Biotechnological approaches to improve the physiology of forest trees in water stress areas

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Abstract

This paper reviews various biotechnological approaches to improve the physiology of forest trees in water stress areas. Response of trees to water stress areas is a complex biological process which can be analyzed by studying of physiology of trees using biotechnological approaches like plant –genetic transformation techniques, gene isolation and characterization etc. A very close relationship is observed in physiology and genetics as gene encode enzymes which regulate physiological process. Here we discuss some of the biotechnological approaches which can be applied for forest trees to sustain in water stress condition.

Key Words: **Physiology, water stress, enzymes and biotechnological approaches**.

Introduction

The mandate of physiology is to understand how plant works. The improvement of forest tree in the future will require input from various scientific disciplines, including physiology. Stress can be defined as a influence of outside the normal range. If tolerance to stress can be exceeded, then a new physiological state can be obtained by activating the mechanism at molecular, biochemical, physiological and morphological levels. In recent day the genetics research lies in the area of cellular or molecular biology and invitro culture. Basic studies of gene action and regulation offers also many opportunities .Effort may be expended in micro propagation, culture of various organs and tissues, resistance screening, generic transformation etc.Moreover a very close alliance between genetics and physiology has been observed. Genes encode enzymes which regulate physiological process (Evans L.T.1993). This paper reviews various biotechnological and molecular research works to improve the physiology of trees in water stress condition.

Water stress as a plant growth inhibitor:

Water accounts for 50% of the fresh weight of woody plants. Although India is not a water deficit country, but due to some reasons like improper maintaining and monitoring of water resources, several regions in the country undergoes water stress from time to time. Which cause lead to water scarcity during the present time .Water stress is a multidimensional environmental constraint which can affect from the molecular level. Negative impacts of drought are observed in many aspects of forest health including seedling recruitment, productivity and mortality of larger/mature trees, susceptibility to pathogen or insect attack, and vulnerability to damage from fire (Zhao and Running, 2010; Reichstein *et al*.,2013).The growth and development of trees depend upon on the nutrients supplied by the root systems . Thus root systems are the key component of forest ecosystems as they are responsible for water and nutrient uptake, provide physical stabilization, store nutrients and carbohydrates etc. In addition, roots may act as sensors for water-deficit conditions and send signals to shoots above ground (Hamanishi and Campbell, 2011). For example, some forest trees increase water uptake through deeper and more extensive root systems (Nguyen and Lamont 1989), modify a variety of leaf characteristics , including altered morphology (e.g. cuticular wax, Hadley and Smith , 1990). Again when water potential declines trees reduce transpiration by closing their stomata, but reducing water loss is done at the expense of CO_2 assimilation (Jarvis and Jarvis 1963, Cowan 1977). Although stomtal clouser is efficient in limiting water loss (Froux *et al.*, 2005), it can not prevent water-deficit related decline in trees. Water stress can disrupt water fluxes in the xylem, leading to cavitation. The resulting embolisms limit the plant's ability to conduct water, and thus limit tree growth (Tyree *et al*.1994, Rice *et al*.2004).The ability to avoid drought stress is dependent on the tree's ability to minimize loss and maximize uptake of water (Chaves *et al*. 2003) .Moreover active accumulation of solutes in vacuoles (i.e., osmotic adjustment) is a common physiological response to drought. Physiological processes of forest trees are inhibited more often by water stress than by any other single factor. Growth is reduced directly by decreased cell enlargement and indirectly because of decreased leaf area, stomatal closure, and damage to the photosynthetic machinery. All of these effects reduce the photosynthetic production of the whole plant and decrease the amount of carbohydrate available for growth. Information is needed to elucidate how mild water stress affects enzyme-mediated processes, the reasons for differences in tolerance of protoplasmic dehydration, the importance of osmotic adjustment, and the advantages and disadvantages of prompt stomata1 closure under mild water stress.

Water loss from plant tissue results

1. Growth inhibition

2. Metabolic and physiological changes like

   a. Accumulation of ABA
   b. Stomatal closure resulting in reduced transpiration rates
   c. Decrease in the water potential of plant tissue
   d. Decrease in photosynthesis

How Physiology of forest trees response against drought

Several aspects of tree physiology and metabolism are affected by environmental stress which shows negative impact on tree growth, development and distribution. Mechanisms of stress response and tolerance involve in prevention of cellular damage, resumption of growth and re-establishment of homeostasis. Adaptation to environmental stress is controlled by molecular networks and significant progress using transcriptomics, proteomics and metabolomics has facilitated discoveries of abiotic stress –associated genes and proteins in volved. Plant Growth Regulator also play a very important role in water stress condition. These chemicals act on plant processes at very low concentrations. Often they are produced at one location and transported to another where they exert their influence; however, they may also act on the same tissue in which they are produced. As for example, response of ABA is related to water stress. ABA builds up to very high levels during water stress which is believed to signal the closure of stomata. Even after water stress is relieved stomata in some plants do not immediately reopen which is believed to be due to residual ABA still in the leaf. Mutant plants with an inability to produce ABA have been found to wilt permanently and their stomata to never close. Applications of ABA to the leaves of well watered plants will result in stomatal closure. Enhanced tree growth under abiotic and biotic stress conditions is one of the major goals for tree improvement.

Biotechnological approaches against water stress

Forest tree biotechnology emerged during the 1980s and encompasses a developing collection of tools for modifying tree physiology and genetics to aid breeding, propagation, and research (Burdon and Libby 2006). Biotechnology is not a single approach, it includes, tissue culture, micropropagation, genetic engineering, and genetic markers. The same is true for biotechnology as applied to forest trees. Over the past two decades, these various methods have become increasingly sophisticated, but all are still considered under the larger umbrella of forest tree biotechnology (FAO 2004). Among all biotechnology methods, genetic engineering has received the most attention and scrutiny by regulators and the general public.

Name of some biotechnological approaches which can be applied against drought

1. Combination of conventional breeding
2. Selection technique
3. Rapid clonal propagation
4. Noval molecular and biotechnological methodologies

5. In vitro clonal propagation
6. Study of drought specific proteins and genes
7. Genetic transformation

Genetic engineering can provide a specific tool to manipulate for growing of trees or how they respond to stress. Because GE circumvents sexual barriers, novel genes can be introduced from virtually any species, or they can be newly created or modified based on fundamental scientific principles. Genetic engineering is the only practical way to introduce resistance genes in a useful time frame. With pressures from factors such as an increasing global economy and climate change, the threats of exotic pests and climate stresses are growing ever more significant; there are literally dozens of major forest tree species under serious threat throughout or in some parts of their ranges (Strauss *et al*. 2009). A combination of approaches, including genomics, cloning of the best trees, and genetic engineering is providing renewed hope that fully resistant trees can be developed (Wheeler and Sederoff, 2009). Genetic engineering is the most powerful tool for studying gene function in biology today, including forest trees. For example, GE can be used to manipulate the level or timing of gene expression with specificity and precision that is not provided by any other approach. Armed with a more thorough understanding of gene function, scientists can modify the frequency of different natural gene variants (alleles) with conventional breeding that is augmented by genetic markers. Thus, genetic engineering, used only as a tool for research, can substantially augment breeding by the insights it can provide.

The pace of gene discovery in many forest tree species has increased substantially due to technical advances in high-throughput genomic tools, including genome sequences (Tuskan *et al*. 2006 and Grattapaglia *et al*. 2009). A key feature is that the asexual insertion process typically involves a small number of well-defined genes (one to a dozen). This contrasts with sexual reproduction in which copies of all genes, typically tens of thousands, are combined together following fertilization.

The first genetically engineered tree, reported by Fillatti *et al.* (1987), was developed by a team of scientists from the University of Wisconsin, the U.S. Forest Service, and the biotechnology company Calgene (now part of Monsanto). Since then, dozens of other forest tree species have been genetically engineered for research purposes, though none have seen commercial use in the U.S. Traits such as herbicide tolerance and insect resistance that have been widely used in commercial agriculture in the U.S. were also shown to be highly effective in field-grown forest trees. In China, genetically engineered poplar trees containing insect resistance (Bt) genes have been deployed that are very similar to those used in agricultural crops. Wood-specific genes are of particular interest (Groover, 2005).

The 'omics' (genomics,proteomics,metabolomics)technologies provide the researchers to identify the genetics behind plant response to stress. Changes in gene expression is responsible to plant response in stress which result in composition of plant transcriptome,proteome & metabolome.As for example in recent days RNA sq.based transciptome studies is done against drought in Populus(Salicaceae) in green house condition.(Peng *et al* 2012).Similarly microarray based transcriptone is studied in climate chamber condition in Populus against drought (Yan *et al* 2012 and Raj *et al.* 2011).

Recent transcriptome analyses in roots of *Populus* sp. and *Pinus* sp. underpin several of the metabolic changes identified in physiological and biochemical studies (Wilkins *et al*. 2009; Cohen *et al*., 2010; Lorenz *et al*., 2011 and Perdiguero *et al*., 2012). Ative analyses of different genotypes led to the identification of several major gene clusters and regulators that are important in the response of roots to drought. Of the interrogated genes, 8% (5331 transcripts) were differentially expressed in poplar and 9% (2445 transcripts) in pine (Cohen *et al*., 2010; Lorenz *et al*., 2011). In both species, genes involved in ABA biosynthesis and signaling were differentially expressed.

Achievements and limitations

Plants adaptation to various environmental stress like drought , salinity etc. is dependent upon the activation of cascades of molecular networks involved in stress perception, transduction of signals and expression of specific stress related genes and metabolites. Consequently engineering genes that protect and maintain the function and structure of cellular components can enhance tolerance to stress. Profiling of stress associates metabolites and gene is most relevant to the successful molecular breeding in stress tolerant trees (Current opinion of Biotechnology, Volume 16, Issue 2, April 2005, pages 123-132).

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