrupted. The examples are more easily and effectively dramatized for animals than they are for plants. A typical example from our research would be koa's relative, koa haole (*Leucaena leucocephala*). Hawai'i's koa haole is derived from a single self-fertilized plant, probably near Acapulco about 1580, and came through the Philippines to Hawai'i around 1850 (Brewbaker 1995). There is no genetic variation at all in Hawaii's "native" koa haole (Sun 1996), and it succumbed badly to the introduced leucaena psyllid in 1984. Another example is Hawai'i's "native" keawe (*Prosopis pallida*), that evidently traces back to two cross-fertilizing trees, ultimately from Peru (*idem*). This germplasm could never serve as a solid base for genetic improvement.

The fragility of an inbred genetic base is more easily seen in the Hawaiian crow or perhaps the nene, two species that will attract vastly more research money than koa ever will in my lifetime. These species will need continual coddling, particularly if ecologists will allow no thought be given to introducing some vigor and pest tolerance from related birds (as I would).

Genetic diversity of koa

In the 1960s we initiated germplasm collections of *Acacia koa* throughout the islands, and concluded from field morphology and isozymic observations that they were genetically variable. When CTAHR's Hamakua Research Station (2200 ft elevation) reopened in the late 1980s, we initiated a set of annual performance trials. These normally contain families derived from individual trees, in two reps of 10 trees each. A valuable added trial location was provided by HSPA-HARC at Maunawili, O'ahu (600 ft elevation) in 1993. We have not been able to add important additional high-elevation sites to this study from Kamehameha Schools Bishop Estate, State of Hawai'i Division of Forestry, and other agencies, despite their help in seed collections.

Evaluation of koa's genetic diversity by Sun (this conference) reveals impressive genetic variability, to be sure. Among about 200 families studied, genetic variations have been observed in form, vigor, limbiness, flut-

ing, rate of phyllody, tolerance of rust, and several other traits. In general, about 10 percent of our families can be ranked of sufficient quality to encourage progeny studies, and possible interim use as parents. Put another way, 90 percent should be discarded. Among the most disappointing provenances have been those provided commercially in Hawai'i. High uniformity characterizes many families, suggesting a high degree of self-fertilization in this species. Differences among the islands do occur, but variation within each island is much greater than that between.

Koa is a fast-growing tree under these experimental conditions, with careful attention to weed management, exclusion of animals, and provision of enhanced soil fertility during the first year of growth. Canopy closure can be achieved in six months, and weed suppression is good after the first year. Without this care, koa is a very weak competitor with aggressive grasses like kikuyu. Genetic differences in growth rate are clearly evident in one year, and juvenile-mature regression coefficients in height and diameter are very high. Outstanding genotypes reach tree heights of 30 ft in four years and can be found with straight boles and low limbiness or fluting. Most koas can be pollinated within five years, when thinned to allow good solar interception. High wood figure ("fiddleback") characterizes a small fraction of koa trees, attracting top prices in the market, and has proven to be heritable in other trees. Thus this is a species that appears to lend itself well to genetic advance through selection.

Genetic constraints of koa

Koa can hardly be considered at present to be "domesticated," relative to trees like teak, blackwood, mahogany, rosewood, or even koa haole (Brewbaker and Sorensson 1994). In nature, it grows under an increasingly debilitating environment of exotic pests: pigs, goats, cattle, lianas like banana poka, and aggressive woody pests like strawberry guava. These exotic pests probably have much to do with koa's "sudden-death" syndrome, for most koas in the state are growing under atrocious conditions from a forest-plantation viewpoint.

This conference could be important in dramatizing how much needs to be known of koa's biology, its genetic variation, its nutritional requirements, its response to biotic and abiotic stresses, or its growth response to the simplest of agricultural loving care. Few at the conference would even agree on the rotation age for koa

grown in well-managed plantations, nor the quality of wood from such plantations. My guess is that harvest can be under 20 years, given the best genotypes under the best management. And if we consider relevant the studies of *Acacia mangium* and related tropical species, now grown commercially on over a million acres in Southeast Asia, wood from these "fast-grown" trees (5-7 years) will be of fully acceptable hardwood quality.

What might be the genetic constraints of koa? It is clear that koa suffers badly from some or all of the following factors:

Poor form, limbiness, and fluting

Poor wood color, rotting of heartwood

Response to sustained waterlogging of soils

Response to sustained drought

Susceptibility to black twig borers, koa moths, psyllids

Susceptibility to leaf fungi such as fusiform rust

Susceptibility to root diseases such as *Fusarium oxysporum*

Intolerance of inadequate phosphate in soil

Inability to clone by vegetative propagation, micro-propagation, or grafting

Many of these issues will be considered in detail at this conference. Some can be addressed through control measures, assuming costs are manageable. For many of these constraints, genetic improvement based on intraspecific variation may be remote. Even more remote may be the funds to permit modern genetic approaches involving intra- and inter-specific gene transformations such as those common today for coffee, papaya, corn, and tomatoes.

There is evidence, however, that genetic variation may presently occur in koa for all of the conditions listed above. The geneticist's attitude must be that any long-range selection and breeding program will achieve major improvements.

A proposed genetic improvement program for koa

1. Extensive evaluation of >1000 families at four sites
2. Selection of superior families on basis of clonability, exploiting root-sprout technology
3. Extensive intraspecific hybridization to expand site adaptability range
4. Introduction and hybridization with all species in Section Heterophylla
5. Use of juvenile-mature correlations to identify superior progenies
6. Research based at the University of Hawai'i and the Hawaii Agricultural Research Center
7. Long-term, low-input support (e.g., two graduate students)
8. Determination of heritability for tolerance of *Fusarium oxysporum*, tolerance of rust(*Endoraecium acaciae*), and "fiddleback" (overlapping spiral grain)
9. Major survey of genetic variability between islands, based on molecular markers
10. Major survey of chromosome number variation, based on flow cytometry
11. Short-range breeding: Multiple breeding populations evaluation for breeding value, with progenies combined as seed orchards
12. Long-range breeding: Evaluate clones for G*E, planting high-quality, high-figure clones

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