CONTRIBUTION OF GENETICS TO THE SUSTAINED MANAGEMENT OF GLOBAL FOREST RESOURCES

Third IUFRO-FAO Consultation on Forest Genetics and Tree Improvement
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CONCLUSIONS AND RECOMMENDATIONS

A hundred Forest Tree Geneticists and Breeders of 33 countries contributed by their invited papers and their discussions to defining the role of forest genetics for the enhancement and sustainability of forest production at the threshold of the XXIst century.

While they have admitted that for political reasons certain developed countries have had reduce or stop genetic improvement, they have recorded that in a majority of regions breeding is of the highest social and economical importance.

During the conference participants have decided to propose a series of statements and research priorities which are now summarised.

New challenges, new technologies

Selection and improvement of forest trees are developed in about a hundred countries in the world. Strategies and tools must be adapted to social needs, to the scientific and technical background and to financial possibilities. In developing countries, priority should be given to traditional tree improvement. In the more developed countries integrated programs applying traditional breeding and new technologies will be critical to the success of forest tree improvement. Advanced breeding should focus on a limited number of species used in intensively managed plantations. When appropriate it should include new technologies such as genomic mapping, marker assisted selection, genetic engineering and short generation model species. Such technologies should be used to shorten breeding cycles and increase their efficiency. They should be supported by long term multigeneration breeding programmes using sound quantitative genetics tools.

While classical quantitative genetics appear to be a relatively mature field, new advances still have to be made. The attention of scientific decision makers should be drawn upon the fact that quantitative geneticists are lacking because of competition for young scientists with more attractive research subjects involving new technologies. However one should look to applying or adapting various advances made by animal geneticists working on methodology dealing with multivariate data from multiple generations with more complex classifications, and greatly increased computing power.

Adaptive potential of forest trees

The first step of any genetic improvement programme is testing the adaptation potential of species, populations and individuals. Testing trees on a large amount of environments, sometimes waiting for the occurrence of rare biotic or abiotic events, should now be assisted by gene makers. Particularly the following research topics should be considered:

Studies on phenotypic plasticity in tree species with respect to both individuals and populations. Forest tree species seem to deviate substantially in their adaptive strategies. Verification of specific adaptive strategies are needed instead of generalising results obtained on "model" species.

Utilisation of markers adapted to each purpose. Knowledge gaps are evident in the use of markers to study population dynamics and particularly reproduction processes.

Differential modelling with respect to species and processes. Avoidance of oversimplification is particularly indicated with respect to selection: need for differentiation among disruptive, stabilising or directional selection.

Generally it is concluded that the existing knowledge gap between genetic markers and the expression of adaptive traits, among individuals, families and populations needs to be bridged in close cooperation with physiologists. It is time to finish the era of "looking for Mendalian inheritance". Genetic mapping of QTLs and of loci which are involved in response to biotic and abiotic stresses should be developed rapidly.

Adaptation to a changing environment

The global environment is changing. Air CO_2 and O_3 are increasing. Temperatures are changing. Forests are now and will continue to be impacted by these changes. Although forest geneticists have at their disposal the methods and capabilities to study the genetic implications of global environmental change and the implications for forest sustainability, there is still insufficient research to date on the impacts of global environmental change on genetic resources of forest tree populations.

The following recommendations are made :

- Genetic diversity should be among the highest priority research areas in biodiversity studies related to global environmental change.
- Genetic diversity and improved adaptability are important components of forest sustainability under global environmental change.
- A better integration of genetics in forest ecosystem studies related to global environmental change is needed.
- Understanding genetic control of tolerance to global environmental change will help determine how best to maintain adaptability and variability under global environmental change.

The following research avenues are recommended

- Impacts of greenhouse gases and temperature change on forest productivity, genetic diversity, community dynamics and reproductive fitness.
- Genetic markers and bio-indication as indicators of genetic change due to global environmental change.
- Conservation of genetic resources under the changing environment.

- Impact of global environmental change on reproductive biology in connection with reproductive fitness.

Maximising productivity while maintaining sustainability

To protect the large areas of natural forests, particularly in the tropics, the world demand for wood will increasingly be met from plantation forestry with fast growing, often exotic, species. International exchange of germplasm, which has historically proceeded with little restriction, should continue thanks to bilateral technical agreements between governmental and non-governmental organisations.

There is a widely held assumption that naturally regenerated forests are more stable than planted ones, because they have maximum diversity. It is necessary to recall that properly managed breeding programmes can maintain or even increase genetic variation relative to natural populations just because the gene flow is optimised and the genetic pollution minimised.

Intensive forestry should include research on risk assessment particularly when high genetic gain varieties are used. Special attention should be paid to clonal varieties which do not necessarily require large number of clones: varieties with 10-30 unrelated clones may present more genetic diversity than certain provenances particularly when seeds have been collected on a too limited number of individuals.

The *Pinus teada* breeding programme in Southeast USA can be presented as a good example to demonstrate how forest genetics and tree improvement can contribute significantly to the sustainable development of forestry. After more than 40 years of research efforts it has been shown that only 15% of the commercial forests which are in plantations can produce 50% of the required wood supply and that improved wood production on limited commercial lands reduces the logging pressure on natural forests.

Such an approach should be extended to all regions where a high demand of wood is anticipated.

Conservation Genetics
New tools

It is essential to raise awareness, at all levels, on the importance of conservation and sustainable utilisation of forest tree gene resources to fulfil the needs of current and future generations. These needs include genetic improvement for which this source of genes may become of the greatest importance to face unpredictable occurrence of pests, diseases and of abiotic adversaries.

The prerequisite to any conservation scheme includes the examination of the amount and distribution of genetic diversity. Molecular makers have become a powerful tool for this purpose. But, as for genetic improvement research, there is the need to also examine adaptive characters in genetic conservation research since risk analysis is a very useful approach in decision process for conservation.

The amount and distribution of genetic diversity can often be inferred from knowledge of determinants of genetic diversity. Research efforts should continue to be developed on mode of reproduction, breeding system, gene flow mechanism, geographic range, life cycle and population size, at scales varying from stand size to range size.

Networking

There is an urgent need to demonstrate to policy-makers and to the general public, that genetic conservation is fully compatible with a wise management of forest resources and that it is an integral part to the overall maintenance and enhancement of biological diversity.

Country-driven efforts should be linked and streamlined, and, if needed, supported by regional and international initiatives when they exist. But in certain regions capacity building and creation of conservation frameworks and mechanisms are still needed.

Priorities

In view of the large number of tree species of current or potential interest it is necessary to carry out in-depth priority setting according to environmental, social and economic factors.

Most forest tree species can be classified in three groups:

- Species of current high socio-economic value, likely to be already included in improvement and conservation schemes,
- Species with clear potential or future value, for which a main research objective could be to understand the extent and patterns of genetic variation,
- Species of current unknown value, into which a large majority of tree species falls, for which the continued existence of samples of populations could be the only management objective.

Managing Genetic Resources with Appropriate Silviculture

Although most forestry practices and stand management systems have been applied on local forests for generations, very little is known about their effect on the usually high natural diversity of forest tree species. But genetic erosion must not reach an unacceptable level because of unadapted forestry practices.

Genetic diversity must be considered throughout all steps of tree domestication: selection, breeding, seed handling, nursery operations, planting, thinning, and also in natural regeneration.

Much of the gene conservation must take place in managed areas since these dominate most landscapes. It should be an integrated part of stand management. Most early monitoring of changes in genetic diversity must be the responsibility of forest managers. But scientists should provide them with indicators which give alarm when something threatens to go wrong.

Simultaneously, studies on the effects of different forest interventions on genetic variability in sample forest ecosystems (from natural reserves to fiber farms) should be started to allow scientists acquire background data on genetic diversity in key species and to look for suitable indicators of disruption from normal genetic processes. Modelling should be based on suitable indicator species in each area.

Because studying the effect of forest management is a global issue, IUFRO should play an important role in the coordination of international research, particularly in propos-

ing standard methods to monitor changes and in establishing reference trials with selected species in various parts of the world.

The Right Messages through the Right Messengers

Breeding and improvement of forest trees is a long term process. Improvement strategies should be explained to all stakeholders to convince them of their need, of their environmental harmlessness and of their cost. Breeders may not be the best messengers because of their fundamental believe that genetic improvement of forest trees is useful to society, adapted to the need for renewable woody raw material and environmentally friendly. Best messengers probably are of two types:

- actors of the extension chain of genetic gain such as seed merchants, nursery managers and forest owners,
- current opponents, such as greens who generally have a strong biological background and who, once they are convinced, would be much better conveyors of the right messages because of they have large access to media.

Funding Policy and Cooperative Research

In North America, public sector support for tree improvement research has declined significantly, including federal, state and university programs. In New Zealand, these programs have been privatized to a large extent. In tropical developing countries, there is inadequate state funding and a need for more financial support by international organizations and foundations.

It is recommended that in most regions of the world, increased financial support by the public sector be a requisite for long-term tree improvement research. However cooperation between public and private agencies and foundations will be needed for the development of long-range research programmes in tree improvement with reasonably secure funding sources.

Regardless of advances in modeling and genetic engineering, provenance research is still needed in many regions and traditional breeding will continue to be important to practical objectives such as adaptation, resistance and yield. Nevertheless more efficient designs will be needed for population sampling and progeny testing, New approaches such as small-population intensive breeding and the use of model species should be considered. Species priorities will have to be established for each region. Existing valuable field experiments and selected seed orchards must be preserved for future research.

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