Chemical Science Review and Letters ISSN 2278-6783

Review Article

# Breeding for Abiotic Stress Tolerance in Ornamental Crops: A Review

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**Abstract**

Abiotic stress is major problem affecting large parts of India. It is caused by temperature (low/high), drought or salinity representing a major constraint over crop growth and productivity. In ornamental crops meagre efforts have been done towards this approach. Now ornamental crops are the potential source of earning higher income as compared to the other crops and have a definite role in national economy. Breeding of ornamentals which can also be grown in stressed environment is the new challenge of the era. Various approaches have been developed for abiotic stress tolerance but very few have been proved worthy in case of ornamental crops. Wide distant (interspecific and intergeneric) hybridization is the basic approach found promising strategy to improve drought tolerance of some crops through introducing abiotic stress-tolerant trait from their wild relatives into cultivated. *In vitro* mutagenesis is important technique that combines both tissue culture technique and induces mutation strategy for inducing stress tolerance and improvement of the yield and quality of crop plants. Genetic engineering is the latest technology which is used for breeding programme. The introduction of novel characteristics such as new colours, biotic and abiotic stress tolerance in ornamental crops are usually difficult through conventional breeding, but could be achieved relatively easily by genetic transformation.

**Keywords:** Abiotic stress, Hybridization, Mutation, Genetic engineering

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## Introduction

Phenotypic performance of a plant is determined by its genotype, environment and the genotype-environment interaction. When some factor of the environment interferes with the complete expression of genotypic potential, it is called stress. Stresses are also classified as biotic (pathogens, pests, weeds, etc.) and abiotic depending on their biological/abiological nature. Abiotic stresses result due to moisture, temperature (high/low), minerals (deficiency/ toxicity), salinity, soil pH, air pollution, etc. Abiotic stress conditions cause extensive losses to agricultural production worldwide [1]. Individually, stress conditions such as drought, salinity or heat have been the subject of intense research [2]. However, in the field, crops and other plants are routinely subjected to a combination of different abiotic stresses. In drought-stricken areas, for example, many crops encounter a combination of drought and other stresses, such as heat or salinity.

## Characteristics of abiotic stresses

- The characteristics of an abiotic stress may vary considerably depending on the location.
- The relative importance of different abiotic stresses is manly location specific.
- The degree of some stresses is likely to vary during the crop season.
- A given abiotic factor may increase / decrease the level of another abiotic stress, *e.g.*, in a saline soil, moisture stress would enhance salinity stress.
- Different plant/ crop species show marked differences in their abilities to withstand a given stress.
- Different varieties of a crop also show large difference in their abilities to tolerant abiotic stresses.
- The effects generated by one abiotic stress may overlap some of those generated by another stress. For example, salinity stress generated some features produce by drought stress, so that strains develop for salt resistance also show enhance drought tolerance.

## Drought

Drought is a condition of unusually dry weather within a geographic area where there is a lack of precipitation. It is governed by various factors like extremes in temperature, photon irradiance and paucity of water. It is low water potential due to high solute concentration.

## Mechanism of drought tolerance

### *Drought escape*

It is defined as the ability of a plant to complete its life cycle before supply of water in soil is depleted and form dormant seeds before the onset of dry season. These plants are known as drought escapers since they escape drought by rapid development.

### *Drought avoidance*

It is the ability of plants to maintain relatively high tissue- water potential despite a shortage of soil-moisture. Drought avoidance is performed by maintenance of turgor through roots grow deeper in the soil, stomatal control of transpiration and by reduction of water loss through reduced epidermal i.e. reduced surface by smaller and thick leaves.

### *Drought tolerance*

It is the ability to withstand water-deficit with low tissue water potential. Drought tolerance is the maintenance of turgor through osmotic adjustment (a process which induces solute accumulation in cell), increase in elasticity in the cell and decrease in cell size.

## Effect of drought stress

- **Effect on Growth:** Reduction in turgor Pressure, due to cell sizes will be smaller.
- **Effect on Photosynthesis:** Photosynthesis decreases due to disruption of PS II (Photo System II), stomatal closure, decrease in electron transport.
- **Decrease in nuclear acids and proteins:** Protease activity increase, free amino acid increase, RNAase activity increase, RNA hydrolysis, DNA content falls down
- **Effect on Nitrogen Metabolism:** Nitrate reductase activity decrease, nitrite reductase activity insensitive
- **Effect on Carbohydrate metabolism:** Loss of starch and increase in simple sugars, carbohydrate translocation decreases.

### *Salt stress*

Salt stress causes loss of water use efficacy, increase ions, induction of heat stress and reduces stem extension. Biological macromolecules are damaged due to production of free ions. It was found that salinity stress resulted in decrease of water content, accumulation of hydrogen peroxide and electrolyte release in plants [3]. One of the severe factors is salt accumulation in soil limiting the productivity of plants, causes adverse effects on germination, plant growth and crop yield. Throughout the world, about 45 million hectares of irrigated land is affected by salt [4]. Salt stress affects plants in numerous ways such as; ion toxicity, nutritional disorders, physiological drought, oxidative stress, modification of metabolic processes, membrane incompetence and reduction of cell division.

### *The response of ornamental plants to salt stress*

Salt effects on plants are the combined result of the complex interaction among different morphological, physiological and biochemical processes. One of the first responses of plants to salinity is a decreased rate of leaf growth [5] primarily due to the osmotic effect of salt around the roots, which leads to a reduction in water supply to leaf cells. High external salt concentrations can also inhibit root growth [6], with a reduction in length and mass of roots [7] and of function. Reduction in cell elongation and division in leaves reduces their final size, resulting in a decrease in leaf area [8, 9]. Leaf area reduction could be caused by a decrease in turgor in the leaves, as a consequence of changes in cell wall properties or a reduction in photosynthetic rate Such consequences are seen in ornamental plants: Cassaniti

[10] showed that the decrease in shoot dry weight and leaf area were the first visible effects of salinity both in sensitive and tolerant species such as *Cotoneaster lacteus* and *Eugenia myrtifolia*, respectively. Another common response to high salt level is leaf thickening, which occurred in ornamental plants such as *Coleus blumei* and *Salvia splendens* [11].

### *Heat stress*

The adverse effect of temperatures higher than the optimal is considered as heat stress. Heat would affect survival, growth and development and the physiological processes, the nature and extent of the effects depending mainly on the temperature, the plant species and the process in question. Heat stress is often defined as the rise in temperature beyond a threshold level for a period of time sufficient to cause irreversible damage to plant growth and development [12]. Heat stress affects plant growth throughout its ontogeny, though heat-threshold level varies considerably at different developmental stages. Heat stress due to high ambient temperature is a serious threat to crop production worldwide. Different global circulation models predict that greenhouse gases will gradually increase world's average ambient temperature. At very high temperatures, severe cellular injury and even cell death may occur within minutes. At moderately high temperatures, direct injuries include protein degradation, aggregation and increased fluidity of membrane lipids. Indirect injuries include inactivation of enzymes, inhibition of protein synthesis, protein degradation and loss of membrane integrity.

### *Cold stress*

Cold stress is a serious threat to the sustainability of crop yields. It can lead to major crop losses. Various phenotypic symptoms in response to cold stress include poor germination, stunted seedlings, yellowing of leaves, reduced leaf expansion and wilting, and may lead to death of tissue (necrosis). Cold stress also severely hampers the reproductive development of plants. The major negative effect of cold stress is that it induces severe membrane damage. Plants experience cold or chilling stress at temperatures from 0-15 $^{\circ}$C. Under such situations, plants try to maintain homeostasis to acquire freezing tolerance and this involves extensive reprogramming of gene expression and metabolism [13, 14].

## Breeding methods for abiotic stress tolerance

### *Wide distant hybridization*

Wide distant (interspecific and intergeneric) hybridization has become a promising strategy to improve abiotic stress tolerance of some crops through introducing stress-tolerant trait from their wild relatives into them, for the wild species usually have high abiotic stress-tolerant trait that cultivars do not possess [15, 16]. For example, an improved drought-tolerant perennial ryegrass (*Lolium perenne*) was developed through intergeneric hybridization by inheriting drought tolerance of Atlas fescue (*Festuca mairei*) [17]. In addition, many chrysanthemum cultivars with improved drought tolerant have been bred through interspecific hybridization [18]. Develop interspecific hybrids between *Dendrenthema morifolium*and and *Dendrenthema nankingense* by using ovary rescue, to improve cold tolerance in cultivated species [19].

### *In vitro mutagenesis*

It is an important technique which can induce stress tolerance and improve the yield and quality of crop plant. *In vitro* mutagenesis combining both tissue culture technique and induce mutation strategy. One NaCl tolerant chrysanthemum (*Chrysanthemum morifolium* Ramat.) variant (E2) has been developed in a stable form through *in vitro* mutagenesis using ethylmethanesulfonate (EMS) as the chemical mutagen. Salt tolerance was evaluated by the capacity of the plant to maintain both flower quality and yield under stress conditions. Enhanced tolerance of the E2 variant has been attributed to the increased activity of superoxide dismutase (SOD), ascorbate peroxidase (APX), and dehydroascorbatereductase (DHAR), and, to a lesser extent of membrane damage than NaCl treated control plants. Isoform analysis revealed that an increase in total SOD activity in the E2 variant was solely due to significant activation of the Cu/Zn isoform. Elevated levels of carotenoids and ascorbate in E2 leaves have been reflected in their higher free radical scavenging capacity (RSC) expressed in terms of DPPH (2,2-diphenyl-1-picrylhydrazyl) scavenging ability. Data reflect that a proper balance between enzymatic and non-enzymatic defence systems is required for combating salinity stress in chrysanthemum. Better performance of the E2 progeny under same salinity stress condition, even in the second year, confirms the genetic stability of the salt-tolerance character. On the whole, the E2 variant, developed through 0.025 % EMS treatment, might be considered as a NaCl tolerant strain showing positive characters towards NaCl stress [20].

## Genetic engineering for abiotic stress tolerance

Development of plant varieties with a high level of tolerance to abiotic stresses is crucial for establishing full yield potential and to stabilize production. Due to the multitude of abiotic stresses and their complex genetic control the progress of breeding for tolerance to abiotic stresses using conventional approaches has not been very rewarding. The development of tolerant crops by genetic engineering requires the identification of key genetic determinants underlying stress tolerance in plants and introducing these genes into crops. Introduction of molecular change by genetic engineering takes less time compared to plant breeding methods: only desired gene can be transferred, whereas, in conventional breeding approach is associated with simultaneous transfer of undesired gene [21]. Recent advances in cellular and molecular biology have made it possible to clone important genes and mobilize them in any organism across barriers of sexual hybridization for stable expression and transmission. All living organisms have evolved mechanisms for avoidance or tolerance to one or more of the abiotic stresses. Plants producing crucial enzymes or proteins from various organisms involved in abiotic stress tolerance mechanisms have shown significant advantage over their wild type controls under stressed environment. The enhanced level of compatible osmolytes, radical scavengers and other transgene products correlated with the degree of tolerance. Further understanding of the molecular mechanisms of stress perception, signal transduction and response by plants and other organisms may help to engineer plants with high levels of tolerance to multiple stresses. Perspectives and additional approaches for further improving the tolerance to abiotic stresses through genetic engineering are discussed.

**Table 1** List of transgenic research for abiotic stress tolerance in ornamental crops

| Abiotic Stress | Gene | Origin | Transgenic plant | References |
|---|---|---|---|---|
| Cold | CBF3 | Arabidopsis | Petunia | [22] |
| Salt and drought | ATNHX1 | Arabidopsis | Petunia | [23] |
| Cold | LTP (lipid transfer protein) | Rice | Orchid (*Phalaenopsis amabilis*) | [24] |
| Salt | NnCIPK (calcineurin B-like protein kinase ) | Lotus | Lotus | [25] |
| Cold | DREB1C | *Medicago truncatula* | China Rose | [26] |
| Salt and drought | RhEXPA4 | Rose | Arabidopsis | [27] |
| Drought | RhNAC2 and RhEXPA4 | Rose | Rose | [28] |
| Salt, cold and drought | ICE1 | *Chrysanthemum dichrum* | *Chrysanthemum grandiflorum* | [29] |
| Salt (iron) | Fro2 | Arabidopsis thaliana | Rhododendron | [30] |

## Conclusion

Abiotic stress caused by temperature, drought or salinity represents a major constraint over crop growth and productivity. Breeding methods like interspecific, intergeneric hybridization, *in vitro* mutagenesis and genetic engineering for improving abiotic stress tolerance in ornamental crops have proven to be the potential approaches. Genetic engineering improved abiotic stress tolerance through adding one or more new traits that are not already found in that organism.

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Publication History

| | |
|---|---|
| Received | 11th June 2017 |
| Revised | 28th June 2017 |
| Accepted | 10th July 2017 |
| Online | 30th July 2017 |