



## Mini Review

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# Genetic Engineering for Drought Resistance in Rice



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## Introduction

Drought is actually a meteorological event which implies the absence of rainfall for a period of time, long enough to cause moisture-depletion in soil and water deficit with a decrease of water potential in plant tissues. But from agricultural point of view, it's working definition would be the inadequacy of water availability, including precipitation and soil-moisture storage capacity, in quantity and distribution during the life cycle of a crop plant, which restricts the expression of full genetic potential of the plant. It acts as a serious limiting factor in agricultural production by preventing a crop from reaching the genetically determined theoretical maximum yield.

The effect of drought on crop production and overall economy is well known. Most of the crops are sensitive to water deficits, particularly during flowering to seed development stage. Even crops grown in arid and semi-arid regions such as pearl millet, sorghum and pigeon pea are also affected by drought at the reproductive stage. In agriculture, drought resistance refers to the ability of a crop plant to produce its economic product with minimum loss in a water-deficit environment relative to the water-constraint-free management. An understanding of genetic basis of drought resistance in crop plants is a prerequisite for a geneticist to evolve superior genotype through either conventional breeding methodology or biotechnological approach.

## Osmoregulation Mechanism of Plant Drought Resistance in Plants

In genetic sense, the mechanisms of drought resistance can be grouped into three categories, viz. drought escape, drought avoidance and drought tolerance. Drought escape is defined as the ability of a plant to complete its life cycle before serious soil and plant water deficits develop. This mechanism involves rapid phenological development (early flowering and early maturity), developmental plasticity (variation in duration of growth period depending on the extent of water-deficit) and remobilization

of preanthesis assimilates to grain. Drought avoidance is the ability of plants to maintain relatively high tissue water potential despite a shortage of soil-moisture, whereas drought tolerance is the ability to withstand water-deficit with low tissue water potential. Mechanisms for improving water uptake, storing in plant cell and reducing water loss confer drought avoidance.

The responses of plants to tissue water-deficit determine their level of drought tolerance. Drought avoidance is performed by maintenance of turgor through increased rooting depth, efficient root system and increased hydraulic conductance and by reduction of water loss through reduced epidermal (stomatal and lenticular) conductance, reduced absorption of radiation by leaf rolling or folding and reduced evaporation surface (leaf area). The mechanisms of drought tolerance are maintenance of turgor through osmotic adjustment (a process which induces solute accumulation in cell), increase in elasticity in cell and decrease in cell size and desiccation tolerance by protoplasmic resistance.

This osmoregulation was realized mostly by accumulation of osmolytes Bray [1]. The accumulation of compatible solutes or osmolytes under osmotic stress is well known in many organisms. Osmolytes are synthesized mostly in response to osmotic stress and do not interfere with normal cellular biochemical reaction. Therefore, they help to maintain an osmotic balance under drought stress.

## Improving Plant Drought Resistance by Genetic Engineering

It is an important method to improve plant drought-resistance by the conventional breeding. But with the gradual understanding of mechanisms of drought tolerance in plants, researchers have already realized the importance of genetic engineering in improving plant drought-resistance. It is proved by increasing studies on dehydration and drought tolerance of plants by the new genetic approaches. It is an outline below

that offers new ways to evaluate the contribution of individual genes to dehydration tolerance. Kishoret [2] introduced and over expressed a gene which encoded the mothbean [ $\delta$ ]-pyrroline-5-carboxylate synthetase (P5CS) to tobacco.

The transgenic plants produced a high level of the enzyme and synthesized 10 to 18-fold more proline than control plants. Their results suggest that the activity of the first enzyme of the pathway is the rate-limiting factor in Pro synthesis. The osmotic potentials of leaf sap from transgenic plants were less decreased under water-stress conditions compared with those of control plants. Overproduction of Pro also enhanced root biomass and flower development in transgenic plants under drought-stress conditions. Shenet [3] isolated and characterized the CMO gene from *Atriplex hortensis*, and by introducing it into tobacco, and they found that over-expression of AhCMO improved drought tolerance in transgenic tobacco when cultured in medium containing PEG-6000. The transgenic plants also have a better performance under salt stress.

The BADH gene was also used in transgenic plants to improve tolerance to environment stress. Liang et al. [4] transformed the BADH gene to tobacco plants mediated by *Agrobacterium tumefaciens*. Ninety kanamycin resistant transformants were selected. This result conformed that transgenic plants had strong expression of BADH gene and had the ability to tolerate high salinity. Owing to their solubility, levan may help plants survive periods of osmotic stress induced by drought. Trehalose, a non-reducing disaccharide of glucose, it is known as a reserve metabolite in yeast and fungi. Biochemical studies have also shown that trehalose stabilizes proteins and membrane lipids. By PCR Procedure, a plant expression vector with TPS gene from *Saccharomyces cerevisiae* and drought responsive promoter Prd29A from *Arabidopsis* has been constructed and used for the genetic transformation of tobacco Zhao et al. [5]. The transgenic tobacco with Prd29A/TPS demonstrated changes including dwarf and fine shoot, drought-sharped leaves and vigorous auxiliary buds have been observed in a few transformed plants. Presently, many LEA genes have been cloned and analyzed. LEA genes have enormous sorts.

Dure et al. [6] classified LEA proteins into three types according to the structure of LEA protein:

- a. Production of Em gene;
- b. RAB (responsive to ABA) and production of dehydrin;
- c. Production of other LEA.

Expression of LEA protein has the peculiarity in different developmental phases and the tissues in plants. And LEA gene is induced during ABA, salt or drought treatment and dehydration. Nevertheless, not all LEA gene can be induced by drought stress. An example for genetic engineering of LEA gene is given by the barley LEA gene HVA1. Xu et al. [7] produced rice plants transgenic for HVA1. Transgenic plants accumulated HVA1 protein in both leaves and roots and its content was 0.5%-2.5% of the soluble

protein, and showed tolerance to drought and salinity. This study provides direct evidence supporting the hypothesis that LEA proteins play an important role in the protection of plants under water- or drought-stress conditions.

Thus, LEA genes hold considerable potential to be used as molecular tools for plant genetic improvement toward drought tolerance. Expression of a number of genes is induced by both drought and low temperature, although these stresses are quite different. Previous experiments have established that a cis-acting element named DRE (for dehydration-responsive element) plays an important role in both dehydration- and low-temperature induced gene expression in many plants.

### Future Strategies

The future research programmes for drought resistance should consider the following strategies:

- a. There is an urgent need for exploration of the plant genetic resources with attributes related to drought resistance in different crop plants and their characterization to facilitate transfer of desired traits through conventional plant breeding or biotechnological method.
- b. A single trait cannot confer drought resistance satisfactorily. Therefore, breeding programme for drought resistance should aim at pyramiding a number of relevant traits in a crop.
- c. Plant genetic engineering also generated transgenic plants with only one transgene in all cases. Many different genes responsible for biosynthesis of different solutes and osmolytes conferring drought resistance should be considered for transfer in a crop plant at a time.
- d. Attention should be concentrated on better understanding of genetic basis of drought resistance through antisense RNA technique, observing the effect of expression level of different enzymes/ proteins in different biochemical pathways on drought resistance.
- e. Several stress proteins (such as LEA, dehydrin, etc.) are synthesized and accumulated in plant tissues under drought condition. A comparative assessment of various polypeptides produced in response to drought, between sensitive and tolerant genotypes may be used in identification of protein marker, which could help in producing transgenic drought resistant plants.

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