Role of Tree Breeding in Timber and Wood Supply in World and India: Status and Outlook

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Abstract

Tree breeding is an important component of tree improvement which involves the application of genetic principles for the mass production of seedlings with desired traits in order to achieve higher productivity, better adaptability of the environment and vigorous growth rate. It helps in increasing yields and shortened rotations so it has a large potentiality to supply timber and wood demand of the world. Species choice, provenance selection and propagation method are the major aspects of tree breeding. Plus tree selection, progeny testing, provenance test and vegetative propagation have been used since early of civilization and often regarded as conventional tree breeding techniques while seed orchards, clonal propagation, somatic embryogenesis, micro-propagation or in-Vitro propagation, and biotechnology are modern tree breeding techniques. Different countries have been developing tree breeding techniques and achieving maximum benefits from it. Southeast Asia is using Acacia mangium, A. crassicarpa, Gmelina arborea, and Eucalyptus spp.; Populus deltoids, Casuarina equisetifolia, Eucalyptus spp. have been using by India; Teak has been vegetative propagated in Thailand; Salix babylonica has been growing in Greece for biomass production. Increasing yield and shortened rotation are the major prospects while loss of genetic diversity, higher production costs and requirement of constant upgrading are the major hindrances of tree breeding.

Key Words: Hybrids, Seed orchards, Micro-propagation, Biotechnology, Tree Improvement

Introduction

Tree breeding is the application of genetic principles to the genetic improvement and management of forest trees (http://en.wikipedia.org/wiki/Tree_breeding).

Success in the establishment and productivity of forestry plantations is determined largely by species used and the source of seed within species(Zobel and Talbert, 1984 as cited in

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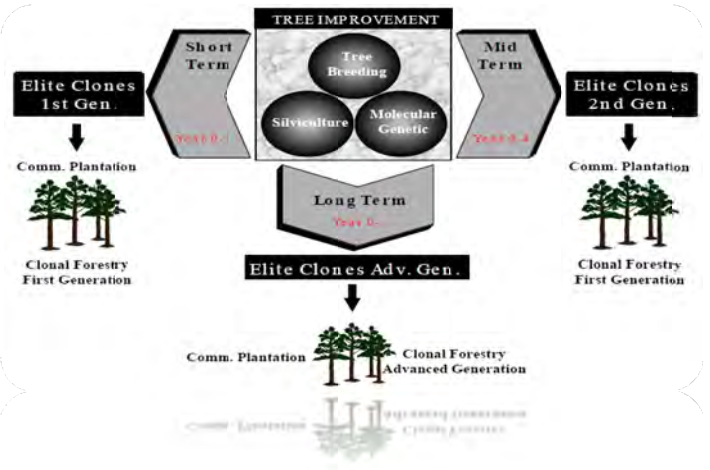
White, Adams and Neale, 2007 and also on http://www.westcoastpaper.com/images/docs/captive_plantation.pdf).

Linkages of Tree Breeding with Tree Improvement

Tree improvement most often has relied on traditional breeding techniques like selection of superior (plus candidate) trees for volume and stem straightness, and grafting these into breeding orchards and producing seed orchards. When breeding orchards begin to flower, pollination of selections is artificially controlled, seeds are collected, progeny tests are established, and the best offspring are chosen for the next cycle of breeding. At the same time, selections whose offspring did not perform well in the progeny tests are removed from the production seed orchards to improve genetic quality (Tridasa, Hoon and Cheol, 1996). Success of tree improvement depends upon tree breeding, silviculture and molecular genetics of species and its particular varieties.



Goal of Tree Breeding

Tree breeding helps in genetic adjustment of plants to the service of humans, and capitalizes the natural variability and packages of the best traits (Zsuffa, 1989 as cited in Chuntanaparb and Ranganathan, 1981). It consists of packaging the desired traits into improved individuals, mass production of improved individuals for planting purposes and developing and maintaining a genetic base population for advanced generation.

Importance of Tree Breeding

Tree breeding helps in increasing yields and shortened rotations, so planted forests become increasingly attractive as an investment for producing industrial wood, and it can ensure supplying of fuel wood as well as meet other needs of rural people if introducing fast-growing multi-purpose tree species for farmland planting (Shea and Carlson, 1984).

The principles and practices of plant breeding of trees are well established and they apply equally to industrial plantations and small land-holder agroforestry and community plantations also. The goal of tree improvement for agroforestry is to increase the effectiveness of land for productivity, suitability and sustainability of land use for rural communities (www.westcoastpaper.com/images/docs/captive_plantation.pdf). There are a number of key problems or needs that can be addressed by appropriate use of multipurpose tree species through tree breeding strategy. In the Asian region, about 600 million people are experiencing an acute shortage of fuel wood. Either animal dung or crop residues are widely used for fuel or for maintaining and improving agricultural soil fertility. Breeding programs of fast-growing multi-purpose tree species for farmland planting can ensure supplying of fuel wood as well as meet other needs of rural people (Chuntanaparb and Ranganathan, 1981).

Essential features for Tree Breeding

Choosing appropriate species and sources is the single most important genetic decision in Tree Breeding. The largest, cheapest, and fastest gains in most tree breeding can be made by using proper species and seed sources within the species (Zobel and Talbert, 1984 cited in White, Adams and Neale, 2007). The wrong choice can lead to loss in productivity or at worst, complete plantation failure (White, Adams and Neale, 2007).

A list of components which are of almost universal importance for tree breeding are listed below (Koski and Vihera-Aarnio, 1986 as cited in Yangchuk, 1994);

I. High rate of net photosynthesis;
II. Efficient light interception;
III. Full utilization of the growing season;
IV. High harvest index;
V. Efficient use of water and nutrients;
VI. Rapid juvenile growth;
VII. Tolerance to competition;
VIII. Tolerance to abiotic stress;
IX. Freedom from pests and diseases;
X. Suitable biomass properties; and
XI. Ease of reproduction and plantation establishment

Types of taxa and their attributes for plantations:

i) **Native versus exotic species**

Native species offers some advantages if a local provenance is used, then adaptation to the climate and soils of the planting zone is ensured. There are many examples in the world of large successful plantation based on native species: *Pseudosuga menziesii* in the western USA and Canada; *Pinus taeda*and *P. elliottii* in the southern USA, *Pinus sylvestris* and

Picea abies in Europe and *Tectona grandis* in India. There are many excellent examples of successful exotic plantations: *Picea sitchensis*, *Pinus contorta*, *Pseudosuga menziesii*, and *Eucalyptus globulus* are planted on a large extent in different parts of Europe. The two most widely planted exotic tree species in the world are *Eucalyptus grandis* and *Pinus radiate* (White, Adams and Neale, 2007).

ii) **Interspecific Hybrids**

Hybrid vigor possesses the superiority of hybrid over parental species. Moreover, it is ease of vegetative propagation of hybrid clones and popularity of hybrids in plantation of many genera includes *Populus*, *Salix* and *Eucalyptus* (White, Adams and Neale, 2007).

iii) **Subspecies, varieties, provenances and land races**

Genetic differentiation within each variety or sub species can be great, necessitating consideration of them as separate entities and field testing of many provenances or sources are required (White, Adams and Neale, 2007).

Tree breeding techniques

Tree breeding is a continuous process and assumed that it might be started from the early period of civilization. Both conventional and modern methods are being applied in the tree breeding.

Some conventional tree breeding techniques are listed below:-

I. Plus tree selection
II. Progeny testing
III. Provenance test
IV. Vegetativepropagation

Some modern tree breeding techniques are listed below:-

I. Seed orchards
II. Clonal propagation
III. Somatic Embryogenesis
IV. Micro-propagation or In-Vitro propagation
V. Bio technology

1. Some conventional tree breeding techniques

I. Plus tree selection

"Tree breeder usually select individual trees that are phenotypically superior in respect to the traits" (Yanchuk, 1998). Squillace, 2005 states, "If environmental effects are strong,

offspring-parent regression will tend to be weak and genetic gains will tend to be small. Similarly, if the environmental effects are weak, parent-offspring regression will tend to be strong and genetic gains will be large. According to Jonathan, 2003, desired qualities/ traits can be readily achieved through plus-tree selection and resulting genetic gains up to 15% in height and diameter growth, and up to 35% in volume per unit area.

II. Progeny testing

Progeny testing refers to estimate the relative genetic values of parents based onperformance of their offspring. Parental selection through progeny performance is called backward selection since data from progeny are used to rank and re-select top parents (Werner and Josefina, 2001).

The pre-requisite for progeny testing are as follows:-

- Plus trees whose progeny perform consistently well,
- Must have superior breeding values and
- Favored for inclusion in the breeding and propagation populations.

III. Provenance test

"A very strong differentiation of adaptive traits can be found among tree populations growing under different ecological conditions. Such variabilities are characteristic of provenances and may be expressed by various traits on the genetic, morphological, phenotypic and phenological levels which can be obtained by submitting provenances to specific testing procedures" (Eriksson 1996, 1998 cited in Werner and Josefina, 2001).

Prof. Champion initiated provenance trial test of Chir Pine at Dehradun,India during 1930s. He realized the importance of geographical variations, and applied the knowledge of forest genetics (http://fri.icfre.gov.in).

IV. Vegetative Propagation

Vegetative propagation of plant has been carried out through using vegetative tissues, resulting genetically identical to the original "donor" plant. Vegetative Propagation is one of the most important tool and widely used in tree breeding to manage breeding population more effectively. It has major advantage over sexual reproduction as a means of mass production. All the genetic components of "donor" plant can becaptured and duplicated (www.westcoastpaper.com/images/docs/captive_plantation.pdf).

Vegetative Propagation occurs both naturally and artificially:-

- Natural vegetative propagation: Many plants spread through rhizomes, corms, bulbs, tubers and runners.
- Artificial vegetative propagation: grafting, cutting and tissue culture.

Huge leap in short rotation plantation productivity offered by specific hybrids have beenmade operationally possible through the development of technique of vegetative propagation by cutting. The main advantages and importance of vegetative propagated Eucalyptus, Acacia, Pines and Poplars etc. are namely uniformity, adaptation, cost and wood productivity (www.westcoastpaper.com/images/docs/captive_plantation.pdf).

Mass vegetative propagation has become an important tool for increasing thecompetitiveness of the forestry based industry. This method reaches its highest potential when it is used to establish clonal forests of hybrids endowed with better wood quality and higher volumetric growth (Teotônio, et al. 2004).

Some modern tree breeding techniques-

I. Seed Orchard

A seed orchard is an intensively-managed plantation of specifically arranged trees for the mass production of genetically improved seeds to create plants, or seeds for the establishment of new forests. Seed orchard is a common method of mass-multiplication for transferring genetically improved material from breeding populations. It is a plantation of genetically superior trees where favoured trees are isolated to reduce pollination from genetically inferior ones, intensively managed to produce frequent, abundant, and easily harvested seeds; and designed and managed to produce seeds of superior genetic quality compared to those obtained from seed production areas, seed stands, or unimprovedstands (http://en.wikipedia.org/wiki/Seed_orchard).

There are two main types of seed orchards regarding to the way of establishing (Kyu-Suk Kang, 2001 cited in Tellalov, 2006):-

- Seedlings seed orchards, which have been grown from seeds collected form plustrees and having large genetic base.

- Clonal seed orchards, which have been grown either from grafts or from rootedcuttings

II. Clonal propagation

Clonal propagation offers several advantages over traditional seedling establishmentpractices, including planting stock and product uniformity, alternative disease management strategies, vegetative propagation of conifers and potential to capture greater amounts of the genetic variation (Tuskan, 2002).

Most of the world's large successful cloning emerged through using juvenility of the tissues of trees such as eucalyptus *(Eucalyptus sp.)*, poplars *(Populus sp.)* willows *(Salix sp.)*, Chinese fir *(Cunninghamia lanceolata)* and *Acacia hybrid* (Tuskan, 2002).

III. Somatic Embryogenesis for Clonal Forestry

Somatic embryogenesis (SE) in conifers is a recently developed cloning technique, anunlimited number of genetically identical copies of trees can be produced from a single seed which can offset deficit in genetically superior and high-value trees by deploying the best available genetic stock to commercial sites (www.fao.org/DOCREP/ARTICLE/WFC/XII/0221-B2.HTM).

IV. Micro-propagation or In-Vitro propagation

It is the practice of rapidly multiplying stock plant material to produce a large number of progeny plants; used to multiply novel plants, such as those that have been genetically modified; used to provide a sufficient number of plantlets for planting from a stock plant which does not produce seeds, or does not respond well to vegetative reproduction (http://en.wikipedia.org/wiki/Micropropagation). Some widely used micro-propagation techniques are in Fagus, Eucalyptus, Acacia, Aegle etc (http://www.fao.org/docrep/006/ad223e/AD223E05.htm).

V. Biotechnology

Biotechnology comprises any technique that uses living organisms to make or modify a product, to improve plants or animals, or to develop micro-organisms for a specific use (Haines 1994, 1994a cited by Sedjo, 1999). Currently, biotechnology refers to the commercial application of living organisms or their products, which involves the deliberate manipulation of their DNA molecules (Sedjo, 1999).

The creation of transgenic trees will be commercially attractive if a few transgenic plants can provide the basis for large-scale, low-cost propagation. This is likely to be possible only through some type of low-cost cloning, which will allow replication of transgenic plants. However, replication for some tree species has been shown to be relatively easy. For example, improved hardwoods, such as hybrid poplars, are readily replicable through simple vegetative propagation (Sedjo, 1999).

Major contribution of Tree Breeding in supplying timber and wood in World & India

The southern US has greatest potential lies in intensively managed pine plantations, growth of 4 cd/ac/yr (chord per acre per year) can be achieved from good sites with tree breeding and intensive silviculture, even on marginal sites, growth rates of 2 cd/ac/yr can be achieved (Kellison, 2005).

The wood resource for pulp mills in Southeast Asia is primarily from plantations of Acaciamangium, A. crassicarpa, Gmelina arborea, and Eucalyptus spp. Plantation tree growth rates of 25 m^3/ha/yr are harvested at an age of 6 year. With genetic improvement and tree breeding, average growth rates of35 m^3/ha/yr are being anticipated (Kellison, 2005).

The average productivity of poplar under agroforestry system is 20-25 m^3/ ha/ yr, which is five times higher than traditional forest throughout Punjab, Haryana, UP and some parts of Bihar, West Bengal and Assam state (Singh et al., 2001 cited in Swamy, et al.2005)

A tree breeding program initiated with C. equisetifolia in Andhra Pradesh at the Regional Forest Research Centre (RFRC) of Rajahmundry in 1994. Plus-trees have been selected and clonally propagated, progeny and clonal tests have been established, primary species selected for the establishment of shelterbelts, established at an initial stocking of 2500 trees/ ha and managed on a 7-year rotation (Prasad and Dieters, 1998).

In Thailand, tree breeding through vegetative propagation of Teak has been given highpriority with great success. Tissue-culture technique of teak has developed on a commercial scale in Thailand (Kaosa-ard et al., 1987; Kaosa-ard, 1990; Kaosa-ard, 1993). Price for this planting stock is approximately two to three times higher than the price for traditional seedlings and/ or stumps. However, combination of tissue culture and subsequent cutting of tissue-culture plantlets proved to be both technically and economically feasible for large scale production of clonal planting material (Apichart K., Verapong S. and Erik D. K, 2000).

Breeding of Salix babylonica of clonal selection for biomass production has been established in Greece. The production of plantation yielded 30 t per ha per year, which was comparatively very high than poplar plantation, and it has high potential for future development of biomass producing clones, and it is more tolerant in a wide variety of climatic and soil conditions (Aravanopoulos, 2010).

Cloning of Poplar in Greece for biomass or wood production is largely successful. More than 100 intra- and interspecific crosses of Poplar have been included in tree breeding. The best clone of Poplar is P. xeuramericana with an average production of 16.54 ton per hectare per year (t/ha/yr) followed by I-214 with an average production of 14.40 t/ ha/yr. (Aravanopoulos, 2010).

Critical analysis and outlook

Prospects of Tree Breeding

Forest productivity can be increased significantly through clonal forestry.Some tree species such as Eucalyptus, Poplar and Acacias have already shortened the harvesting cycle through tree breeding and tree improvement programs. This shortened rotation can harvest after five years without sacrificing the quality of wood. The current findings suggest that wood density or pulp yield is independent of growth rate. Increasing yield per hectare and reducing the unit cost of wood may boost up Sustained Commercial Forestry in near future

(www.westcoastpaper.com/images/docs/captive_plantation.pdf).

Problems of tree breeding

Loss of genetic diversity, competition between clones and clone specific silviculture required are the major biological concerns. Production/ management costs, propagule costs higher and clonal testing costs as great and requires constant upgrade are the major economic concerns. Social acceptance and regulation are the prime social and environmentalconcerns (www.forestry.gov.uk/pdf/f_d-thompson.pdf/.../f_d-thompson.pdf).

Conclusions

Tree breeding helps in mass production of seedlings for achieving higher productivity oftimber and wood products. Both conventional and modern techniques have been used for tree breeding in global and Indian level. It assists in supplying large quantities of timber and wood for growing enormous demand of wood market across the world including India. Since modern tree breeding techniques are advancing each day, it has a great potentiality to supply large biomass demand of the world including India.

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