UNDERSTANDING BIOCHEMICAL AND GENETIC RESPONSES OF PLANTS TO COMBAT DROUGHT STRESS UNDER CHANGING CLIMATE

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Abstract

In this current situation, ensuring the availability of food for the ever-growing population is one of the major challenges. Beside this the climate change that includes global warming resulting in severe drought condition has already thrown food scarcity challenge in front of us. It is high time to focus on understanding the biochemical and genetical responses that plant uses to combat drought stress. Even by understanding the crosstalk between plants and microbial community can help us designing modified plants. Modern genetic and functional omics approaches, such as transcriptomics, metabolomics and proteomics can help identifying and incorporating certain useful characters into crop plants that in turn can combat drought stress and yield high productivity.

Key words: Drought, Stress Resistance, microbiome, Genomics

Introduction

Among the other abiotic stresses that a plant has to face in its lifespan, drought stress is a common issue for many crop plants now a days. The over growing population is continuously giving immense pressure on the crop productivity. Drought in every way limits the productivity of the crop plants as it reduces the leaf size, leaf number, stem extension, etc. Other factors such as cell water content, turgor pressure, tissue water potential, cell enlargement, stomatal closure also gets altered. Due to all these forthcoming abnormalities, the normal photosynthesis process and metabolism of plants gets enormously affected which ultimately results in growth cessation and death of the plant. In course of evolution plants have developed certain unique strategies to combat stress. Metabolic and hydraulic readjustments along with physiological adaptations help the plants to tolerate the drought stress. In addition to this, upregulation of certain genes that are involved in osmolyte metabolism, secondary metabolite synthesis and hormone synthesis facilitates the response mechanism and crosstalk between the plant and microbial community.

Morpho-biochemical changes in plant under adverse impact of climate change and drought stress: -

- Water loss is reduced by increasing diffusive resistance,
- Developing deep root system for water uptake,
- Developing small, succulent leaves for reduced transpiration water loss,
- Potassium helps in osmotic readjustments,
- Silicon improves water retention capacity,
- Phytohormones like ABA, Auxin, Gibberellic acid helps in modulating drought response,
- Polyamines and secondary metabolite regulate antioxidant functioning. [1,2]

Molecular mechanisms adapted by plants to resist drought: -

a) **'Cry for help' strategy**: This strategy is important for the survival of both the individual plants and their offspring. Drought increases the abundance of Actinobacteria and Monoderm in the rhizosphere or endosphere of plant roots which results in co adaptive strategy for microbes and plants under a particular stress. Plant hormones play a crucial role in long distance signaling for systemic acquired resistance of plants that enables long term adaptation to stress at a whole plant level.[3]

b) **'Defense Biome' Concept:** The stress modulates the leaf/root exudate profile (via biosynthesis, transport, and secretion processes), which consequently attracts particular bacteria and/or fungi. Bio-weapons such as antimicrobial compounds and quorum-sensing quenching molecules are used by beneficial microbes to compete for space and resources that in turn inhibit pathogen growth and virulence. In case of co-occurrence of microbes in nutrient poor conditions, metabolites of one microbe can be utilized by other community members, which can result into simultaneous increase in both microbial strains in response to plant stress. [4]

c) The intricated **DNA damage response (DDR)** network consists of an impressive array of DNA damage sensing and signal transduction pathways leading to DNA repair and cell survival or, alternatively, triggering cell death. ROS and redox signals are involved in the regulation of gene expression at transcriptional (redox-sensitive transcription factors) and post-transcriptional (miRNAs) levels. [5]

Microbial Community Responses: -

- Soil microbial communities can draw out a mixture of positive and negative effects on plant physiological responses to drought, depending on the plant's metric of interest. [6]
- Greatersoil moisture of the inoculated plants results in higher photosynthesis rate but also inducelower tissue drought tolerance (as indicated by turgor loss point) compared to controls.

- In case of well-watered and moderate drought conditions, the effects of soil microbial communities on plant function can greatly impact plant physiological responses to subsequent severe drought (i.e., zero soil moisture).
- The mechanism opted by microorganisms to provide resistance against the drastic alteration in environmental conditions is done by specific *"response traits"* that protect against desiccation by producing thick peptidoglycan cell wall in monoderm. These organisms are referred as stress-tolerant strategists according to the recently proposed high **yield–resource acquisition-stress** tolerance **(Y-A-S)** theory. [7]

Advances in Plant breeding and Biotechnology for raising drought stress resistant plants: -

For plant- microbe interaction research, the use of Metagenomics along with Metabolomics and a culture dependent synthetic community (SynComs) approach has been developed recently. This combined approach follows the following steps:

1) Determines the structure and function of plant-associated microbial metagenomes.
2)Isolates and culture the identified bacteria, fungi, or oomycetes for reconstruction of a SynCom. [3]

Designing of biochemical and molecular strategies to produce drought resistant plants: -

Recent researches on modern genetic and functional omics approach, such as transcriptomics, metabolomics and proteomics, have already identified and characterised several drought-responsive genes in plants, that codes for osmolyte synthesis, water channels, ion transporters, detoxification, late embryogenesis abundant proteins and proteolysis.Transcription factors (TFs), phosphatases and protein kinases, including mitogen-activated, Ca-dependent and transcription regulation protein kinases controls signal transduction and gene expression during drought stress.

- Notably the dehydration-responsive element binding (DREB) and CRT element binding factors in the AP2/ERF family,have been well studied for their role in protein structure stabilisation, DNA binding and post-translational modification through transgenic studies.[8]
- Other genes induced during desiccation include those encoding osmo-protectants, such as proline, glycine betaine, sugars and ABA biosynthetic pathway, signalling proteins, antioxidant components and TFs. TFs are reported to regulate several downstream stress-responsive genes by binding cis regulatory elements in the promoter region of genes.
- Current advances in drought stress research with experimental evidence confirming the key roles of novel signalling molecules, such as hydrogen sulphide, melatonin and jasmonic acid.

Perspective of Genomics research for future crops: -

- An overall understanding of the biological rationale behind the stress-induced microbiome shifts will enable the design of customized Defence Biomes and chemicals to combat crop stresses.
- The advancement of genomic technologies and gene mapping tools such as genome-wide association study (GWAS) andgenome editing with the CRISPRCas9 system has served for the generation of alleles thatimproved plant yield and performance under various types of stresses. Molecular studies using tissuespecific or cell specific

promoters along with live microscopy techniques for real-time visualization of cellular processes can be efficient for analysis of drought response networks that can be targeted by various approaches. Small molecules such as peptides or hormone agonists may be useful for fine-tuning drought response pathways while enhancing yield in agriculture. [9]

- Horizontal gene transfer, adaptation and compositional changes in microbial communitiescan determine future drought responses of the plant-microbe halobiont.
- Manipulating the rhizosphere microbiome by introducing the selective traits into crops, or by inoculating soils with probiotics is likely to be more successful when combined with other measures to increase the sustainability of Agro-ecosystems.

Conclusion

Drought is one of the major limiting factors responsible for cutting back crop production worldwide. So, to meet the ever-growing need of production, certain biochemical and genetical changes in the crops with the help of genomics can help farmers to combat drought stressed crop plants. Understanding the role of plant microbe interaction in regard to drought recovery can open many doors in designing drought resistant plants.

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