

# Drought adaptive mechanisms of plants – a review

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## Abstract

Drought stress is one of serious threats of mankind particularly in arid and semiarid regions, it is the most serious threat to world food security, there are various negative effects on plant growth and total yield occurs under drought conditions, therefore, plants have different responses for adaptation and survive with drought conditions such as morphological, biochemical, physiological responses, and a molecular mechanism. Plants acclimatize with drought stress by use various strategies includes drought escape, drought avoidance and drought tolerance. Plant breeding using biotechnology and classical breeding techniques for improving plant drought tolerance, also, use of Exogenous plant growth regulators improving plant tolerant for drought stress.

**Keywords:** Drought stress, drought escape, drought avoidance, drought tolerance, exogenous plant growth regulators.

## Background

Drought stress is the most serious threat to world food security. It is considered the mainly popular environmental aspect limiting plant growth and crop productivity. At the same time climate change is increasing the occurrence of severe drought conditions in different area all over the world particularly in arid and semiarid regions, in term of its severity and average of drought in the coming Era.<sup>1</sup>

Drought stress causes different negative effects on plant growth and total yield by drought such as:

Decreased leaves absorption of photosynthetic active radiation.<sup>2</sup>

Reduced radiation-use efficiency.

Minimized harvest index.

Drought tolerance could be defined as the plant ability to preserve vegetative growth and crop yield under drought conditions, also, drought tolerance is evaluated as increase cell membrane stability under water shortage conditions.

Drought severity is changeable as it depends on numerous factors like soil structure and it is water reserve capacity, average of rainfall, and evapotranspiration rate.<sup>3</sup> Plants have various responses for acclimatization and survive under drought conditions through induction of morphological, biochemical, physiological responses; also, there is a molecular mechanism in the plant under water deficit conditions.

Progress of plants tolerant to drought stress might be a promising approach,<sup>4</sup> however, plant adaptations for drought stress could be divided into three strategies which involves:

1. Drought escape
2. Drought avoidance

## 3. Drought tolerance

Generally, drought-tolerant plants are able to survive dehydration through osmotic adjustment and production of molecules that stabilize proteins.<sup>5</sup>

This work is aimed to understand plants adapting drought conditions and explain main mechanisms and some practice to reduce drought effects to improve plant growth and total yield.

## Drought tolerance

Drought tolerance is defined as the ability to grow, flower and display economic yield under sub-optimal water supply. The plant ability to preserve leaf area and growth under extended vegetative stage are considered as other definition for stress tolerance.<sup>6</sup> Also, drought tolerance evaluated as amplify cell membrane stability under water shortage conditions.

The root system is the main plant organ for adaptation of drought stress conditions. The main basis of variation appears to be constitutive, therefore, root system architecture that allows reserve of more water quantity are the most important tool for drought tolerance.

Drought stress alone inhibited plant growth in term of reducing shoot length and fresh weight of the hypocotyls. The drought, tolerant plants initiate defense mechanisms against water deficit, plants use different mechanisms of drought tolerance at different levels of aridity. Some of this is morphological mechanism such as escape from drought, drought avoidance and phenotypic flexibility. Also, there are physiological mechanisms to avoid negative effects of drought on plant growth.

## Drought Resistance Mechanisms

Plants respond and adapt to survive under drought stress by the induction of various morphological, biochemical and physiological

responses; also, there is a molecular mechanism in the plant under water deficit conditions.

Some of physiological mechanisms are cell and tissue water preservation, Cell membrane stability and endogenously produced growth regulator. However, the deficit of plant cellular water occurs under dry soil conditions considered as molecular mechanisms.

Under water deficit stress, plant uses some changes in gene expression to avoid hazard effects of water stress. Drought stress affects the water relations of plants at cellular, tissue and organ levels, causing specific as well as unspecific reactions, damage and adaptation reactions.<sup>7</sup>

## Mechanisms of drought tolerance

### Morphological mechanisms

Plants under drought conditions use various changes to tolerate stress conditions and increase drought tolerance which includes changes in whole-plant, tissue, at physiological and molecular levels. Appearance of a single or a combination of inherent changes determines the ability of the plant to stand under aridity conditions. Plants use various morphological mechanisms operative under drought conditions like:

#### *Drought escape*

Escape from drought allowed production of new seeds before the harsh environment conditions end the life cycle of the plant. In these conditions, plants develop rapidly and reduce vegetative growth period. Also, early flowering is an important mechanism plant use to adapt with drought. Therefore, short life cycle considered a proper technique to escape from climatic stresses.<sup>8</sup>

#### *Avoidance*

In previous researches drought avoidance has been referred to as dehydration avoidance, avoidance mechanisms and depends on the decrease water loss from plants by control transpiration, and increase water use efficiency. At the same time, the root system plays a vital role in avoiding drought mechanism and the root system characters change (it becomes deeper and thicker) to adsorbing water from extra depths to contribute to producing yield under drought conditions. Plant reserve water uptake through prolific root system,<sup>9</sup> in this condition plants reducing transpiration, limiting vegetative growth, or increasing root growth, and avoid dehydration during transient periods of drought stress.

#### *Phenotypic flexibility*

As a morphological mechanism for drought tolerant, plants reduced the number and size of leaves in response to drought stress just to reduce the water consumption to avoid loss of yield.<sup>9</sup> Meanwhile the root system is the only source for absorbing water from the soil, therefore, improving the root growth rate, root density, spread, and size are basic reactions of plants to tolerate drought stress and at the same time plants bearing small leaves.<sup>10</sup>

### Physiological mechanisms

Plants use various responses for drought tolerance such as osmotic adjustment, osmoprotection, antioxidation, and a scavenging defense system, which has been the most essential response for drought tolerance. However, the physiological basis of genetic variation in drought tolerance is not clear. The different suggested mechanism with short explanation of this mechanisms are mentioned as follows:-

### *Osmotic adjustment*

The cell could reduce osmotic potential through osmotic adjustment, consequently, preserve cell turgor by increasing the gradient for water influx-enhanced tissue water status could be achieved through changes in cell wall elasticity or adapted osmotic pressure. This mechanism is important to preserve physiological activity for complete periods of drought.<sup>11</sup> Of course, sensitive genotypes plants affected by reduce relative water content in plant tissues more than tolerant ones, under drought stress,<sup>12</sup> for more clearance for drought effects preferable determination of leaf water statues at two times: First one in the morning and the second in afternoon. This could be more useful for examined drought tolerance in the plant genotype.<sup>13</sup>

Accumulation of solutes play a vital role by attracting water into the cell through reduced osmotic potential of the cell and maintain turgor cell, by reduce leaf water volume. Also, osmotic adjustment kept cell water balance with active accumulation of solutes in cytoplasm. This action may be reducing negative effects of drought on plant growth, with the accumulation of solutes, the osmotic potential of the cell is lowered, which attracts water into the cell and helps turgor maintenance. The maintenance of turgor despite a decrease in leaf water volume is consistent with other studies of species with elastic cell walls. Osmotic adjustment helps to maintain the cell water balance with the active accumulation of solutes in the cytoplasm, thereby minimizing the harmful effects of drought.<sup>14</sup>

#### • Roles of osmotic adjustment

It is an important trait in delaying dehydration damage under water-shortage conditions by continued maintenance of cell turgor and physiological processes.<sup>15</sup>

The osmotic adjustment enhancement translocation of pre-anthesis carbohydrate partitioning during grain filling.<sup>16</sup>

Osmotic adjustment kept cell water balance with active accumulation of solutes in cytoplasm,<sup>14</sup> while high turgor maintenance increase photosynthetic rate and growth.<sup>4,16</sup>

### *Cell membrane stability*

Generally, it is known that cell membranes are the first target of many abiotic stresses, therefore, the main component for drought tolerance in plant is to preserve integrity and stability of cell membrane.<sup>17</sup> Also, membrane stability of the leaf segment is the essential trait to examine the germplasm for drought tolerance.<sup>18</sup> On other side Cell membrane stability depleted quickly when exposed to drought with heat stress at once.<sup>19</sup>

### *Plant growth regulators*

Phytohormones play vital roles in drought tolerance of plants and have influence on physiological processes in plant.<sup>14</sup> Under drought stress the production of endogenous auxins reduced, however, abscisic acid and ethylene produce increase usually.<sup>20</sup> Auxins breaking root apical dominance and stimulate produce new root, to improve the imperative role of prolific root system in drought tolerance.<sup>21</sup>

#### • Role of Absciscic acid:

Absciscic acid is a natural growth inhibitor, and is produced under abiotic stress conditions, including drought. All higher plants respond to drought under various stresses by producing and accumulating abscisic acid. It is recognized as a stress hormone that regulates gene

expression and acts as a signal for the initiation of processes involved in adaptation to drought and other abiotic stresses. Under drought conditions, synthesis of abscisic acid increase to close stomatal and reduce water loss through reduced transpiration.<sup>14</sup> The high levels of abscisic acid leads to change in plant growth rate as aerial parts, so, the root-to-shoot dry weight ratio increased, and leaf area decreased.<sup>22</sup> It has been reported that there is an opposite roles for cytokinin and abscisic acid in drought stress.

### Molecular mechanisms

During drought conditions, there are changes in gene expression of plants that occur as a response of this stress. Different genes are induced at the transcriptional level, and these gene products has effective role in tolerance to drought.<sup>10</sup>

Gene expression could be triggered as a direct result for stress conditions or injury responses, nevertheless, it is well recognized that drought tolerance is a complex phenomenon including the intensive action of several genes.<sup>23,24</sup>

### Stress proteins

Under stress conditions plant produce proteins as a response for stress to survive under different stresses including drought, Majority of the stress proteins are soluble in water and it is play important role in stress tolerance by hydration of cellular structure.<sup>25</sup>

### Signaling and drought stress tolerance

There is signaling for drought detection in plant as quick responses to stress via the redox system to stimulate repairing of damaged deoxyribonucleic acid. There are various signaling including chemical signals like reactive oxygen species, calcium, calcium regulated proteins,<sup>26</sup> and Mitogen-activated protein kinase cascades and cross-talk between different transcription factors, mitogen-activated protein kinase play vital role in signal transmission. It is connecting the perception of external stimuli to cellular responses.<sup>27</sup>

It has been recognized that osmotic adjustment, abscisic acid and induction of dehydrins, could provide tolerance against drought hazards by preserve high tissue water potential than other different mechanisms.<sup>28</sup>

## Managing Drought Stress

There are different strategies for management of drought stress including:

### 1. Plant breeding

Using biotechnology and classical breeding is a good approach for improving drought tolerance, also, produce appropriate drought-tolerant genotypes could be another technique to manage drought stress and improve plant response to stresses.<sup>29</sup>

### 2. Use of Exogenous plant growth regulators (EPGR)

Enhancing plant tolerant through foliar application of EPGR both natural and synthetic, has verified for enhancement growth against a variety of abiotic stresses include drought, under drought stress, EPGR treatments increase water potential inside cell and improved chlorophyll content.<sup>30</sup>

### 3. Proper agricultural practice

sowing time, plant density and farm management could be another way to adapted managed drought stress.

## Some Agricultural practice to increase drought tolerance

Usage of potassium fertilization under drought stress increased the drought tolerance, due to implement cell membrane stability.<sup>31</sup>

Also, seedlings hardening increased drought tolerance primarily by reducing osmotic potential and stomatal regulation, improved new root growth capacity and enhanced cell membrane stability,<sup>32</sup> nevertheless, exogenous application of indole-3-yl-acetic acid enhanced net photosynthesis and stomatal conductance in cotton Indole-3-butyric acid is naturally occurring auxins.

## Conclusion

Drought stress is one of the most serious threats to world food security. There are various negative effects on plant growth and total yield occurs under drought conditions, therefore, plants have different responses for adapted and survive with drought conditions such as morphological, biochemical, physiological responses, and a molecular mechanism. Plants acclimatize with drought stress through use various strategies which include drought escape, drought avoidance and drought tolerance. Plant breeders using biotechnology and classical breeding techniques for improving plant drought tolerance, from another side, using of exogenous plant growth regulators could improve plant tolerant for drought stress

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