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17. Breeding for Abiotic- Salt Resistance in Crop

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Abstract

The non-living factors must influence the environment beyond its normal range to adversely affect the performance of population or physiology of individual plant in a significant manner. It is nearly impossible to avoid the abiotic stress. It is a constraining factor as plants are dependent on various environmental factors. It is the primary factor for concern regarding crop growth and productivity. Abiotic stress takes many different forms in real-world situations. The most prevalent stressors are easily recognized, but there are numerous other, less obvious abiotic stress elements that continuously alter surroundings. Extreme temperatures, the chemical composition of the soil, moisture, toxicity, salinity, and other natural calamities (such as tornadoes and wildfires) are among the most frequent and significant stressors. One of the main abiotic factors lowering agricultural output is salt of the soil. According to estimates, increased salinity from agricultural practices might result in the loss of up to 30% of arable land by 2025 and up to 50% by 2050. Mineral stressors, such as mineral toxicity or deficiency, can arise from the accumulation of an excessive number of soluble salts in the root zone. Salt stress negatively impacts seed germination, root and shoot length, plant height, and fruit development (Liang et al. 2014).

Keywords: Abiotic stress, Salt Resistance, Crop Yield, Physiology,Salinity

17.1 Abiotic Stress:

Abiotic stress is defined as the negative impact of non-living factors on living organisms in a specific environment. The stresses include drought, salinity, low or high temperatures, and other environmental extremes. Abiotic stresses, especially hyper salinity and drought, are the primary causes of crop loss worldwide. In contrast to plant resistance to biotic stresses which mostly depends on monogenic traits, the genetically complex responses to abiotic stresses are multigenic and thus more difficult to identify, control, and manipulate. Abiotic stress is typically inescapable, and our only option is to handle it.

A. The most common sources of stress are: Extreme temperatures, Soil-chemical properties, Moisture, Toxicity, Salinity and Other natural disasters (tornadoes and wildfires)

B**.** Lesser-known stressors (occur on a smaller scale) include: Poor edaphic conditions like rock content and pH levels, High radiation, Compaction, Contamination and Highly specific conditions like rapid rehydration during seed germination.

This article discusses the impacts that result from abiotic stress. It is a component of every ecosystem by nature and has various kinds of effects on living things. Although these effects may either be beneficial or may not be, but the impact extent depends upon the area in which it is located. On higher latitude of the area affected, the impact of abiotic stress will be greater on that particular area. Therefore, abiotic stresses are far less likely to affect the tropical zones.

17.1.1 Characteristics of Abiotic Stresses:

An abiotic stress's effects and properties might differ greatly depending upon the region and sometimes may be location specific. The occurrence of some stresses is unpredictable, e.g., drought, flood etc. As per the crop season also, the degree of occurrence may vary. Some stresses, like salinity and drought, can be slightly reduced once they arise through appropriate management techniques, but other stresses, like temperature stress, are unmanageable.

One abiotic factor may increase or decrease the impact of another stress (Salinity stress would be exacerbated by moisture stress in a saline soil). The crop, variety, and growth stage at which a stress occurs determine the tolerance level to that particular stress. When the crop encounters the stress at reproductive stage, compared to all other phases of crop growth, the economic loss is substantially greater. Also, the effects of one stress may interfere with another (salinity stress have some features of drought stress, so that strains developed for salinity resistance have shown enhanced drought tolerance too).

17.2 Salt Affected Soil:

The excessive buildup of soluble salts in the root zone, which has a negative impact on the development and growth of plants. When soils are impacted by salt, this condition is more noticeable. Such soils are mainly of two types:

- Saline soil
- Alkaline soil

These soils vary in terms of the kind of salt they contain, their physical characteristics, their geographic distribution, and the biological effects they produce.

Table 17.1: Saline soil groups and how they affect the growth of most crops

Sr. No	Salinity class	Conductivity (dSm^{-1})	Effect on crop plant
1	Non saline	0-2	Negligible
2	Slightly saline	2-4	Yields of sensitive crops may be restricted

Sr. No	Salinity class	Conductivity (dSm^{-1})	Effect on crop plant
3	Moderately saline	4-8	Yields of many crops restricted
4	Strongly saline	8-16	Only tolerant crops yield satisfactorily
5	Very strongly saline	> 16	Crops that are only extremely tolerant yield satisfactory

(Singh, 2022)

A. Effects of Salinity Stresses:

Plants that are growing in saline conditions faces three types of stresses:

- Due to the presence of salts in solution, the osmoticum causes water stress.
- Salts-induced mineral toxicity stress
- Disturbances in the plants' mineral nutrition.

B. Problem of Salinity Can Be Overcome by Two Ways:

- Soil reclamation: expensive, transient and time-consuming.
- Resistant varieties: they take longer to develop, are more affordable, effective, and long-lasting.

Table 17.2: Some important vegetable crops differing in their tolerance to salinity

Sr. No.	Category	Crop
1	Sensitive	Bean (rajma), Carrot, Okra, Onion
2	Moderately Sensitive	Cabbage, Cowpea, Cucumber, Pepper, Potato, Radish, Sweet potato, Tomato
3	Moderately Tolerant	Broccoli, Sorghum
4	Tolerant	Sugar beet

(Singh, 2022)

C. Behavior / Features of Plants in Relation to Salt:

- High yielding varieties are less tolerant than land races. In regions impacted by salt, there are varieties of tolerant plants.
- The ability of different species to tolerate salt varies. Additionally, cultivars differ genetically in terms of their ability to withstand salt.
- The way that various crop plants react to salinity varies.

D. Signs of Salt Stress in Plants:

- Growth retardation or cessation
- Necrosis
- Leaf abscession
- Turgor loss
- The plant's ultimate death

E. Salinity Resistance:

Resistance to salinity can result from:

a. Osmotic effects of salinity or resistance to water stress.
b. Toxic effects of salinity or resistance to salinity-induced ion toxicity.

F. Resistance to Salinity-Induced Water Stress:

Stress due to salinity Osmoregulation is a typical reaction. By doing this, turgor can be maintained and other negative effects of turgor loss, such as leaf desiccation, can be avoided. The main method for reducing the osmotic effects of salinity is this. Osmoregulation can be attained by glycine-betaine (sugarbeet), proline (pea), myoinositol (tomato), sugars (in tomato), and K^+ ions (sorghum).

G. Resistance to Salinity-Induced Ion Toxicity:

Ion toxicity avoidance involves a mechanism, which maintains a low non-toxic level of salts in the cytoplasm. This may be achieved in one of following two ways:

a. Ion exclusion: Ion or salt exclusion occurs when a species or genotype absorbs less of the harmful ions, such as Na^+ and Cl^-, such that the concentration of these ions in their tissues is significantly lower than that of other species or genotypes. Salt exclusion at root is an effective mechanism of avoiding ion toxicity.

b. Salt tolerance: Salt tolerance may be defined as a differential effect on various life processes of the same tissue concentration of salt in different genotypes of a species. There is considerable evidence that genotypes differ in tolerance to the same amount of salt in their tissues. As per the plant age its response to salinity may change. Salt stress increases with the plant growth and transpire under saline conditions. Therefore, the desire adaptive response would be the one in which plants become more resistant with age due to plant age or a process of hardening.

H. Mechanisms of Salt Tolerance:

a. Salt Tolerance: In response to salinity stress, plants store salt in various parts of their bodies, such as their roots, glands and cells etc.

b. Salt Avoidance: The plants can prevent salt stress by either absorbing water or by keeping constant concentration of salt in their cells. E.g. Rice, chenopodiaceae family or by salt exclusion e.g. Tomato, soybean, citrus, wheat grass. Glycophytes (non-halophytes) plants owe their resistance primarily to avoidance. E.g. Barley Hallophytes (plants that grew in salty or alkaline soils) show tolerance by ion accumulation mechanism.

I. Sources of Salinity Resistance:

Salinity resistance may be available in a

a. Cultivated varieties
b. Germplasm collection
c. Related species
d. Somaclones
e. Transgenes

a. Cultivated species: A comparison of cultivated and wild accessions revealed that one of the most resistant lines was a cultivated variety. So, it is possible that cultivated varieties possess salinity resistance. One example of this would be muskmelon.

b. Germplasm collection: It is expected that materials adapted to salt-affected areas will have salinity resistance. For example, ‘Kharchia’ wheat adapted to salt affected areas of Rajasthan was found to be the most salinity resistant whaet line.

c. Related species: Many crop species have salinity resistance in their wild relatives. For instance, *Solanumpennellii*, *Lycopersiconcheesmanii*, and *Lycopersiconperuvianum* are all tomato relatives.

d. Somaclones: Salt resistant variants have been isolated through tissue culture by utilizing somaclonal variation, in many crops.

e. Transgenes: Osmoregulation-related transgenes have been identified, cloned, and some of them have been expressed in plants.

J. Breeding Approaches for Salinity Resistance:

The mission of India's CSSRI (Central Soil Salinity Research Institute), Karnal, is to breed crop plant varieties resistant to salinity. The various approaches for the development of salinity resistant cultivars are as follows:

- Use of resistant rootstocks
- Selection
- Hybridization
- Interspecific hybridization
- Cell selection
- Genetic engineering

a. **Use of resistant rootstocks:** this approach is not a breeding program but a horticultural strategy. This approach is applicable to perennials like fruit trees. In this case it allows cultivation of salt sensitive variety in a salt affected area.

Table 17.3: Some examples of rootstocks used in different fruit crops are:

Crop	Rootstock
Citrus	'Cleopatra', 'Gou Tou Cheng', 'Rangpur lime'
Guava	'Crioula'
Grape	'Dogridge', 'Salt Creek' (syn. 'Ramsey')
Mango	'Gomera-1', 'Olour', 'Nekkare'
Pear	Pyrusbetulifolia

(Sharma *et al.* 2019)

b. **Selection**: Developing salinity-resistant lines with enhanced stress performance has proven to be a successful application of this technique.
c. **Hybridization**: Salinity resistance in one parent combined with the other parent's high yielding capacity is achieved through inter-varietal hybridization. According to the pedigree method, after handling the segregating generations, one of the two methods below may be used in the selection process for yield and salinity resistance:

- Seedlings are subjected to high salinity levels for about 6 weeks, a significant percentage of the seedling population—up to 90% are rejected. After this selection, the lines remaining are evaluated for yield across a range of levels of salinity. Suitable checks are included in these evaluations to enable identification of superior yielding salinity resistant lines.
- (B) The goal of selection is to maximize productivity both in stressful and non-stressful conditions. Therefore, selection during the segregating generations is based on an index, which includes yield as an important component.

d. **Interspecific hybridization**: Inter-specific transfer of salinity resistance has been attempted in tomato. Tomato variety 'Walter' was crossed with salinity resistance species *Lycopersicon cheesmanii* ssp. *minor*. F_2 and subsequent generations were subjected to salinity stress by germinating the seeds in presence of NaCl (up to 300mM). After gradually removing NaCl from the seedlings, the remaining seedlings were matured in the field and their plant growth, fruiting, and yield were assessed.
e. **e Cell selection**: Somaclonal variation can be utilized to develop salt resistant lines of plants. Cell cultures are started from the selected variety of the concerned crop. It is needless to say that the callus should have high potential for regeneration of complete plants.
f. **Genetic engineering**: Salinity and drought resistant transgenic plants have been sought to be produced by transferring transgenes concerned mainly with osmoregulation and polyamine biosynthesis.

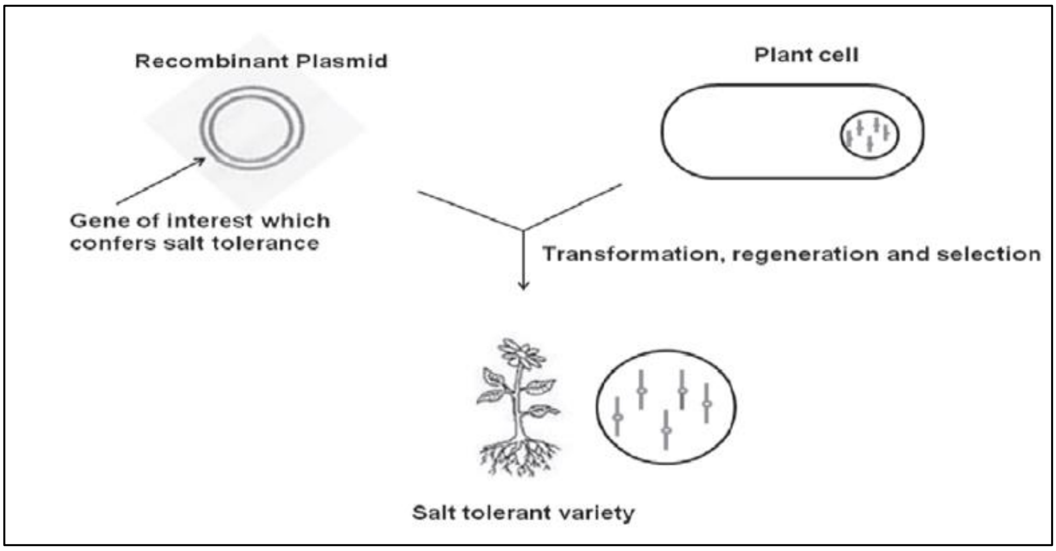

Figure 17.1: Diagrammatic representation of salt resistance through genetic engineering (Singh *et al.* 2013)

K. Problems in Breeding for Salinity Resistance:

- Creation of reliable, dependable and controlled salinity environment for selection work is laborious, costly and beyond reach of many breeders.
- For salinity resistance, there is no simple to score, trustworthy and dependable selection criterion.
- The genetic control of salinity resistance is complex and polygenic, which makes transfers from germplasm lines and especially, related species a very difficult task.
- The basis of salinity resistance is poorly understood. This makes genetic analysis and breeding efforts considerably difficult.

17.3 References:

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