# PHYSIOLOGY OF SALT STRESS IN PLANTS

## PERCEPTION, SIGNALLING, OMICS AND TOLERANCE MECHANISM

Edited By

Pratibha Singh | Madhulika Singh
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# Preface

This edited book entitled Physiology of Salt Stress in Plants: Perception, Signalling, Omics and Tolerance Mechanism is an important contribution to Plant Science containing information related to salt stress and its mitigation strategy by experimental techniques based on theoretical concepts. The salt-stress-related problems are rising in the soil and water due to natural and anthropogenic activities. Anthropogenic activities include repeated irrigation through canal system and heavy crop production practices which has led to enhanced salt level in crop/agricultural field, hence substantially declining the crop productivity. Therefore, study on salt toxicity is continued as an area of scientific interest in direction to understand their whole mechanism of its toxicity and their entry into crop plants.

In this book, the authors explain a number of approaches to ease the negative impact of salt stress in crop plants. These approaches include nutrients, antioxidants, osmolytes, phytohormones and extra cellular compounds, etc. They are endo as well as exogenous in nature. In this book, the adverse impact of salt ion toxicity on plants and implication of advance approaches in alleviating salt toxicity have briefly been reviewed. This work enables the scientific world to design strategies for reducing NaCl-mediated loss to crop by the application of different endo and exogenous substances in the farm soils. The governments and other organizations may design a holistic approach to reduce NaCl and other salt toxicity by different types of practices. Agriculturalists may be enlightened with several awareness programmers by the government and non-government actions wherein the content of this book may be used. It is widely useful for all post-graduate courses in the biological sciences. The idea of this work has a wide-ranging scientific and socio-economic utility.

All the editors thankfully acknowledge the contributions from all the scholars working across the Indian subcontinent and across the world. An authoritative book written by an individual that remains relevant over the coming years is rather cumbersome and instead requires the concerted effort of a team of expert scientists. All editors also gratefully acknowledge the team at John Wiley & Sons Limited which made possible the proposed book in its present form.

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# 1
# An Introduction to Salt Stress Perception and Toxicity Level: Worldwide Report at a Glance

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## 1.1 Soil Salinity: An Introduction

The threat of global warming is not limited only to the earthen atmosphere but slowly progressing toward the lithosphere. Attenuation of vegetative health due to the assimilation of brine substances is referred to as saline toxicity. The destruction caused solely due to the elevated level of sodium chloride (NaCl) is characterized as sodicity and is rather attainable to reclaim. Contrarily, the assorted salt stress enforces salinity, which makes land barren(Gul et al. 2015). Since the Green Revolution, the salinity footprint is engulfing the terrestrial territory quite rampantly. Presently, around one-tenth of the earth's crust accounting nearly 46 M ha has turned non-fertile (Hossain 2019). Excessive groundwater abstraction in the high zones may lead to premature desertification. The Indian Council of Agricultural Research (ICAR) predicted in a geospatial study that the coastal districts will be left with no aquifer water by 2050 without any technical interference (ICAR

2015). This further booms the inland intrusion of saline water. Figures are even more agitating, precisely in coastal regions. The rising sea levels often cause waterlogging in different parts of the world, precisely places located at lower elevations (EL-Raey et al. 1995). India, with a coastline length of approximately 7516 km, is presently under immense risk of temporary submergence. Saline water logging abnormally elevates the sodicity and thereby turns the lands nonproductive or unfertile.

The other reason that may trigger the soil sodicity is extreme groundwater abstraction. The negative aquifer pressure in the coastal regions causes brackish water intrusion and vertical rise by capillary action (Dillon et al. 2009). Whereas, the increase in soil salinity is a complex phenomenon. Studies showcased the discharge of industrial effluents into the water bodies successively raising the dissolved salt content resulting in increased salinity while utilized in irrigation. The other foremost reason for soil salinity involves drying out. Overutilization has already caused drying of a significant chunk of sweet water resources. In the absence of the desired water quality, farmers are moving toward alternate sources with high saline concentration, leading to the salinity of agricultural lands (Staniforth and Davies 2018).

The impact of salt stress is found to be most severe on agricultural crops. The primary issues involve the non-germination of seeds, reduced leaf surface area, retarded plant growth, strength, hampered yield, etc. Elevated soil salinity hampers the plants in various ways such as osmotic stress (OS), ionic toxicity, retarded cell division, reduced photosynthesis, to name a few. The inclusive impact of all the above factors boosts the mortality rate (Lauchli and Grattan 1970).

Immediate exposure to higher saline medium primarily increases the OS, causing reduced leaf surface area (i.e. due to repressed cell division and growth). Whereas, prolonged exposure imparts ionic stress leading to stomatal closure, immature senescence of mature leaves, chlorosis, necrosis, etc. The reduced biomass negatively affects photosynthesis and plant growth (Darko et al. 2019). In contrast, exposure to elevated sodicity, especially NaCl,affects the enzymatic system and augments cell swelling. The mutual impact leads to suppressed energy synthesis. Furthermore, excess exposure hinders all the growth-oriented processes like metabolism and protein synthesis (Acosta-Motos et al. 2017).

Therefore, prolonged exposure provoked the development of a defense mechanism in some species against salt stress and toxicity either by excluding through cells or by enhancing the salt tolerance. Additionally, synthetic species with transgenic properties are also synthesized by genetic engineering by altering the levels of gene expression (Carillo et al. 2011).

## 1.2 Salt Stress Perception and Current Scenario

Accumulation of excessive salt content in the soil causing direct and indirect adverse effects on flora and fauna is termed as salt stress (Shrivastava and Kumar 2015). The above situation can inhibit plant growth, and prolonged exposure may lead to a decrease. Higher saline level impacts the plants in various ways such as genotoxicity, alteration of metabolic processes, oxidative stress, water stress, ion toxicity, nutritional disorders, reduction of cell division and expansion, and membrane disorganization (Hasegawa et al. 2000; Munns 2002). The preliminary exposure to salt stress causes leaf surface area reduction.

The immediate impacts include suppressed cell expansion and cell division and closure of stomata due to osmotic influence (Munns 2002; Flowers 2004). Furthermore, prolonged exposure imparts ionic stress leading to early senescence of mature leaves and thereby reducing the leaf surface area responsible for photosynthesis and plant growth.

The severity of salt stress is most predominant in the case of agricultural crops from a food security perspective; impacts include retarded seed germination, reduced biomass, and small yield. Higher abscisic acid (ABA) concentration results in the formation of specific genes through the plant defense mechanism which leads to counteracting its generation cause (Godoy et al. 1990; Lodeyro and Carrillo 2015). Generally, the acute level of salt toxicity causes instantaneous death in various species, whereas, in selected species, limited stress influences defense mechanisms mimicking halophytes. For instance, conversion of $C_3$ to CAM**,** amendment in epidermal bladder cell to withhold excessive NaCl enabling better survivability over the saline condition. Significant parts of the coastal irrigated areas face salination issues majorly due to the seawater intrusion. More than 45 M ha of cultivable land distributed among hundreds of countries covering more than 10% of the global land surface area have already been sacrificed due to saline irrigation. Additionally, approximately 1.5 M ha of fertile land becomes nonproductive every annum due to soil salinity (Munns and Tester 2008). Presently, about 1150 M ha of productive land are under induced stress, while80 M ha are only affected due to the anthropogenic activities (Rasool et al. 2013; Hossain 2019).

## 1.3 Types of Salt Stress

Based on the origin and root cause, there are two different categories of salinity, namely, primary and secondary. Primary salinity is a natural phenomenon and mostly occurs due to the former presence of salt lakes, slat clads, tidal swamp, etc., at a particular location. It is majorly a kind of sodicity. At the same time, secondary salinity is imposed due to man-made activities such as urbanization, saline irrigation, etc. (Shahid and Rahman 2011). Detailed reasons are delineated below.

Primary salinity:

i. Spreading from the saline artesian well.
ii. Capillary rise from saline groundwater.
iii. Seawater intrusion.
iv. Canopy formation due to the movement of fine sea sand by the sea breeze.
v. Waterlogging.

Secondary salinity:

i. Irrigation with impeded drainage
ii. Effluent discharge
iii. Excess fertilizer dosing
iv. Deforestation
v. Saline irrigation

Furthermore, based on the predominance of the type of anions present and the pH value, salt-affected soils are categorized as saline soil and sodic soil. Sodic soil typically comprises sodium carbonate and or bicarbonate ions with a pH value beyond 8.5, but contrarily, saline soil majorly incorporates chloride and sulphate ions with pH value