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Engineering Drought Resistance in Forest Trees

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Climatic stresses limit plant growth and productivity. In the past decade, tree improvement programs were mainly focused on yield but it is obvious that enhanced stress resistance is also required. In this review we highlight important drought avoidance and tolerance mechanisms in forest trees. Genomes of economically important trees species with divergent resistance mechanisms can now be exploited to uncover the mechanistic basis of long-term drought adaptation at the whole plant level. Molecular tree physiology indicates that osmotic adjustment, antioxidative defense and increased water use efficiency are important targets for enhanced drought tolerance at the cellular and tissue level. Recent biotechnological approaches focused on overexpression of genes involved in stress sensing and signaling, such as the abscisic acid core pathway, and down-stream transcription factors. By this strategy, a suite of defense systems was recruited, generally enhancing drought and salt stress tolerance under laboratory conditions. However, field studies are still scarce. Under field conditions trees are exposed to combinations of stresses that vary in duration and magnitude. Variable stresses may overrule the positive effect achieved by engineering an individual defense pathway. To assess the usability of distinct modifications, large-scale experimental field studies in different environments are necessary. To optimize the balance between growth and defense, the use of stress-inducible promoters may be useful. Future improvement programs for drought resistance will benefit from a better understanding of the intricate networks that ameliorate molecular and ecological traits of forest trees.

Keywords: water limitation, antioxidative systems, genetic engineering, forest tree species, isohydric, anisohydric, avoidance, tolerance

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INTRODUCTION

Forests cover about 30% of the terrestrial land (FAO, 2016). They have strong effects on the local climate (Li et al., 2015), by interacting with biogeochemical water cycles (Ellison et al., 2017). When forest trees die or forests are cleared across large-scale landscapes, the negative consequences of drought are aggravated (Allen et al., 2015; Reyer et al., 2015), as shown for many areas world-wide (Laurance, 1998, 2004; van der Werf et al., 2008; Malone, 2017). Over-utilization of forests as a feedstock for energy, construction materials, or the generation of value-added products for the chemical industries, intensifies the problem.

The negative consequences of drought become even more urgent in current times of climate change because projections suggest that such events will occur more frequently and be more