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Review paper

Utilization of Biotechnology on Some Forest Trees in Turkey

Esra Nurten Yer [1], Sezgin Ayan [1]

[1] Kastamonu University, Faculty of Forestry, Silviculture Department, TR-37100 Kuzeykent, Kastamonu, Turkey

Corresponding author: e-mail: sezginayan@gmail.com

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Abstract

Background and Purpose: Raw wood material requirements are increasing with rapid population growth both in Turkey and in the world. In order to supply deficit for closure of forest products, productivity and quality of production should be improved. Basic ways to increase efficiency in forest production involves silvicultural implementations and classical tree breeding studies. Genetic variation can be increased by utilizing the existing diversity. Thus, new combinations can be obtained and we can raise efficiency using some selection strategies. At this point, biotechnological methods are required to meet the genetic material. Studies of forest tree breeding are a slow process due to the size of the genome and the length of the tree life span. Biotechnological applications in forest trees provide many important benefits in terms of time saving and reducing cost when compared to classical breeding studies. Sustainable forestry practices are gaining rapid acceleration via biotechnology and modern sciences practices. In this study, for some forest tree species in Turkey, the evaluated biotechnology methods included; 1- tissue culture and clonal propagation, 2- molecular marker applications, 3- marker assisted selection and breeding, 4-genomic and proteomic studies, 5- genetic modification and genetic engineering applications.

Conclusions: In this study, the works were carried out on forest tree breeding/propagation in Turkey and it was mainly focused on vegetative production techniques with 25 broadleaves and 9 conifer taxa, which were possible to express. Molecular genetic studies were carried out on 12 broad leaves taxa and 9 conifer taxa; genetic transformation studies were conducted on poplar species. Thus, it might be suggested that a combination of biotechnological tools and traditional propagation methods will ensure advantage for the development of forest-tree species.

Keywords: tree breeding, biotechnology, sustainable forestry, tissue culture, genomics studies

INTRODUCTION

In vitro breeding, gene transfer and marker-assisted breeding approaches of biotechnology contributed greatly on genetical improvement of forest trees to the level comparable with sophistication of ordinary genetic improvement applied for agricultural varieties [1]. It is described in FAO documents that forest biotechnology comprises three main field as follows; using molecular genetic markers to get information on genetic futures of populations and genetic base of traits, using advanced breeding technologies to produce consistent high quality planting rootstock at low price and in order to offer new economic future or ecological value, genetic engineering of trees [2]. Due to big size and long growing times of trees, the advance of forest tree breeding is a slow and challenging process. Recently, forest genomics has offered new medium for studying adaptation in trees. The gene technology for forestry has been used to solve the primary environmental issues, to produce cheap renewable energy, to specify relevant genes for the adaption of forest tree. Especially, forest trees' genes having growth future such which is resistant to disorders, herbicide and environmental stresses and wood future such as reducing lignin and increasing cellulose attracts much attention. The usage of modern genotyping technologies that are a highly beneficial medium to analyze effect of dense forestation process, to specify genes that control amazing phenotypes designates allelic assortment for the candidate genes in forest tree populations and measures adaptive allelic assortment for thousands of genes at the same time [3].

Forest biotechnology is related to a wide range of modern procedures practicable for agricultural and forest science and only some part of these procedures are relevant to genetic engineering. Biotechnology term in silviculture comprises all perspectives of propagation of tree and cloning of plant, genotyping of DNA, manipulation and transfer of gene [4]. Conventional breeding depends more intensely on sexual crosses and monitoring trait phenotypes. In order to ensure more precise or a more sweeping results than the results that can be obtained only using phenotypic selection, biotechnology surrounds different procedures that entails one or more laboratory or greenhouse intensive steps. Such procedures may contribute to saving time, reducing expenses or achieving new goals.

Tissue culture, clonal breeding, genetic markers, gene transferring and genomic technologies are extensively used biotechnological practices. The key determinants of this quick development process are promoting powerful and applicable techniques in the biotechnology field and completing genome sequences of certain forest tree forms. Such techniques and studies have contributed exceptionally to the project of propagation of forest trees. As a consequence of the newly found gene regions, gene transfers studies, etc.; creating genetic maps, clone breeding and improving the quality of wood in forest trees were performed. Approximately 45 000 gene sources have contributed greatly to genomic investigation by sequencing poplar tree (*Populus trichocarpa*) genome. Therefore, QTL analysis, genetic modifications and EST sequencing facilitate finding new genes. Additionally, such studies assist in developing specific robust tree forms for specific environmental conditions [5].

Biotechnological procedures having or probably having specific impact on forest tree propagation and the position of the research in Turkey have been presented in the present study. Namely, for some woody taxa in Turkey, the biotechnology methods: 1- tissue culture and clonal propagation, 2- molecular marker applications, 3 - marker assisted selection and breeding, 4 - genomic and proteomic studies, 5 - genetic modification and engineering applications, were evaluated.

BIOTECHNOLOGY PRACTICES FOR FOREST TREE PROPAGATION

Biotechnology can be assessed in three main fields as follows; traditional propagation, molecular genetics, and genetic transformation. Traditional propagation has been used to develop plants for centuries. Over the last two decades, developments in molecular genetics were introduced into the scientific circles and they completed the tools that have been used by traditional breeders. There are two distinct subcategories in molecular genetics. The first one is "Non-controversial technologies", the plant genome is not altered. This category includes; molecular markers used for DNA fingerprinting and MAS (QTL mapping and association genetics); sequence analysis (genomic DNA, cDNA libraries (ESTs) that helps to discover the gene; and *in vitro* breeding such as somatic embryogenesis. The second in this category is "controversial technologies" that includes recombinant DNA and gene transfer practices. Genetic engineering makes it possible to include new genes among the existing, elite genotypes [6].

Biotechnology comprises change and development of genetic capabilities of plants through different tissue culture and genetic engineering practices. Biotechnology is a technology that is widely practiced and which has a big potential to reduce expenses of production and protection through the energy obtained from non-renewable energy resources as well as to increase agricultural productivity [7].

New biologic inventions in previous years have offered scientists many options, especially in silviculture, to acquire this knowledge.

When we focus on forest trees, biotechnology collaborates with various freestanding disciplines such as vegetative breeding, namely; cuttings, organogenesis, somatic embryogenesis, maturation and micro-propagation; molecular genetics, namely, molecular markers, cloned plant genes and quantitative trait loci and genetic transformation namely; somatic hybridization, gene transfer methods, gene transfers, prospects and limitations [8].

Vegetative Propagation (VP)

Vegetative breeding influences forest trees' developments by using available genotypes for the production of new genotypes valuable in terms of trade. Cutting and in-vitro methods are the major vegetative breeding procedures of forest trees; organogenesis and somatic embryogenesis. Based on their purpose and other similar things, the techniques used differ among different species and within species. The field tests have great importance due to probable unsteadiness in in-vitro regenerated plants [8].

Molecular Genetics (MG)

In recent decades, big developments in molecular genetics of plants enabled the use of it for tree breeding. The possible effect of it relies on the usage of molecular markers and the cloning and characterization of genes and their promoters that manage biological processes' improvement and function [8].

Genetic Transformation (GT)

The traditional gene transfer technique was used effectively in hybridization, however, as it is already known, this technique is only applicable for sexually suitable tree species and it takes many years for its implementation. Such drawbacks can be avoided using the new gene transfer method [8].

In Table 1, a framework for current possible applications of biotechnology for certain forest tree in Turkey can be found.

TABLE 1. Potential applications of biotechnology (VP - vegetative propagation, MG - molecular genetics, GT - genetic transformations) on some forest tree species in Turkey

Family	Tree species	Propagation type		
		VP	MG	GT
Pinaceae	*Pinus sylvestris* L. [9-11]		x	
	Pinus nigra L. [9-15]	x	x	
	Pinus brutia Ten. [9, 16-23]	x	x	
	Pinus pinea L. [9, 11]		x	
	Pinus halepensis Mill [17]		x	
	Pinus pinaster Ait [9].		x	
	Picea orientalis L. Link. [24-28]	x	x	
	Picea abies L. Karst [29]	x		
	Abies spp.[30-32]		x	
	Cedrus libani (A. Rich.) [33, 34].		x	

TABLE 1. Potential applications of biotechnology (VP - vegetative propagation, MG - molecular genetics, GT - genetic transformations) on some forest tree species in Turkey - continuation

Family	Tree species	Propagation type		
		VP	MG	GT
Fagaceae	*Fagus sylvatica* L.[35, 36]		x	
	Fagus orientalis Lipsky [35, 37]		x	
	Quercus petraea ((Mattuschka) Lieb.) [38-40]	x	x	
	Quercus robur L. [38-40]	x	x	
	Quercus ithaburensis Decne subsp. [38-40]	x	x	
	Quercus cerris L. [38- 40]	x	x	
	Castanea sativa Mill. [41, 42]	x		
Salicaceae	*Populus nigra* L. [43-45]		x	
	Populus spp. [45-48]		x	x
	Populus tremula L. [45, 49, 50]	x	x	
	Salix alba L. [51, 52]		x	
	Salix excelsa S.G. Gmel. [51, 52]		x	
Tiliaceae	*Tilia platyphyllos* Scop. [53]	x		
	Tilia tomentosa Moench. [38, 54]	x		
	Tilia rubra DC. [54, 55]	x		
	Tilia cordata Mill. [54]	x		
Betulaceae	*Betula pendula* Roth.[29]	x		
	Betula medvediewii Reg. [56]	x		
	Alnus glutinosa (L.) Gaertn. [57-59]	x		
	Corylus colurna L. [10]	x		
Cupressaceae	*Sequoia sempervirens* (Lamb) Endl. [60, 61]	x		
	Juniperus communis L. [62]	x		
	Juniperus foetidissima Wild. [63]	x		
	Juniperus excelsa Bıeb. [63]	x		
Oleaceae	*Fraxinus oxycarpa* Wild. [38]	x		
Fabaceae	*Robinia pesudoacacia* L. [38]	x		
Elaeagnaceae	*Eleagnus angustifolia* L. [38, 64]	x		
Aceraceae	*Acer negundo* L. [38]	x		
Platanaceae	*Platanus orientalis* L. [38]	x		
Altingiaceae	*Liquidamber orientalis* Mill. [38, 65-68]	x	x	
Myrtaceace	*Eucalyptus* spp. [69, 70]	x		
Cornaceae	*Cornus mas* L. [71]	x		
Taxaceae	*Taxus baccata* L. [72]	x		
Ulmaceae	*Ulmus minor* Mill. [10]	x		
Lauraceae	*Laurus nobilis* L. [73-75]	x		
Anacardiaceae	*Pistacia lentiscus var. chia* [76]	x		

DISCUSSION

Due to the big size and long generation periods of trees, until now, the development of forest tree has been a slow and challenging process. In conformity with tree propagation and forestry programs, it is important that forest biotechnology meets the industry requirements for forest products while enabling protection of natural forests mining [2].

It is required to implement comprehensive precipitated - propagation programs to reforest and develop current forest-tree species. It is predicted that a combination of biotechnological tools and traditional propagation methods will ensure advantage for the development of forest-tree species [77].

In addition to biotechnology's economic advantages for silviculture such as the increase in production, cost effectiveness for consumers and modified trees for allowing easy processing or other production values, the advantages of biotechnology contribute to the protection of biodiversity and to the decreasing global warming issue [78].

Using such technologies will allow forest trees to be more tolerant to abiotic and biotic stresses, gene expression for rapid growth and modification in wood structure.

Additionally, the usage of these technologies on research has some benefits such as escalated genetic gain per generation by an improved selection in traditional propagation programs, quick application of genetically developed tree species for plantations and better understanding of the genes that manage commercially crucial futures. Such trees will carry the silviculture to a different position in terms of productivity and quality. Additionally, when trees are modified to grow on arid or saline soils that were not suitable for growing before, the created forests can improve the wood production and at the same time contribute to the watershed protection and sequester carbon for the mitigation of climate change and similar things [4].

CONCLUSIONS

Phenotypic assessments require a lot of time and investments and in turn they don't ensure information on the gene's variation that manages adaptive variations. A vast number of molecular marker technologies is available, however, most of these technologies measure neutral or high conservative genetic variations of limited adaptive value. In order to assess the vast number of adaptive genes and prospective trees for *in-situ* conservations, it is required to develop quick and elucidative identifying methods. In order to study adaptation in trees, genomics offers new mediums. In order to specify DNA sequences and to genotype a vast number of individuals, forest geneticist may use technologies that are automated, highly effective, quick and productive [79].

One of the areas where biotechnological methods were used recently was the implementation of biotechnology in forest trees. Biotechnological techniques were widely used on important subjects such as obtaining resistance to diseases and herbicide of forest trees, elevating tree growth rates and developing resistance to environmental stresses such as drought, salinity, climate change and similar things. Additionally, reducing lignin and increasing cellulose to develop wood, attracts much attention. This issue is discussed through the application processes, positive and negative impacts of transgenic trees on the environment and it was also tried to be procured on the auditing legislations related to the studies [80].

In short, in addition to the advantages of using biotechnology in silviculture such as the increase in production, cost effectiveness for consumers and modified trees for allowing easy processing or some production values, the advantages of biotechnology are contributing to the protection of biodiversity and decreasing global climate changes.

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