Plant Response and Adaptation to Salinity

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Concept

Among the abiotic stresses, salinity is the most destructive factor, which limits crop productivity considerably. A large area of land in the world is affected by salinity which is increasing daily. Salinity is a more prominent problem in irrigated croplands. Worldwide, around 17% of the cultivated land is under irrigation, and irrigated agriculture contributes more than 30% of the total agricultural production. It is estimated that at least 20% of total irrigated lands worldwide are salt-affected. However, the statistics vary depending on the sources. According to the FAO Land and Nutrition Management Service (2021), 8.7% of the total land in the world is affected by salt (either salinity or sodicity), which accounts for 833 M ha of land (Table 1).

Table 1: Variation in salt-affected areas in the world, in million hectares (M ha)

Region	Total area (M ha)	Saline soils		Sodic soils	
		M ha	%	M ha	%
Africa	1899	39	2.0	34	1.8
Asia, the Pacific, and Australia	3107	195	6.3	249	8.0
Europe	2011	7	0.3	73	3.6
Latin America	2039	61	3.0	51	2.5
Near East	1802	92	5.1	14	0.8
North America	1924	5	0.2	15	0.8
Total	12781	397	3.1	434	3.4

Source: FAO Land and Plant Nutrition Service (2008)

Causes and types of salinity

There are different causes of the development of soil salinity. The major forms are (i) natural or primary salinity and (ii) secondary or human-induced salinity.

Primary salinity is occurred due to the long-term natural accumulation of salts in the soil or surface water. This is a natural process caused mainly by weathering parent materials containing soluble salts through the breakdown of rocks containing Cl^- of Na^+, Ca^{2+}, and Mg^{2+} and sometimes SO_4^{2-} and CO_3^{2-}. In addition, the deposition of sea salt carried in wind and rain also varies with the soil types.

Secondary salinity occurs due to anthropogenic activities that disrupt the hydrologic balance of the soil between water applied (irrigation or rainfall) and water used by crops (transpiration). The water table has risen in many irrigated areas due to excessive amounts of applied water and insufficient drainage. Most of the irrigation systems of the world have caused secondary salinity, sodicity, or waterlogging. In irrigated lands, after irrigation, the water applied to the soil is consumed by the crop or evaporates directly from the moist soil. The excess salt is accumulated in the soil, called salinization (Fig. 1). It is sometimes recognizable by a whitish layer of dry salt on the soil surface. In addition, saline groundwater may also contribute to salinization. The water table rises with excessive irrigation and improper drainage, allowing the salty groundwater to reach the upper soil layers and rhizosphere (Fig. 1).

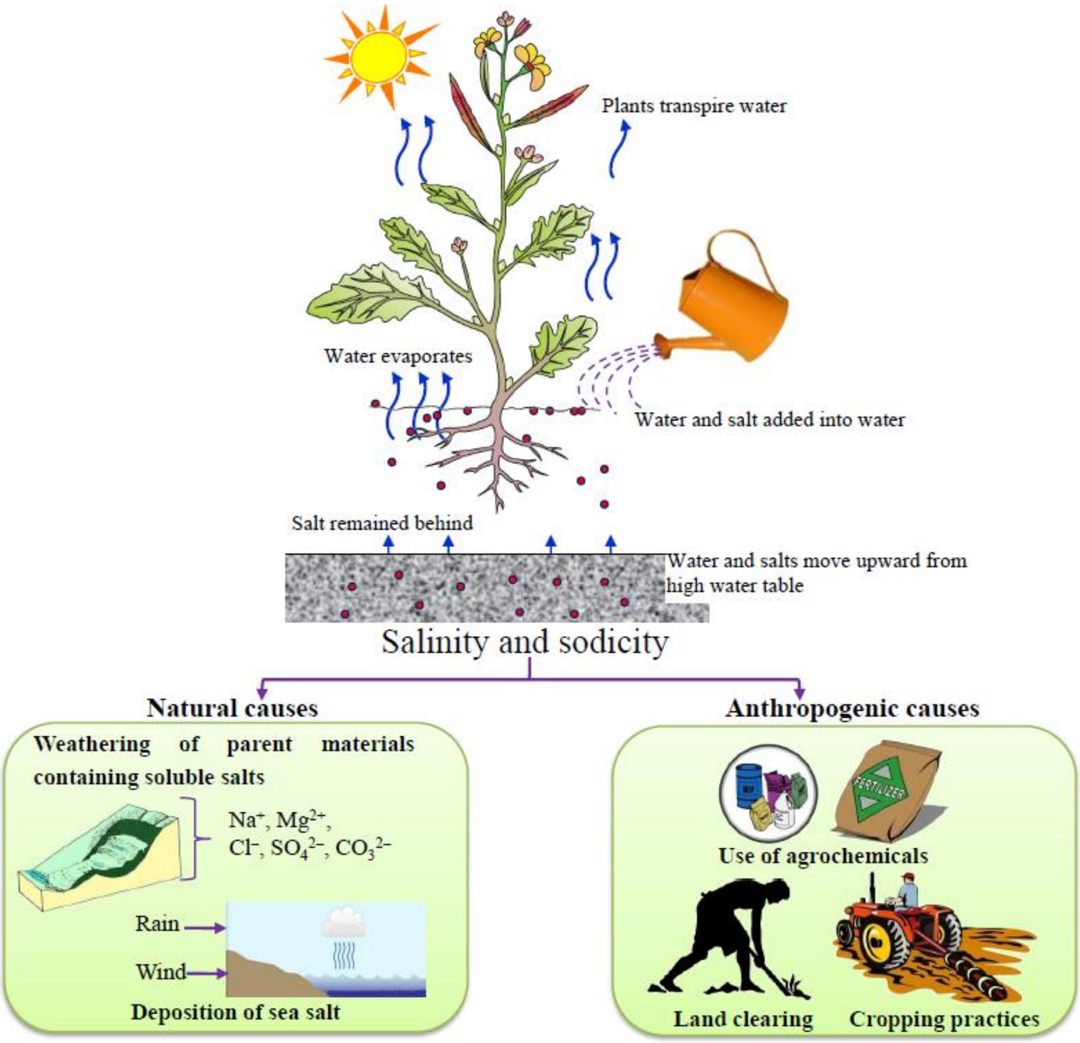


Fig. 2 Causes of salinity and sodicity in soil and water

Based on the nature, characteristics, and plant growth relationships in salt-affected soils, two main types of soils have been coined by Szabolcs (1974). These are:

a. Saline soils - The soluble salts are chiefly NaCl and Na_2SO_4 and sometimes also contain appreciable quantities of Cl^- and SO_4^- of Ca^{2+} and Mg^{2+}. These soils contain sufficient neutral soluble salts to negatively affect most crop plants' growth.

b. Sodic soils – These soils contain Na^+ salts capable of alkaline hydrolysis, mainly Na_2CO_3. Previously these soils have also been termed 'Alkali'.

The saline water is classified as different types based on the salt concentration in Table 2.

Table 2: Classification of water quality based on total salt concentration

Water designation	Total dissolved salts, mg L^{-1}	EC (dS m^{-1})
Fresh water	<500	<0.6
Slightly brackish	500-1000	0.6-1.5
Brackish	1000-2000	1.5-3.0
Moderately saline	2000-5000	3.0-8.0
Saline	5000-10000	8.0-15.0
Highly saline	10000-35000	15.0-45.0

Soil salinity is measured by electrical conductivity (EC). The international system (SI) unit of EC is dS m^{-1}. Salinity is also measured as mM, which is vastly used in a laboratory experiment. In the field, the salinity of soil water or irrigation water is measured in terms of its electrical conductivity or in terms of osmotic potential. Pure water is a very poor conductor of electric current; the conductivity of a water sample is due to the ions dissolved in it. Generally, the higher the salt concentration in water, the greater it's electrical conductivity and the lower its osmotic potential/pressure.

Types of soil salinity and sodicity (FAO 2021)

ECe, DS/M	SALINITY INTENSITY[4]	EFFECT ON CROP GROWTH[5]	ESP, %	SODICITY HAZARD
<0.75	None	None	<15	None
0.75-2	Slight	None	15-30	Slight
2-4	Moderate	Yields of sensitive crops may be restricted	30-50	Moderate
4-8	Strong	Yields of many crops are limited	50-70	High
8-15	Very strong	Only tolerant crops yield satisfactorily	>70	Extreme
>15	Extreme	Only a few very tolerant crops yield satisfactorily		

Nature and mechanisms of salt stress

There are some points at which salt transport is regulated. These are (i) selectivity of uptake from the soil solution, (ii) loading of the xylem, (iii) removal of salt from the xylem in the upper part of the plant, (iv) loading of the phloem and (v) excretion through salt glands or bladders. The toxic ions move into the plant with the water flow. The ions move from the soil to the vascular system of the root by *symplastic* and *apoplastic* pathways. In the symplastic pathway, water enters the roots through plasma membranes of the epidermis, and further cell-to-cell movement occurs through plasmodesmata until the xylem becomes saturated. In the apoplastic pathway, water enters through intracellular spaces to unload the salt in the xylem (Fig. 2). Differential osmotic potential is the dynamic force of energy-driven pathways i.e., symplastic. In contrast, apoplastic is a non-energy-driven pathway. Hence, based on osmotic potential, the plant can control the toxic ions like Na^+ to enter the cell through an energy-driven path.

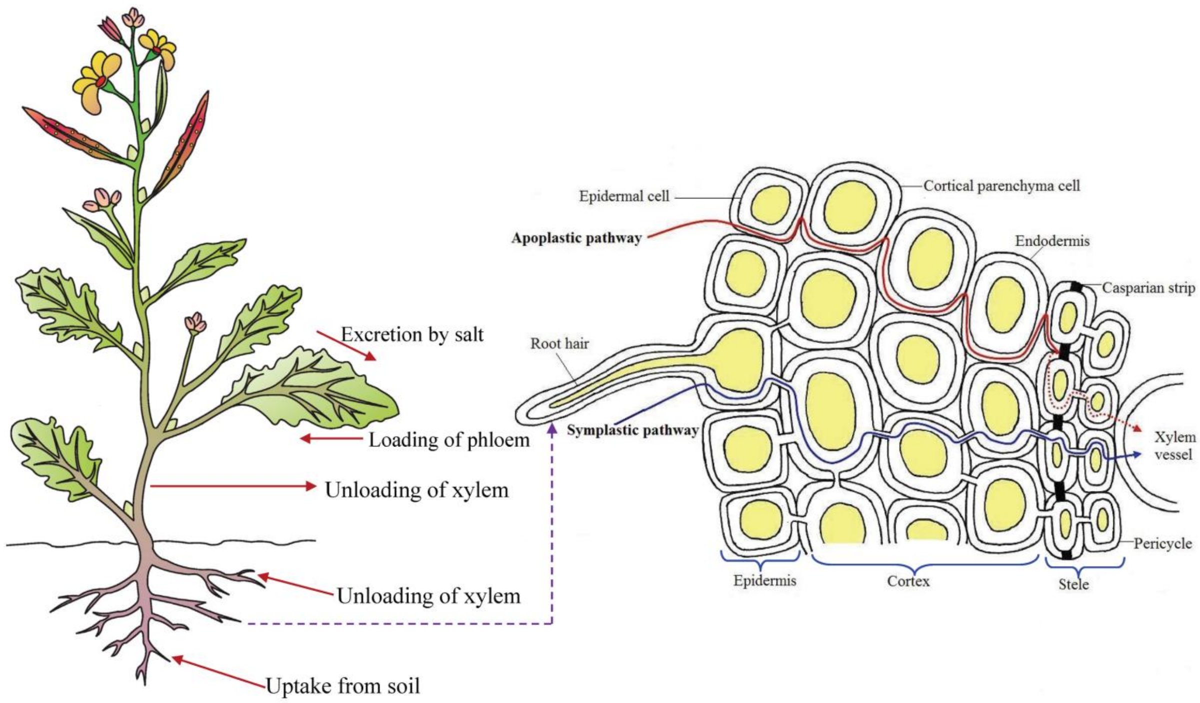


Fig. 2 Transport and regulation of salt in soil-plant system

Plant responses to salt stress

High salinity causes both hyperionic and hyperosmotic stresses and can lead to plant death (Fig. 3). It is reported that plants growing under saline conditions are affected in three ways: reduced water potential in the root zone causing water deficit, phytotoxicity of ions such as Na^+ and Cl^- and nutrient imbalance depressing uptake and transport of nutrients. Na^+ competes with K^+ for binding sites essential for cellular functions. Excess salt concentration also enhances the soil matrix's osmotic potential, which restricts plants' water uptake. Sodium is the primary toxic ion because it interferes with K^+ uptake and disturbs stomatal regulation, which ultimately causes water loss and necrosis. On the other hand, Cl^--induces chlorotic toxicity symptoms due to impaired production of chlorophyll (Chl). Although Na+ and Cl– are the major ions producing many physiological disorders in plants, Cl^- is the most dangerous.

Fig. 3. Various effects of salt stress in plants

Germination

A higher level of salt stress inhibits the germination of seeds, while the lower level of salinity induces a state of dormancy. Salinity has many-fold effects on the germination process: it alters the imbibition of water by seeds due to lowered osmotic potential of germination media, causes toxicity which changes the activity of enzymes of nucleic acids metabolism, alters protein metabolism, disturbs the hormonal balance, and reduces the utilization of seed reserves. However, various internal (plant) and external (environmental) factors affect seed germinability under saline conditions, including the nature of seed coat, seed dormancy, seed age, seed polymorphism, seedling vigor, temperature, light, water, and gasses.

Growth

One of the initial effects of salt stress on plants is the reduction of growth rate. Salinity can affect the growth of the plant in various ways. First, the presence of salt in the soil reduces the plant's water uptaking capacity, which quickly causes a reduction in the growth rate. Munns (2002) summarized the sequential events in a plant when grown in a saline environment (Table 3). She stated, "In the first few seconds or minutes, water is lost from cells and shrinked. Over hours, cells recover their original volume, but the elongation rates are still reduced, leading to lower leaf and root growth rates. Over days, cell division rates are also affected, contributing to lower leaf and root growth rates. Over weeks, changes in vegetative development can be seen, and over months changes in reproductive development".

Table 3: Time-dependent effect of salinity on plant growth

Time scale	Causes	Effects
Second to minutes	Water stress	*Morphological*: Immediate reduction in root and leaf elongation rate, which is sometimes partially recoverable. *Cellular*: Shrinkage of cell volume followed by restoration due to regaining turgor

Hours	Water stress, Ca^{2+} deficiency	*Morphological*: Permanent reduction in root and leaf elongation Cellular: Changes in rheological behavior of cell wall
Days	Water stress, Ca^{2+} deficiency	*Morphological*: Reduction in leaf emergence, increase in root: shoot ratio *Cellular:* Inhibition of cell development
Weeks	Water stress, ion toxicity	*Morphological*: Reduced branches/tiller formation, death of older leaves *Cellular*: Alteration of apical development, Excessive accumulation of Na^+ and Cl^-
Months	Water stress, ion toxicity	*Morphological*: Alteration in flowering time and reduced seed production. Immature death of plants *Cellular*: Alteration in the development of reproductive organs, Reduction of assimilate production

Photosynthesis

The reduction in photosynthetic rates in plants under salt stress is mainly due to decreased water potential. Photosynthesis is also inhibited when high concentrations of Na^+ and/or Cl^- accumulated in chloroplasts. Other factors that reduce photosynthetic rates under salt stress are enhanced senescence, changes in enzyme activity induced by alterations in the cytoplasmic structure, and negative feedback by reduced sink activity. The reduction in stomatal conductance, which results in restricting the availability of CO_2 for carboxylation reactions, is also a factor that reduces photosynthesis under stress. It was reported that stomatal closure minimizes water loss through transpiration, affecting light-harvesting and energy-conversion systems, thus leading to alteration in chloroplast activity. One of the most notable effects of salt stress is the alteration of photosynthetic pigment biosynthesis.

Water relation

Increased salt in the root medium can decrease leaf water potential and, hence, may affect many plant processes. Osmotic effects of salt on plants are the result of lowering the soil water potential due to an increase in solute concentration in the root zone. This condition interferes with plants' ability to extract water from the soil and maintain turgor at very low soil water potentials. Salt treatment caused a significant decrease in relative water content (RWC) in many crops.

Nutrient imbalance

It is well-established that crop performance may adversely affect salinity-induced nutritional disorders. However, the relations between salinity and mineral nutrition of crops are very complex. The nutritional disorders may result from the effect of salinity on nutrient availability, competitive uptake, transport, or distribution within the plant.

Yield

Except for some halophytes yield of most of the crops was significantly reduced due to salt stress. Tolerance and yield stability are multigenic traits complicated to establish in crops since salt stress may be imposed continuously or intermittently, or become gradually more severe at any stage during development. Crop species have exhibited substantial differences in salt tolerance, defined based on their relative yields. Relative yield often exhibits a linear decrease after a threshold salinity has been reached (Fig. 4), and salt tolerance has been defined in terms of two parameters: the threshold electrical conductivity and the percent decrease in relative yield per unit of electrical conductivity in dS m^{-1} above the threshold.

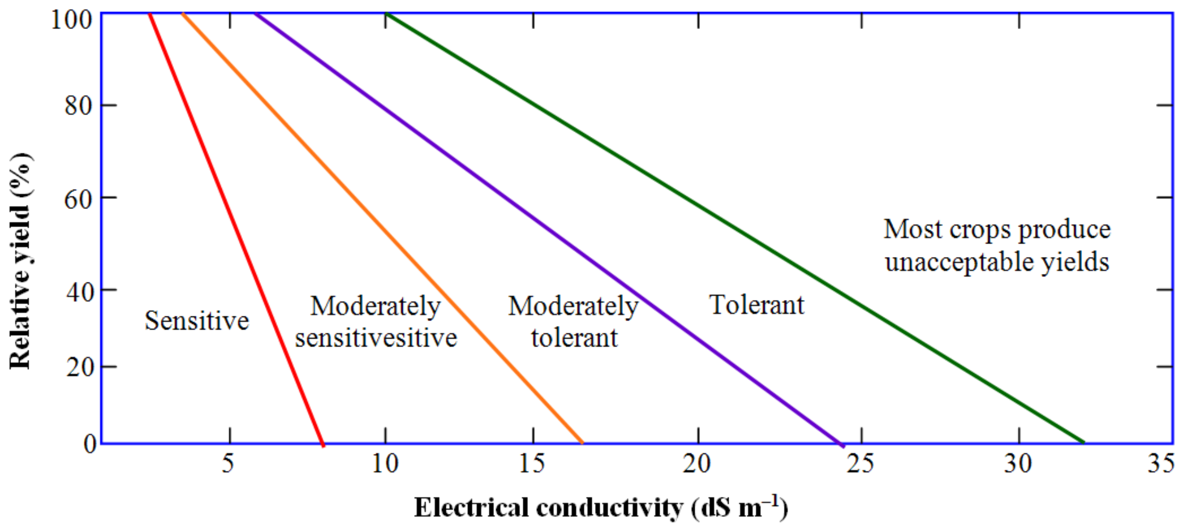


Fig. 4: Relative yield in response to different salinity levels and varying degrees of salt tolerance (Mass 1986)

Salinity induced oxidative stress

Salt stress can lead to stomatal closure, which reduces CO_2 availability in the leaves and inhibits carbon fixation, exposing chloroplasts to excessive excitation energy, which in turn increases the generation of ROS such as superoxide ($O_2^{\bullet-}$), hydrogen peroxide (H_2O_2), hydroxyl radical (OH•) and singlet oxygen ($^1O_2$). On the other hand, salt stress is complex and imposes a water deficit because of osmotic effects on various metabolic activities. This water deficit leads to the formation of. ROS are highly reactive and may cause cellular damage through the oxidation of lipids, proteins, and nucleic acids.

Plants' tolerance to salinity

Excess salt concentration in soil or water adversely affects plant growth and yield. However, there will be some variation in how salinity affects the plant, depending on several factors such as plant genotypes, growth stage, and environmental factors. Some of the major crops showing different tolerance to salt are also presented in Table 4. A plant species may make little or no growth at higher salinity levels but does survive.

Some scientists defined salt tolerance as ''the degree to which osmotic adjustment can be made without sacrifice in growth'' (Bernstein 1961) or ''the absence of negative effects on growth in plants that accumulate salts in their tissues'' (Greenway and Munns 1980).

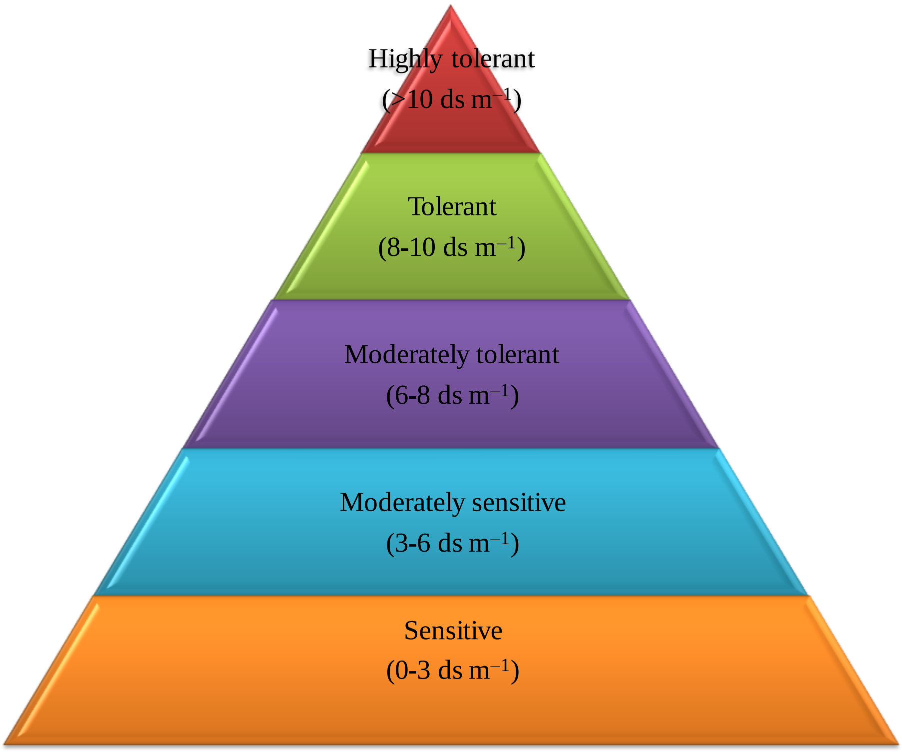
In regards to growth and yield, salt tolerance is defined as "the sustained growth of plants in an environment of excess salts in the growth medium'' (Shannon 1984) or "yield decrease expected for a given level of soluble salts in the root medium as compared with yield under non-saline conditions'' (Maas and Hoffman 1977).

Salt tolerance rating is based on the plants' ability to sustain against the EC value of a soil extract. US Salinity Laboratory classified the plants based on the capacity of tolerance to salt (Fig. 5). Most major cereal crops exhibit high tolerance to soil salinity. In this group are sorghum, wheat, triticale, rye, oats, and barley, where the only exceptions are corn and rice.

Table 4: Major crops showing different salt-tolerance levels (Tanji and Kielen 2003)

Sensitive	*Oryza sativa* L., *Sesamum indicum* L., *Phaseolus vulgaris* L., *Vigna radiata* (L.) R. Wilcz., *Daucus carota* L., *Vigna mungo* (L.) Hepper, *Allium cepa* L., *Fragaria* x *Ananassa* Duch., *Malus sylvestris* Mill., *Prunus armeniaca* L., *Musa acuminata* Colla, *Prunus avium* L., *Mangifera indica* L.
Moderately sensitive	*Cicer arietinum* L., *Zea mays* L., *Linum usitatissimum* L., *Arachis*

	hypogaea L., *Saccharum officinarum* L., *Medicago sativa* L., *Vicia faba* L., *Brassica oleracea* L. Botrytis, *Cucumis sativus* L., *Solanum melongena* L. varesculentum Nees., *Allium sativum* L., *Lactuca sativa* L., *Cucumis melo* L., *Abelmoschus esculentus*(L.) Moench, *Pisum sativum* L., *Capsicum annuum* L., *Solanum tuberosum* L., *Cucurbita pepo* L. var *Pepo, Spinacia oleracea* L., *Lycopersicon lycopersicum*(L.) Karst., *Vitis vinifera* L., *Carica papaya* L.
Moderatelt tolerant	*Hibiscus sabdariffa* L., *Carthamus tinctorius* L., *Sorghum bicolor* (L.) Moench, *Glycine max* (L.) Merrrill, *Helianthus annuus* L., *Triticum aestivum* L., *Vigna unguiculata* (L.) Walp., *Cocos nucifera* L., *Ziziphus mauritiana* Lam.
Tolerant	*Hordeum vulgare* L., *Brassica campestris* L., *B. napus*, *Gossypium hirsutum* L., *Hibiscus cannabinus* L., *Avena sativa* L., *Secale cereale* L., *Beta vulgaris* L., *Asparagus officinalis* L.
Highly tolerant	*Phoenix dactylifera, Allenrolfea occidentals, Pinus pinea, Distichlis spicata*



Different categories of salt tolerance in plants.

Salt tolerance strategies

To achieve salt tolerance, three interconnected aspects of plant activities need to be investigated, these are: (i) damage must be prevented or alleviated, (ii) homeostatic conditions must be re-established in the new, stressful environment, and (iii) conducive conditions must be established for optimum growth or crop yield. Plants growing naturally on saline stands have evolved various mechanisms to cope with salinity. Fig. 5 gives examples of control mechanisms in plants for maintaining a rather constant level of salt concentration in the living plant tissues.

Fig. 5 Different salt tolerance strategies in plants

Salt exclusion

One of the mechanisms of salt tolerance involves the ability to reduce the ionic stress on the plant by minimizing the amount of Na^+ that accumulates in the cytosol of cells, particularly those in the transpiring leaves. Salt exclusion is a very efficient but complex way of preventing ion uptake in the root zone, enabling a lower uptake and accumulation of salts in the upper parts of the plant, especially in the transpiring organs, especially leaves.

Accumulation

Although all of the halophytes exhibit better salt accumulation, the level of total salt accumulation in the shoot is mostly species-specific, depending on different adaptive strategies.

Vacuolar compartmentation

One of the common features of salt stress is the accumulation of toxic ions (Na^+ and Cl^-) in plant parts. However, in salt tolerant plants, one of the tolerance mechanisms is associated with the efficiency of such plants in delivering these toxic ions into the vacuoles. For example, *Suaeda maritime*, a potential halophyte, occupies 77% of the mesophyll cells for vacuoles and can accumulate salts to concentrations higher than 500-800 mM.

Synthesis of metabolites and alteration of metabolic activities

Most plant species accumulate certain organic solutes such as sugar, alcohol, proline, glycinebetaine, trehalose, etc., in response to osmotic stress termed as compatible solutes or osmoprotectants because even in high concentrations, they do not interfere with enzymatic activities. These are localized in the cytoplasm. The inorganic ions such as Na^+ and Cl^- are preferentially sequestered into the vacuole, thus leading to the turgor maintenance for the cell under osmotic stress.

Change in photosynthetic pathway

It is noteworthy that some halophytes (especially facultative halophytes), such as *M. crystallinum* shift their C_3 mode of photosynthesis to CAM. This change helps the plant open the stomata at night, reducing water loss and thus decreasing transpiration loss under saline conditions. In *Atriplex lentiformis* a shift from the C_3 to the C_4 pathway in response to salinity is noticed.

Salt Excretion

Salt excretion is also a very efficient way of preventing excessive concentrations of salts building up in photosynthetic tissues. Some halophytes possess multicellular salt glands and salt hairs (bladders). These structures are common for many halophytic genera. Salt glands are composed of a set of epidermal cell complexes that remove salt from the mesophyll cells beneath them, to which numerous plasmadesmata connects them. They secrete it at the leaf surface, where a layer of salt crystals is formed (Fig. 6). This energy-dependent process and the energy (ATP) required for the ion pump is provided by the active respiration of the glandular cells.

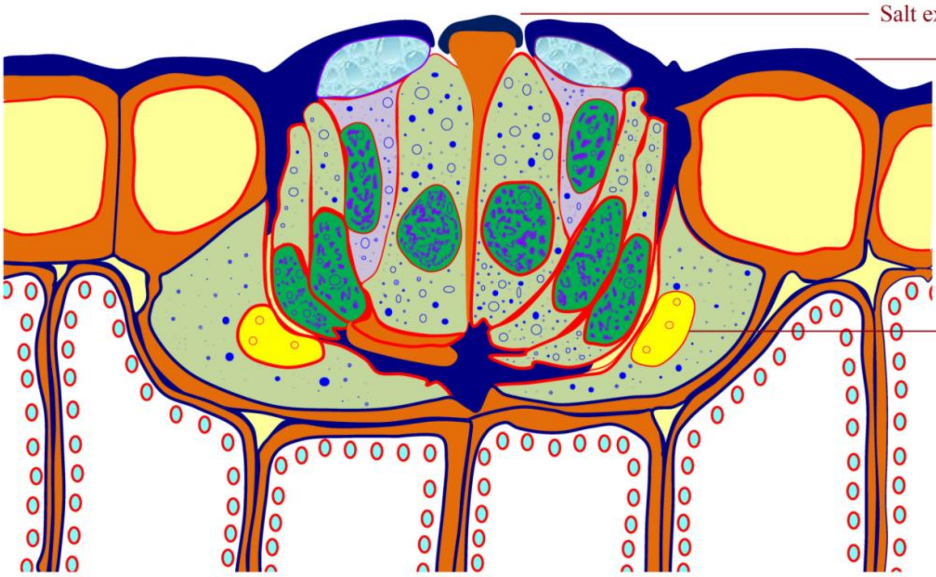


Fig. 8 Cross section of a salt gland

Agronomic management for biosaline agriculture

1. Use of salt tolerant varieties

To overcome this adverse situation, the Bangladesh Rice Research Institute (BRRI) and the Bangladesh Institute of Nuclear Agriculture (BINA), under a joint collaboration with International Rice Research Institute (IRRI), have developed four salt-tolerant rice varieties. BINA developed Binadhan-8 and Binadhan-10 while BRRI developed BRRI dhan47 and BRRI dhan55. All these four varieties have the capacity to fight salinity condition up to 10-12 dS m^{-1}. These varieties have yield potential of five to seven t ha^{-1} under normal conditions in non-saline areas while the yield will be around 3 to 5 t ha^{-1} in saline-prone areas, depending on the degree of salinity

2. Reclamation of salt-affected soil

Soils with enough salt levels to significantly damage plants and reduce growth; thus, the reclamation of saline or sodic soils is necessary. Reclamation should be done in the fall or spring prior to planting. Several reclamation methods may be applied considering the soil, crop types, and climatic conditions.

Irrigation water management

One of the major causes of salinity in the soil is irrigation water. Therefore, ensuring good quality water is recommended as the first step of saline soil reclamation. Thus, before using water for irrigation, quality should be ensured.

Drainage

Proper drainage is one of the efficient ways to minimize the sodicity problem. Good drainage facilitates facilitate Na^+ removal from the rhizosphere. Drainage can also be improved by altering the topography or installing tile drains. From a salinity perspective, the leaching of accumulated salts from the crop root zone and associated deep drainage is a cause for concern.

Tillage

Tillage is the agricultural preparation of the soil by mechanical agitation of various types, such as digging, stirring, and overturning. Tillage often is necessary to physically break up sodium-rich layers and mix amendments into the soil. Tillage is especially useful for reclamation of sodic soil where the soil structure is greatly hampered.

Mulching

As saline water evaporates from the soil, it leaves behind salts. Good mulch under the crop helps reduce surface evaporation, maintains moisture near the soil surface, and lessens the build-up of soil salinity. In some instances, salt crusts formed at the surface can be removed by mechanical means. Salt scraping is the simplest and most economical way of reclaiming saline soils in small agricultural farms. Scraping can minimize the salts temporarily; however, they can reappear with a continuous feed of groundwater to the surface.

Leaching

Leaching is the removal of excess salt from the soil. This is the most effective procedure for removing salts from the root zone of soils. Leaching is most often accomplished by ponding fresh water on the soil surface and allowing it to infiltrate.

Using proper fertilizer

Table 5: salt index of some fertilizers

Material	Analysis	Salt Index	Partial Salt Index*
Nitrogen/Sulfur			
Ammonia	82% N	47.1	0.6
Ammonium nitrate	34% N	104.0	3.1
Urea	46% N	74.4	1.6
UAN	39% (ammonium nitrate, 31% urea)	63.0	2.3
	32% N (44% ammonium nitrate, 35% urea)	71.1	2.2
Ammonium sulfate	21% N, 24% S	88.3	3.3
Ammonium thiosulfate	12% N, 26% S	90.4	7.5
Gypsum	23% Ca, 17% S	8.1	0.2
Magnesium Oxide	60% Mg	1.7	0.0
Phosphorus			
APP	10% N, 34% P_2O_5	20%	0.5
DAP	10% N, 46% P_2O_5	29.2	0.5
MAP	11% N, 52% P_2O_5	26.7	0.4
Phosporic Acid	54% P_2O_5		1.613**
	72% P_2O_5		1.754**
Potassium			
Monopotassium phosphate	52% P205, 35% K_2O	8.4	0.1
Potassium chloride	62% K_2O	120.1	1.9
Potassium sulfate	50% K20, 18% S	42.6	0.9
Potassium thiosulfate	25% K20, 17% S	68.0	2.7
Miscellaneous			
Calcium carbonate, lime	35% Ca	4.7	0.1
Dolomite	21.5% Ca, 11.5% Mg	0.8	0.0
Manure salts, 20%		112.7	4.6
Manure salts, 30%		91.9	3.1
SUL4R-PLUS™	**21% Ca, 17% S**	**8.1**	**0.2**

* The salt index of a mixed fertilizer containing N, P and K is the sum of the partial salt index per unit (20 lbs) of plant nutrient times the number of units due to each component in the formulation.

** Per 100 lbs of H3PO4

Different chemical fertilizer has various chemical constituents and different types of reactivity with soil. More importantly, all fertilizers have a salt index which indicates what the fertilizer contributes to soil salinity. When irrigation water or soils are saline, changing to fertilizers with similar nutrients but a lower salt index may help. For example, (muriate of potash) KCl has a salt index of 120.1 but K_2SO_4 has a lower salt index of 42.6 (Table 5). However, Information on the salt index of each fertilizer should be available from the fertilizer manufacturer, which is still unavailable in developing countries.

Soil amendment

Soil amendments are materials, such as gypsum or calcium chloride, that directly supply soluble calcium for the replacement of exchangeable Na^+, or other substances, such as H_2SO_4 and elemental sulfur (S), that indirectly, through chemical or biological action, make the relatively insoluble $CaCO_3$ commonly found in sodic soils, available for replacement of Na^+. Organic matter (i.e., straw, farm, and green manures), decomposition, and plant root action also help dissolve the calcium compounds found in most soils, thus promoting reclamation, but this is a relatively slow process.

Reclamations of salt-affected (saline-sodic and sodic) soils by chemical amendments have become cost-intensive, require high capital investment, and are not always a practical solution to the problem of soil salinity and sodicity.

Therefore, biotic approaches such as the cultivation of salinity- and sodicity-tolerant plants and crops on salt-affected soils, i.e., ‘biosaline agriculture’, maybe another alternative (Pessarakli and Szabolcs 2010).

Potential use of halophytes in saline environments

Halophytes are plants capable of completing their life cycle under highly saline conditions. Many scientists defined halophytes based on different criteria. Schimper (1903) described halophytes as plants capable of normal growth in saline habitats and also able to thrive on 'ordinary' soil. Walter (1961) has classified the halophytes into 3 types; (i) salt excluding, (ii) salt excreting, and (iii) salt accumulating (Table 6).

Table 6: Walter's Classification of halophytes

Types of halophytes	Characteristics and examples
Salt excluding	In these plants, the root system possesses an ultrafiltration mechanism, which leads to establishing such species as the dominant component of the mangrove vegetation.
Salt excreting	These plants regulate internal salt levels through foliar glands.
Salt accumulating	They accumulate high salt concentrations in their cells and tissues and overcome salt toxicity by developing succulence.

Based on ecological aspect, halophytes can be classified as (i) obligate, (ii) facultative, and (iii) habitat-indifferent halophytes.

- Obligate halophytes grow only in salty habitats. They show sufficient growth and development through an increased salt supply. Many Chenopodiaceae belong to this category.
- Facultative halophytes can establish themselves on salty soils, but their optimum lies in a salt-free or at least low-salt condition. However, they can tolerate salt. Most Poaceae, Cyperaceae, Brassicaceae, and many dicotyledons like *Aster tripodium*, *Glaux maritima, Plantago maritima* etc., belong to this group.

Potential use of halophytes under saline condition

The study of halophytes can be useful from three perspectives.

- First, the mechanisms by which halophytes survive and maintain productivity in saline water can be useful for developing tolerant varieties in conventional crops.
- Second, halophytes grown in an agronomic setting can be used to evaluate the feasibility of high-salinity agriculture.
- Third, halophytes may become a direct source of new crops.

Recently, a new environmentally safe and clean technique known as ***phytoremediation*** has been introduced to address the salinity problem. This includes the introduction of salt (ion) removing species to control salinity and to maintain the sustainability of agricultural fields. Several halophytic plant species have been tried in the past for their possible use in the reclamation of salt-affected soils.

Phytoremediation has shown to be advantageous in several aspects:

- No financial involvement in purchasing chemical amendments,
- Accrued financial or other benefits from crops grown during amelioration,
- Promotion of soil structure and other qualities,
- Greater plant-nutrient availability in the soil after phytoremediation,
- Environmental considerations in terms of carbon sequestration in the post-amelioration soil.

