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BIOTECHNOLOGICAL APPLICATIONS IN FORESTRY

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ENVIS Newsletter on Environmental Biotechnology is a half-yearly publication publishes articles related to the thematic area of the ENVIS Centre. Popular or easily intelligible expositions of new or recent developments are welcome.
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Figures and typed table should be in separate pages and provided with title and serial numbers. The exact position for the placement of the figures and tables should be marked in the manuscript.

Articles should be sent to

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EDITORIAL

ENVIS Centre on Environmental Biotechnology at DESKU is publishing news letter in regular intervals. This volume emphasises biotechnological application in forestry. In fact, forest resources depletion throughout the world during the last several decades has created al alarming situation. Apart from carbon sequestration, forest also plays havoc in resource and livelihood generation towards the societal benefit. This is to be noted that globally natural forest area is decreasing while the planted cover area is increasing. In India, forest cover is also increasing. Forest in the future will increase its beneficial impact to the society by providing food, wood, energy, shelter, generating income etc. Though conventional silviculture protects and breeding techniques have attributed in the improvement of forest tree species and the plants, tree breeding for forest increasing yield and shortens rotation. Forest biotechnology is very much useful for list intensively managed planted forest and also helps in vegetation propagation.

Continued research in biotechnology will improve the knowledge base pertaining to forest value and efficiency of trees.

IN THIS ISSUE:

BIOTECHNOLOGICAL APPLICATIONS IN FORESTRY

INTRODUCTION

Forests are gift of nature and it is useful to man. It controls temperature, bring rain, prevent soil erosion, improve soil fertility, provide compost and medicinal herbs and valuable timber, fuel and fodder to cattle. It is habitat of the wild life and inexhaustible source of energy and also an important part of our ecological system. It also provides different goods and services that humans depend on, such as water reservoirs, biodiversity and wildlife habitats, carbon sequestration, timber, recreation and other social and spiritual values. About a quarter of the world's land surface is covered by forest. Forests are transformed by management activities such as livestock grazing, recreation, water diversions, roads, and the harvesting of trees.

India has the huge forest resources as well as significant population of tribal and rural communities which are very much linked to the forest ecosystem. Those peoples are mainly depends on forest resources for their livelihood and the forest is also their way of life socially and culturally. It meets basic needs like fuel wood, fodder and small timber that are important for them and their livestock. Degradation and depletion of the forest resources are increasing poverty and suffering among the tribal and rural people. Therefore, it is imperative to rehabilitate degraded forest resources in order to sustain rural livelihoods. This can be possible only with the active support of local organizations people's participation in forest management and silviculture which is generally known as Joint Forest Management (JFM) in India. Now, it is recognized that participatory management of forests is key to sustainable development for people and forests. The promotion of Non-Timber Forest Products (NTFP) species, through productivity improvement and value addition is necessary to reverse this trend and to sustain the livelihood of the tribal rural families. The NTFP are categorised as food security (Honey, mushroom, edible fruits and nuts, foliage and rhizomes), Wood and Biomass (fuel, furniture, thatching, forage and manure), Medicines and Plant Protection (**f**or human beings, animals and for control of pests and diseases in agricultural crops), Aromatics, Dyes and Oilseeds (medicinal and industrial uses). The sustainable use of forest resources can promote poverty reduction, creation of livelihood, environmental security and conservation of biodiversity.

Globally, natural forest area is decreasing and planted forest area is increasing. As of 2015 reported natural forest accounts for 93 percent of total forest area. The global annual net loss of natural forests decreased from some 10.6 million ha in the 1990s to 6.5 million ha between 2010 and 2015. The largest area of natural forests is found in Europe, with about 925 million ha, of which about 85 percent is in the Russian Federation. South America and Africa account for the largest loss of natural forests, followed by Asia and North and Central America. In Europe and Oceania the trend is relatively stable. Planted forest area has increased by over 105 million ha since 1990 and accounts for 7 percent of the world's forest area. The average annual rate of increase between 1990 and 2000 was 3.6 million ha. The rate peaked at 5.3 million ha per year for the period 2000–2010 and slowed to 3.2 million ha between 2010 and 2015, as planting decreased in East Asia, Europe, North America, South Asia and Southeast Asia. Among world regions, Europe accounts for one-quarter of total forest area, followed by South America and then North and Central America. South America is the region with the highest percentage of forest cover (almost half of the land area) and Asia is the region with the lowest percentage of forest cover (less than 20% of land area Table 1, Figure 1). South America is the region with the highest percentage of forest cover (almost half of the land area) and Asia is the region with the lowest percentage of forest cover.

Table: 1 World Forest Cover, 1990-2010

Region	Total forest cover		
	1990	2000	2010
	Million Hectares		
Africa	749	709	674
Asia	576	570	593
Europe	989	998	1,005
North and Central America	708	705	705
Oceania	199	198	191
South America	946	904	864
World	4,168	4,085	4,003

Source: Compiled by Earth Policy Institute from U.N. Food and Agriculture Organisation 2010.

The spread of planted forests has been accelerating, rising from an expansion of 3.7 million hectares annually in the 1990s to 4.9 million hectares annually. Planted forests now cover some 264 million hectares, comprising nearly 7 percent of total forest area. Plantations now have the potential to produce an estimated 1.2 billion cubic meters of industrial wood each year, about two thirds of current global wood production. Where forests have already been cleared, plantations can alleviate the pressure on standing forests.

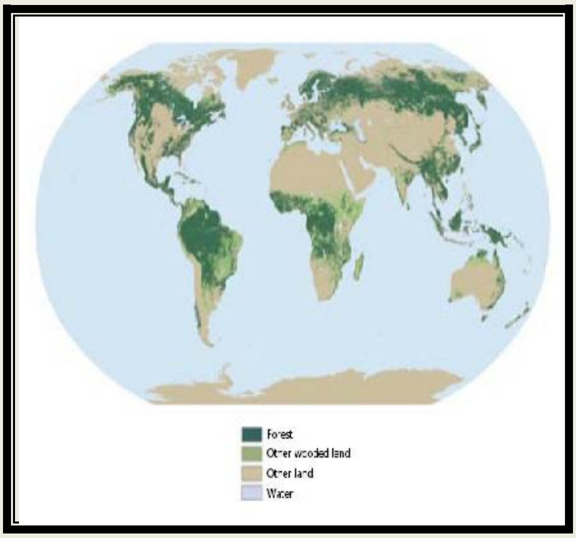

Fig. 1: World's forest cover area
Source: https://www.greenfacts.org

In case of India Government announced that India's forest and tree cover has increased by 5081 sq km. While the total forest cover of the country has increased by 3775 sq km, the tree cover has gone up by 1, 306 sq km. The total forest and tree cover is 79.42 million hectare, which is 24.16% of the total geographical area. The total carbon stock in the country's forest is estimated to be 7044 million tones, an increase of 103 million tonnes, which is an increase of 1.48 in percentage terms over the previous assessments [India State of Forest Report (ISFR), 2015] (Figure 2).

Forest trees are important for our environment, as a source of timber and a range of other products in our daily lives. Conventional silvicultural practices and breeding techniques have contributed significantly to the improvement of forest tree species in the past, and will continue to have a substantial impact on the genetic gain and productivity of economically important tree species by providing better germplasm and improved management practices for plantation forests.

Continued research in biotechnology may address and solve other issues, such as why some woods resist rot and others do not and why some species are susceptible to insects and others are not. Through this continually expanding knowledge will come advancements that will maximize the value and efficiency of trees.

The forests of the future will increase the resilience of communities by: providing food, wood energy, shelter, fodder and fibre; generating income and employment to allow communities and societies to prosper; and harbouring biodiversity. They will support sustainable agriculture and human well-being by stabilizing soils and climate, and regulating water flows.

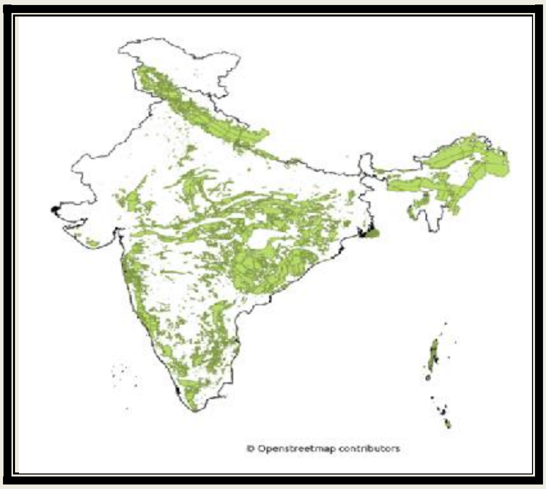

Fig. 2: Indian Forest cover map
Source: https://en.wikipedia.org

What is forest biotechnology?

Forest biotechnology is to understand the mechanisms driving plant development and plant adaptation to environmental changes. It utilizes fundamental discoveries in the field of plant tissue culture for clonal forestry, gene transfer techniques, molecular biology, and genomics. Biotechnology provides exciting opportunities to further expand our understanding of genome organization and functioning of genes associated with complex value-added traits, and to transfer such genes into economically important tree species. This will help the future demand of the world's ever-increasing population for timber and other forest products, while preserving natural forests for future generations. It can contribute to improving productivity and reducing vulnerability of forest ecosystems to disease, degradation and human disturbance. It is a growing field of study that has many potential benefits for humankind and our environment. The challenge continues to be to ensure sufficient genetic gains while maintaining genetic diversity at the ecosystem and landscape levels. In recent the forest biotechnology focused on to mitigate the effects of forest fragmentation on genetic diversity, and promote gene flow by managing tropical forest ecosystems for pollination, seed dispersal and soil symbionts.

Forest biotechnologies is suitable for the least intensively managed planted forests and includes a range of vegetative propagation methods such as tissue culture, biofertilizers and genetic fingerprinting using molecular markers. It can also be complemented by conventional technologies such as early-stage tree improvement programmes. But the dysgenic plantation may reduce the local gene pool, soil fertility, loss of ecosystem and biodiversity (Quesada et al., 2009). Overall the applying biotechnologies the forest plantation contribute to the health and quality of indigenous tropical forests and of exotic species (Figure 3).

Fig. 3: The genomes of forest trees
Source: https://www.newphytologist.org/symposia

Tree breeding

The management and genetic improvement of forest trees can be implemented through plant breeding technology. Applying this techniques development of individual trees, varieties, populations which are suitable for human needs and environment are produced.

The forest tree breeding programme was started for the development of better phenotypes in a natural or planted forest and improve the performance of the forest. Based on mass selection techniques suprier genotypes and phenotypes offsprings are developed. The best selected trees are multiplied by either seeds or graftings for orchards and forest plantation. This system is frequently used in pines and other conifers. Alternatively the best genotypes can be directly propagated by cuttings or in-vitro methods and used directly in clonal plantations in broadleaves plants like, poplars, eucalyptus etc. In recent the tree breeding techniques adopted to take advantage of the fast development in plant genetics and genomics (Figure 4).

Importance of tree breeding

Tree breeding helps in increasing yields and shortened rotations.

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.

There are a number of key problems or needs that can be addressed by appropriate use of multipurpose tree species through tree breeding strategy.

Breeding programs of fast growing multi-purpose tree species for farmland planting.

Fig. 4: Biotechnological tools for the genetic transformation of trees
Source: https://www.intechopen.com

Forest biotechnologies can be classified in many ways, there are five major, though undoubtedly overlapping, categories.

1. Popagation
2. Molecular markers
3. Marker-assisted selection and marker-assisted breeding (MAS and MAB)
4. Genomics, metabolomics and proteomics
5. Genetic modification or genetic engineering.

1. Propagation

Propagation of plants involves the formation and development of new individuals, which are used in establishment of new plantings. It is simply the reproduction or multiplication of a plant from a source that is often referred to as a mother plant. In general, two methods are employed: **(1) sexual,** and **(2) asexual.** The sexual propagation is recombination of genetic materials to form uniquely genetic individual through the formation of seed, and asexual or vegetative propagation involves the use of vegetative organs to create plantlets genetically identical to parent plant (clone).

Plant cloning has been used for centuries for tree breeding and propagation using grafts and cuttings. This technology describes the various stages in the vegetative propagation of trees (from tree nursery management to cuttings, grafting, and layering). The concept of vegetative propagation is that an exact copy of the genome of a mother plant is made and continued in new individuals. Vegetative propagation aims at the identical reproduction of plants with desirable features such as high productivity, superior quality, rapid multiplication of genotypes, or high tolerance to biotic and/or abiotic stresses, and plays a very important role in continuing a preferred trait from one generation to the next**.** This techniques used as the ancient forest application mostly applicable for species having few or recalcitrant seeds or seedlings and for multiplying selected genotypes in a short period of time.

The National Chemical Laboratory in Pune and the Tata Research Institute in Delhi produce up to a few million teak plantlets annually. Phytosanitary measures also require tissue culture when moving germplasm from one country to another. This reduces the spread of plant viruses. Some of the disadvantages are the high costs of maintaining a tissue culture laboratory and quality control. Without quality control, one often sees the occurrence of somaclonal variations and deformed plantlets (Figure 5). Integrating traditional methods such as in situ conservation and seed storage with biotechnologies such as micropropagation and cryopreservation can provide successful solutions (Table-2).

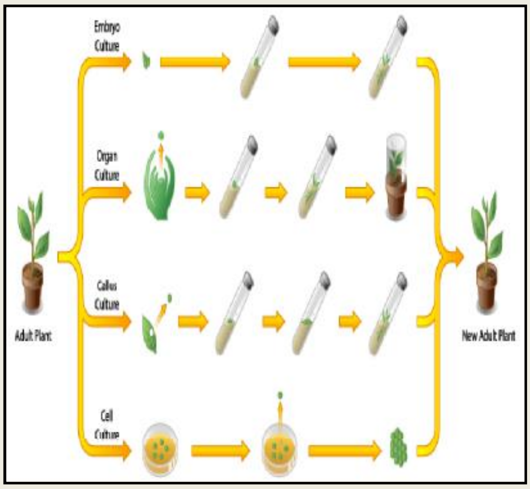

Fig. 5: Plants in vitro culture propagation

Source: https://www.pinterest.com

Table: 2 Tissue culture of some tree on a commercial scale

Countries	Species
India	*Tectona grandis, Anogeissus latifoglia Bamboo spp*
Indonesia, Malaysia and Vietnam	*Acacia mangium and Acacia mangium x Acacia auriculiformis hybrids*
India, Vietnam and South America.	*Eucalyptus spp*
Chile	*Pinus radiata*
Brazil, Indonesia, Malaysia and Thailand	*Tectona grandis*

Micropropagation

Aseptic method of clonal propagation is called as Micropropagation and it offer the advantage of large number of true-to-type plantlets can be produced with relatively short time and space from a single individual. Approximately 34% of all biotechnology activities reported in forestry over the past ten years related to propagation (Chaix and Monteuuis, 2004; Wheeler, 2004). Micropropagation is used to multiply (bulk-up) desirable genotypes or phenotypes to create large numbers of genetically identical individuals of clones or varieties. These techniques are gaining increased attention by foresters and tree breeders because vegetative propagation offers a unique opportunity to bypass the genetic mixing associated with sexual reproduction. Over 70 angiosperm and 30 gymnosperm tree species for which successful methods for the production of plantlets have been reported (Figure 6).

In vitro Propagation Techniques

Micropropagation systems fall into three broad categories: **axillary shoot** (or bud) **multiplication**, **organogenesis** and **somatic embryogenesis**.

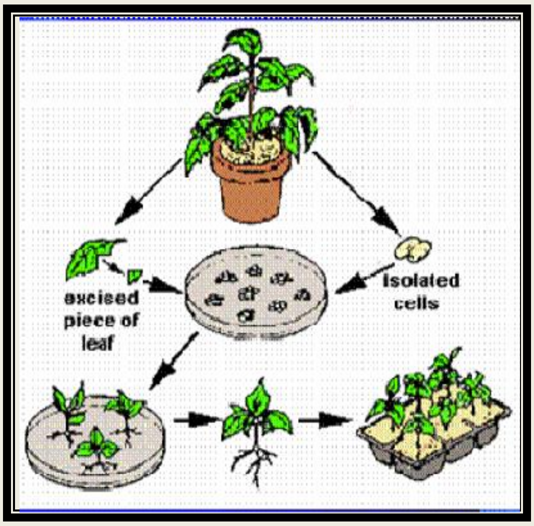

Fig. 6: Tree propagation

Source: https://ceresmarsproject.wordpress.com

Axillary shoot methods rely on multiplication of preformed structures, while **organogenesis** and **embryogenesis** rely on *de novo* generation of either plant organs or embryos, respectively (i.e. morphogenesis). All three regeneration systems have great potential to be applied for mass propagation of forest tree species (Figure 7).

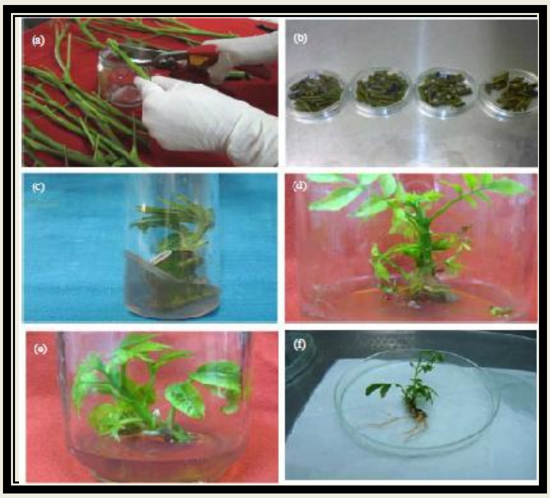

Fig. 7: In vitro propagation of Persian walnut

Source: http://scialert.net/fulltext/

Organogenesis

A plant contains many organs like meristem, cortex, phloem, epidermis are consist of structural unit called cell. A cell have to nature of create whole plant like any organ or tissue of plant also show same nature mean they also create to whole plant in in-vitro condition. If plant organs used in in-vtro conditions to generated new plant this process called organogenesis. Micropropagation by organogenesis involves *in vitro* culture of very small plant parts, tissues or cells, particularly meristems from germinating embryos or juvenile plant apices. Organogenesis of plant included two different stages first is **de-differentiation (calllus formation)** and other is **re-differentiation (budding on callus)** of organ or explant. organogenesis of plant is require to gain how a organ generated or developed to an whole plant. organogenesis is method to regeneration of plant for of organs from callus.

Formation of organ in callus depends on medium constitutes because medium of tissue culture also contain growth regulators which determine to shoot regeneration or root regeneration. For this auxin and cytokinin ratio used in a appropriate ratio which responsible for callus regeneration. More concentration of cytokinin compare auxin generated to shoot part in callus and more quantity of auxin generated to roots in callus. Plant growth regulators like auxin, cytokinin, gibberelin, ethylene, abscisic acid, etc are affect to callus regeneration according ratio of them in medium.

Plants arising from shoots of adventitious origin may show undesirable advanced maturation characteristics (Frampton and Isik, 1987). There have been many different media developed for organogenesis, depending on the species (McCown and Sellmer, 1987). Shoots are elongated on a medium without cytokinin (Figure 8).

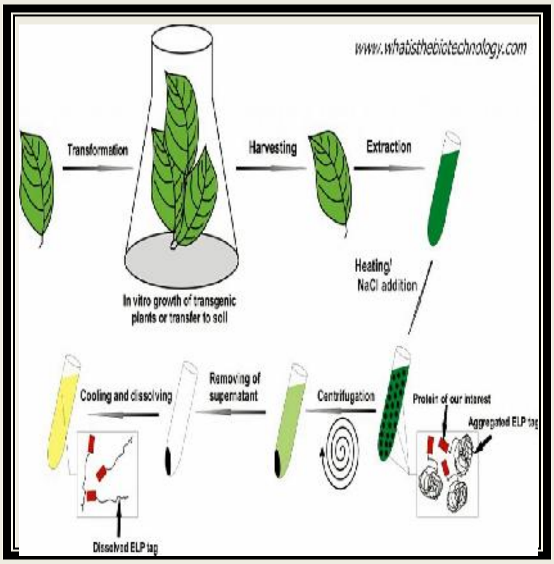

Fig. 8: Organogenesis

Source:http://www.whatisthebiotechnology.com

The maintaince and preservation of clones in tissue culture done by organogenesis, serial propagation (repeated subculture), minimal growth media, cool storage and cryopreservation. Radiata pine clones have been maintained as shoots for more than ten years with repeated subculture every 6–8 weeks (Horgan, Skudder and Holden, 1997). However, long-term success at halting ageing is uncertain and the costs are high because of the requirement for regular transfers and a controlled environment.

Embryogenesis

There are two types of embryogenesis in plants: zygotic and somatic. **Zygotic** process begins with double fertilization, followed by determination of the three axes of embryos (longitudinal, lateral, and radial) and morphologic changes of the embryos (globular, heart shaped, and torpedo-shaped).

Somatic embryogenesis (SE) is the process by which somatic cells, under induction conditions, generate embryogenic cells, which go through a series of morphological and biochemical changes, that result in the production of bipolar structure without vascular connection with the original tissue. The development of somatic embryos closely resembles the development of zygotic embryos both morphologically and physiologically (Figure 9).

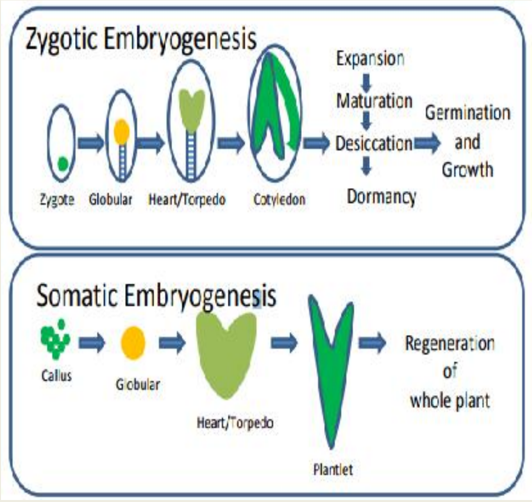

Fig. 9: Zygotic vs somatic embryogenesis
Source: http://cdn.intechopen.com

Successful embryogenesis was first reported for sweetgum (*Liquidambar styraciflua*) in 1980 (Sommer and Brown, 1980) and for spruce (*Picea abies*) in the mid-1980s (Hakman & Von Arnold, 1985; Chalupa 1985). Since then, somatic embryogenesis has been investigated for many forestry species, including hardwoods such as Poplars, Willows and Eucalypts, and Conifers such as Spruces, larch (*Larix* spp.), Pines and Douglas fir.

2. Molecular Markers

Molecular markers are now widely used to track loci and genome regions in several crop-breeding programmes. Molecular markers include gene introgression through backcrossing, germplasm characterization, genetic diagnostics, characterization of transformants, study of genome organization and phylogenetic analysis. The introduction of biochemical (e.g. terpenes and flavanoids) and Mendelian inherited protein (allozymes) markers in the latter quarter of the past century drove a rapid increase in evolutionary biology studies in forestry. These markers also found valuable application in seed orchard management (Wheeler et al, 1993; El-Kassaby, 2000). In the past decade, the development of molecular markers based directly on DNA polymorphisms has largely replaced allozymes for most practical and scientific applications. This replacement was accelerated by the development of the polymerase chain reaction (PCR) technique. Molecular markers come in many forms, each with an array of benefits and drawbacks (Ritland, 2000). The utility of these molecular markers and the analytical methods used differ according to the type of question asked and the nature of the markers (dominant vs co-dominant).

3. Marker-assisted selection and marker-assisted breeding (MAS & MAB)

MAS and MAB refer to approaches to tree improvement that rely on the statistical association of molecular markers with desirable genetic variants. Conventional plant breeding is dependent on appropriate environmental conditions in which to identify and select desirable plants. Breeders improve plants by crossing plants with desired traits, such as high yield or disease resistance, and selecting the best offspring over multiple generations of testing. Molecular marker technology offers such a possibility. Marker-assisted selection involves selecting individuals based on their marker pattern (genotype) rather than their observable traits (phenotype).

This type of breeding is the selection of specific plants with desirable traits which involves evaluating a breeding population for one or more traits in field or glasshouse trials or with chemical tests of the quality. The goal of plant breeding is to assemble more desirable combinations of genes in new varieties (Figure 10).

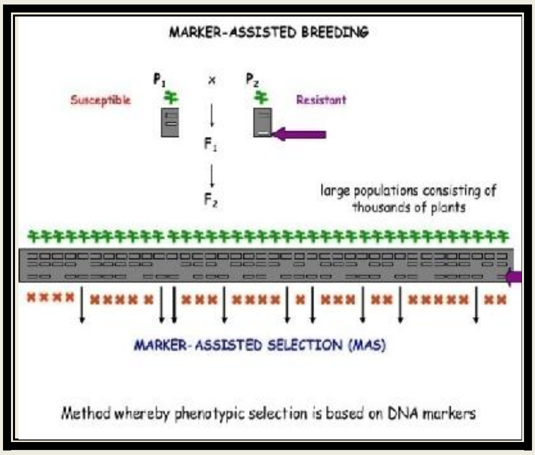

Fig. 10: Marker-assisted selection
Source: https://www.slideshare.net/

4. Genomics, Proteomics and Metabolomics

The complete set of genes inside a cell is called the genome and 'genomics' is deals with the study of the genetic make-up of organisms. The beginning of genomics is the determination of genomic sequence of a organism. Substantial resources have been invested in the genomics sciences of humans, agronomic crops and forest trees. Genomics encompasses a wide range of activities, including gene discovery, gene space and genome sequencing, gene function determination, comparative studies among species, genera and families, physical mapping and the burgeoning field of bio-informatics. The ultimate goal of genomics is to identify every gene and its related function in an organism.

Proteins are responsible for an endless number of tasks within the cell. The complete set of proteins in a cell can be referred to as its proteome and the study of protein structure and function and what every protein in the cell is doing is known as **proteomics**. The proteome is highly dynamic and it changes from time to time in response to different environmental stimuli. The 'proteomics' is the large-scale study of the proteins expressed by an organism, particularly protein structure and function. The term 'proteomics' was coined to make an analogy with genomics, the study of the genes. The proteome of an organism is the set of proteins it produces during its life, and the genome of the organism is the set of genes it contains.

The **'metabolomics**' is the newest term refers to the complete set of low molecular weight compounds in a sample. These compounds are the substrates and byproducts of enzymatic reactions and have a direct effect on the phenotype of the cell. Thus, metabolomics aims at determining a sample's profile of these compounds at a specified time under specific environmental conditions. Metabolomics is the "systematic study of the unique chemical fingerprints that specific cellular processes leave behind" - specifically, the study of their small molecule metabolite profiles.

5. Genetic Engineering

Genetic transformation is the controlled introduction and expression of foreign genes in plants – has become a common technique both for basic research and for the introduction of novel traits into commercially important species. Different tools are now available to transform plants genetically.

Genetic Modification Technologies

Two main technologies are available to transfer foreign DNA into plant cells, and then regenerate plants from these transformed cells. These technologies are the use of bacterium, typically *Agrobacterium tumefaciens* (Gelvin, 2003), or biolistics (gene gun). *A. tumefaciens* is a bacterium that causes crown gall disease in some, particularly dicotyledonous, plants (Figure 11). Genetic modification technology is still new to forestry. However, relatively numerous (124) introduced traits of transgenic trees have been under regulatory examination in many countries.

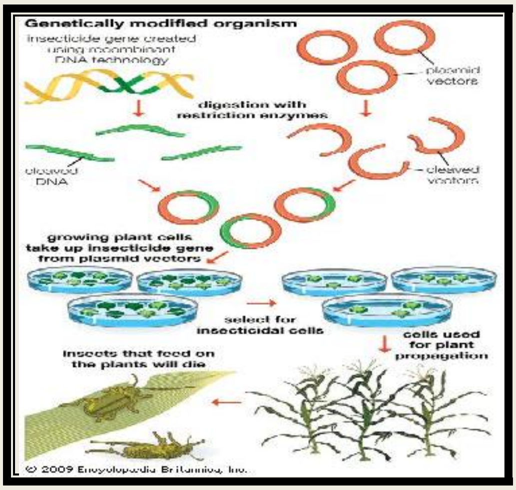

Fig. 11: Genetic engineering
Source: https://www.britannica.com/

Forestry genetic modification activities are taking place in at least 35 countries, 16 of which host some form of experimental field trials (Wheeler & Hendon, 2004). These field trials are generally small (12 to 2850 plants in reported studies) and typically of short duration.

Role of biotechnology in forest conservation

Cryopreservation is one of the biotechnological method of ex situ plant conservation and applicable for long term storage of plant genetic material. Cryopreservation is extremely helpful method to conserve rare, endangered, threatened plant species. The principle is bringing the plant cell and tissue cultures to a non-dividing or zero metabolism stage by subjecting them to supraoptimal temperature in the presence or absence of cryoprotectants. Classical freezing includes the successive steps such as:

- ✓ Pregrowth of samples
- ✓ Cryoprotection
- ✓ Slow cooling (0.5-2°C/min) to a determined prefreezing temperature (usually around -40°C
- ✓ Rapid immersion of samples in liquid nitrogen (LN)
- ✓ Storage
- ✓ Rapid thawing and recovery

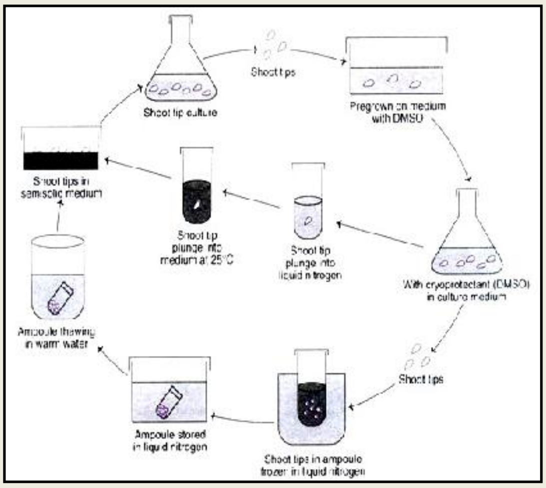

Fig.12: Cryopreservation of shoot tip
Source: http://www.biologydiscussion.com

It needs technical skill as it has several steps such as freezing, storage, thawing, reculture of living plant cells during cryopreservation against cryogenic injuries. Various cryopreservation methods are being used for various plant species such as vitrification, encapsulation–dehydration and encapsulation vitrification (Stacey & Day, 2007). The genetic stability can be maintained during cryopreservation that has been proved by molecular marker study (Liu et al., 2008). The cryopreserved tissue has considered as safer, clean, disease free genetic stock for international exchange (Feng et al., 2011) (Figure 12).

Applications in Forest Tree Improvement

Three broad areas of application of cryopreservation and in vitro storage techniques to forest tree improvement (Table: 3)

Table: 3 Different plants in various forms that are successfully cryopreserved

Plant material	Plant species
Cell suspensions	*Oryza sativa* *Glycine max* *Zea mays* *Nicotina tabacum* *Capsicum annum*
Callus	*Oryza Sativa* *Cassicum annum* *Saccharum sp*
Protoplast	*Zea mays* *Nicotina tabacum*
Meristems	*Solanum tuberosum* *Cicer arietinjm*
Zygotic embros	*Zea mays* *Hordeum vulgare* *Manihot esculenta*
Somatic embryos	*Citrus sinensis* *Daucus carota* *Coffea arabica*
Pollen embryos	*Nicotinatabacum* *Citrus sp* *Atropa belladona*

Source: http://cdn.biologydiscussion.com

• Germplasm Preservation

In vitro storage is now routinely used for germplasm storage of cassava, at CIAT (Escobar et al. 1992, Chavez et al. and for many Solanum genotypes at CIP, in Peru (Withers et al. 1990). ORSTOM, at Montpellier, is developing methods for the preservation of coffee by in vitro culture of immature zygotic embryos (Charrier et al. 1991).

• Maintenance of Juvenility

Cryopreservation is perhaps the most promising approach currently on offer for maintenance of the juvenile state and capture of genetic gains through clonal forestry with industrial species. The technology is applicable mainly in cases where good breeding programmes are in place and clonal forestry is a realistic goal.

- **Transport of Germplasm**

International germplasm exchanges are becoming very important in the breeding of many crops, in particular to and from international genebanks at the International Agricultural Research Centres (IARCs) and other centres. In vitro exchanges are becoming common for some of these, e.g. for potato, coconut, banana and oil palm (Charrier et al. 1991, Withers 1992).

National forest research institute

1. Kerala Forest Research Institute (KFRI)

Kerala Forest Research Institute (KFRI) is a multidisciplinary team of experts conducting research on tropical forests and forestry. This Institute has contributed significantly to research in tropical forestry and biodiversity conservation over the past three decades of its existence. Founded in 1975, Institute is envisioned as a Centre of Excellence in Tropical Forestry to provide scientific support for decision making on matters related to forestry, with particular emphasis on conservation, sustainable utilization and scientific management of natural resources. KFRI became a part of the Kerala State Council for Science, Technology and Environment (KSCSTE) along with five other R&D Centres of the State, when the KSCSTE was constituted in 2002.

2. Forest Research Institute, Dehradun, Uttarakhand.

The Forest Research Institute is an institute of the Indian Council of Forestry Research and Education and is a premier institution in the field of forestry research in India. It is located at Dehradun in Uttarakhand, and is one of the oldest institutions of its kind. In 1991, it was declared a deemed university by the University Grants Commission. Established as Imperial Forest Research Institute in 1906, Forest Research Institute(FRI) Dehradun is a premier institution under the Indian Council of Forestry Research and Education (ICFRE).

3. IIFM (Indian Institute of Forest Management), Bhopal, M.P.

The Indian Institute of Forest Management (IIFM) (founded 1982) is an autonomous, public institute of sectoral management located in Bhopal, Madhya Pradesh, India, established by the Ministry of Environment, Forest and Climate Change, Government of India with financial assistance from the Swedish International Development Cooperation Agency (SIDA) and course assistance from the Indian Institute of Management Ahmedabad. IIFM is a premier national level institute engaged in education, research, training and consultancy in the area of Forest, Environment and Natural Resources Management and allied sectors. The institute's objective is to fulfill the growing need for the managerial human resource in the area of Forest, Environment, and Natural resources Management and allied sectors.

4. Arid Forest Research Institute

Arid Forest Research Institute (AFRI) is a research institute situated in Jodhpur in Rajasthan. The institute carries out scientific research in forestry in order to provide technologies to increase the vegetative cover and to conserve biodiversity in the hot arid and semi-arid region of Rajasthan and Gujarat. It operates under the Indian Council of Forestry Research and Education (ICFRE) of the Ministry of Environment and Forests, Government of India. Forestry research for conservation of biodiversity and enhancement of bio-productivity in Rajasthan, Gujarat, and Dadra and Nagar Haveli, with special emphasis on arid and semi-arid regions.

5. Institute of Forest Productivity

Institute of Forest Products is a premier forestry research institute under Indian Council of Forestry Research & Education

(ICFRE), catering to the forestry research needs in the states of Bihar, Jharkhand, West Bengal and Orissa. The main areas are:

- Managing Forests and Forest Products for Livelihood Support & Economic Growth .
- Biodiversity Conservation and Ecological Security.
- Forest Genetic Resource Management & Tree Improvement

6. Institute of Forest Genetics and Tree Breeding, Coimbatore, Tamil Nadu.

Institute of Forest Genetics and Tree Breeding (IFGTB) is a Forestry Research institute situated in Coimbatore in Tamil Nadu. It works under the Indian Council of Forestry Research and Education (ICFRE) of the Ministry of Environment, Forest and Climate Change, Government of India. To identify and evolve varieties of species used in afforestation and social forestry that will contribute to the national goal of achieving a growth of 3 to 4 cubic meters of biomass per ha per year within the ecological considerations applicable to the area.

Research area:

- Genetic and tree breeding
- Plant biotechnology
- Forestry, Land use and Climate Change
- Seed technology
- Bioprospecting
- Forest protection
- Biodiversity
- Forest research Information Management
- Forest Economics and Extension

7. Tropical Forestry Research Institute, Jabalpur

Tropical Forest Research Institute (TFRI) is a Research institute situated in Jabalpur in Madhya Pradesh. It works under the Indian Council of Forestry Research and Education (ICFRE) of the Ministry of Environment, Forest and Climate Change, Government of India. The institute's mission is to focus its efforts on research programmers for the conservation and development of forests and forestry sector in the state of Madhya Pradesh.The reaearch area are:

- Biodiversity assessment, conservation and development
- Sustainable forest management
- Planting stock improvement
- Climate change
- Environmental amelioration
- Forest products development
- Biofuels from forests
- Development of agroforestry models
- Forest protection
- Forest extension

8. Himalayan Forest Research Institute, Shimla

Himalayan Forest Research Institute (HFRI), Shimla was established as High Level Conifer Regeneration Research Centre during May 1977 for carrying out Research on problem associated with natural regeneration of Silver Fir and Spruce. The institute made its humble beginning from this Centre and at the time of re-organization of forestry research in Indian Council of Forestry Research & Education (ICFRE), Dehradun, during 1998, Government of India appreciated the problems of Temperate Eco-system and decided to upgrade this Centre in to a full-fledged research institute.

9. Indian Council of Forestry Research and Education, Ranchi, Jharkhand

The Tropical Forest Research Institute, Jabalpur is one of the eight regional institutes under the Indian Council of Forestry Research & Education, Dehradun. The Institute came into existence in April 1988, although its origin goes back to 1973 when a Regional Centre of Forest Research Institute, Dehradun was established at Jabalpur to provide research support to the problems of forest management in central India. The institute has not only steadily advanced in terms of infrastructure but also specialized itself as a major nucleus for research on forestry and ecology related problems of tropical forests of the central region comprising of the states of Madhya Pradesh, Chhattisgarh, Maharashtra and Orissa.

10. Centre of Social Forestry and Eco-rehabilitation, Allahabad

Centre for Social Forestry and Eco-Rehabilitation (CSFER), Allahabad was established in October 1992 as an advanced centre under the umbrella of ICFRE, Dehradun.
The Centre aims to nurture and cultivate professional excellence in the field of social forestry and eco-rehabilitation in Eastern Uttar Pradesh, North Bihar and Vindhya Region of Uttar Pradesh and Madhya Pradesh. The important research activities of this Centre are in the field of Planting Stock Improvement Programme (PSIP); Wasteland reclamation; Development of Agroforestry Models; Reclamation of mined areas through Afforestation; Productivity of Ecosystem; Studies on Medicinal plants etc.

11. Institute of Forestry Research and Human Resources Development, Chhindwara

The Centre for Forestry Research and Human Resource Development Chhindwara was established in 1995 as an advanced research centre under the umbrella of ICFRE, Dehradun. Mandate of the centre is Forestry research with Human Resource Development in areas like biodiversity conservation, forest protection, silviculture, non-wood forest products, socio economics and tree improvement for poverty alleviation.The main stake holders for training programmes are farmer, students, Forest officers and scientist from forestry sector.

Potential risks of using biotech trees

1. Gene flow and introgression

Gene flow refers to escape of a transgene into a native population of the same tree species. In some situations gene flow is the desired outcome of releasing biotech trees into the environment. Gene flow from genetically modified trees to native ones and thereby confer resistance to the native population. In some instances gene flow to native populations will be less desirable and have to be managed appropriately to protect forests. Introgression is the infiltration of a transgene from one species into the gene pool of another through repeated backcrossing of a hybrid with one of its parents. This situation has similar ramifications to gene flow, but it adds a confounding factor of moving a transgene from one species to another.

2. Exceptional fitness

While one of the main goals is to produce trees that are better able to thrive in the environment, there are concerns that these more biologically fit trees may out compete native species. This characteristic is commonly referred to as weediness. If a biotech tree is exceptionally fit when compared to its native relatives, there is a chance that it will be so successful in the forest that it keeps other trees from growing as they naturally would. Again, there are instances when exceptional fitness is the desired outcome as well as situations where it can cause ecological problems.

3. Effects on non-target species

Possible non-target species effects might include harm to beneficial soil organisms, insects, birds, or other plants. For example the Bt gene that is one of the more common genetic modifications in plants produces a protein toxic to insect pests. This gene is produced by a bacterium in the soil called *Bacillus thuringensis*. Using the Bt Poplars planted in China as an example, there is concern that the Bt gene can inadvertently harm a species of insect. This situation is highly unlikely because of the rigorous research that has gone into the Bt gene, but we use it here as an example only. Other situations where less thorough research has been completed could harm other species that interact with the biotech tree.

4. Biodiversity effects

These concerns are more broad and can encompass interrelations among forest species that affect the ecosystem as a whole. One such concern focuses on the idea that stands of sterile GE trees would not support a diverse population of species in the larger forest ecosystem. Another concern is that the target function of the biotech tree will have unintended ecosystem consequences. A situation could be envisioned where a biotech tree is exceptionally fit, contains a transgene that inadvertently affects non-target species, and there is gene flow to native trees. This situation could have negative biodiversity effects for the native forest.

CASE STUDIES

Eucalyptus plantations in Brazil

More than 700 species of eucalyptus are found in Australia but their performance as a plantation species is far greater elsewhere (Borralho, 2001) and especially in Brazil.

Clonal propagation of teak in Malaysia

Teak, Tectona grandis, is widely planted in many countries in Asia, South and Central America and Africa. A fifteen-year collaboration between the Sabah Foundation Group (Malaysia) and the Centre de Coopération Internationale en Recherche Agronomique pour le Developpement (CIRAD, France), exploiting molecular markers and micropropagation, has led to the availability of superior quality planting material both for the local market as well as for export (Goh et al. 2007)

Bioprotection in Kerala, India

At the Forest Protection Division of the Kerala Forest Research Institute, India, investigations into control of a serious insect pest of teak viz. the teak defoliator (Hyblaea purea), have been carried out for several years. A Hyblaea purea nuclear polyhedrosis virus (HpNPV) isolated from natural populations of the insect larvae resulted eventually in a very effective biological control method.

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FORTHCOMING EVENTS		
Events	**Date**	**Place & Correspondence**
National Conference on Advances in Science, Agriculture, Environmental & Biotechnology (NCASAEB)	12th November, 2017	Mumbai, Maharashtra, India http://nationalconferences.org
2nd International Convention on Geosciences and Remote Sensing	8-9th November, 2017	Las Vegas, Nevada, USA https://geosciences.conferenceseries.com/
IASTEM- 277th International Conference on Environment and Natural Science (ICENS)	6th-7th November, 2017	Auckland, New Zealand http://iastem.org
The ASAR-International Conference on Renewable Energy, Green technology & Environmental Science (ICREGTES)	5th November, 2017	NewDelhi,India http://www.asar.org.in
5th International Conference on Sustainable Environment and Agriculture (ICSEA 2017)	28-30th October, 2017	Los Angeles, United States of America Website: http://www.icsea.org/

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