

**PHYSIOLOGICAL AND MOLECULAR  
CHARACTERIZATION OF SOME SALINITY  
PHYTOREMEDIATING PLANTS**

**By**

**SUSHMA RANI**

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## **CERTIFICATE - I**

This is to certify that this thesis entitled, “**Physiological and molecular Characterization of some salinity phytoremediating plants**” submitted for the degree of **Doctor of Philosophy**, in the subject of **Botany** of the **Chaudhary Charan Singh Haryana Agricultural University, Hisar**, is a bonafide research work carried out by **Sushma Rani** under my supervision and that no part of this thesis has been submitted for any other degree.

The assistance and help received during the course of investigation have been fully acknowledged.

**(S.C. GOYAL)**

Major Advisor

Associate Professor

Department of Botany and Plant Physiology

College of Basic Sciences and Humanities

CCS Haryana Agricultural University

Hisar-125004, India

## **CERTIFICATE - II**

This is to certify that this thesis entitled, “**Physiological and molecular Characterization of some salinity phytoremediating plants**”, submitted by **Sushma Rani** to the **Chaudhary Charan Singh Haryana Agricultural University, Hisar**, in the partial fulfilment of the requirements for the degree of **Doctor of Philosophy**, in the subject of **Botany**, has been approved by the Student’s Advisory Committee after an oral examination on the same, in collaboration with an External Examiner.

**MAJOR ADVISOR**

**EXTERNAL EXAMINER**

**HEAD OF THE DEPARTMENT**

**DEAN, POST GRADUATE STUDIES**

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## CHAPTER – I

# Introduction

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Sparks (1995) observed that soil, surface water and ground water may become contaminated with hazardous compounds as a consequence of natural activities (e.g. geologic erosion and saline seeps) and human activities (e.g. industry, agriculture, wastewater treatment, construction and mining). Soil is one of the invaluable natural resource. Today, 20% of the world cultivated areas and nearly half of all irrigated lands are affected by salinity (Zhu, 2001). In India nearly 50% of the land area suffers from varying types and degrees of soil degradation. The most important causes of land degradation are soil erosion, water logging, salinity, alkalinity and over exploitation of land by the growing population (Sehgal *et al.*, 1990).

In arid and semi arid regions of the world the increased soil salinity is one of the world's oldest and most serious agricultural problem (Tanji, 1990). Out of the 7.0 million hectares of the salt affected soils in India, about 0.5 million hectares exist in Haryana. About one third area of

these problem soils in Haryana is saline and the chlorides and sulphates of sodium, calcium and magnesium are the dominating soluble salts in them (Dahiya and Laura, 1988). Consequently there is an utmost need to develop effective technology for reclamation and rehabilitation of salinity degraded lands.

Various workers have advocated the use of native flora of saline wastelands for reclamation of soil salinity. In this direction, the first and foremost priority is to collect, identify, inventories and characterize native flora of saline wastelands for recognizing potential hyperaccumulator plants. In this context effects have been made by various workers (Sen and Rajpurohit, 1982, a,b; Mohammed and Sen, 1990; Rajput and Sen, 1991; Gehlot and Sen, 1996; Mahala *et al.*, 2001) regarding ecophysiological studies, salt harvesting mechanisms and phytoremediation potentialities of different native flora of saline soils in arid zones of Rajasthan and adjoining areas.

On the basis of adaptability to saline soil Sen and Rajpurohit (1978) have classified the vegetation as follows

- a) **True halophytes** Plants growing in saline soil-  
*Suaeda fruticosa*, *Cressa cretica*, *Aleurops lagopoides*,  
*Salsola baryosma*, *Haloxylon recurvum* and  
*Zygophyllum simplex*.

- b) **Facultative halophytes** Plants which can grow in saline as well as in non-saline soils. (i) Mainly saline but can grow in non-saline areas- *Trianthema triquetra*, *Launaea nudicaulis*, *Tamarix dioica*, *Eragrostis ciliaris*, *E. trilosa*, *Salvadora persica* and *Cleome brachycaspa* (ii) Mainly non saline but can grow in saline areas- *Pulicaria wightiana*, *Euphorbia gsamilata* and *Indigofera cordifolia*.
- c) **Transitional halophytes** Plants growing only at the transition of saline and non-saline areas-*Haloxylon salicornicum*, *Sporobolus helvolus* and *S. marginatus*.
- d) **Marshy halophytes** Plants growing in waterlogged areas of salt basins- *Scirpus roylei*, *S. tuberosus*, *Mariscus squarrosus* and *Tamarix troupii*
- e) **True glycophytes** Plants growing in non-saline soil- *Dactyloctenium indicum*, *D. aegyptium*, *Cenchrus setigerus*, *C. biflorus*, *Citrullus colocynthis*, *Cucumis callosus*, *Solanum surattense*.

Phytoremediation is visualized as a benign and cost effective plant based technology that depends upon the remarkable ability of some plants to remove or neutralize various chemicals (organics and metal ions) from the soil, water and air (Chaney *et al.*, 1997).

The remediation technologies may be grouped into two categories (Sparks, 1995).

- (I) *Ex-situ* technique It includes excavation followed by thermal treatment, chemical extraction and solidification prior to disposal. It is very costly as it also entails the treated soil to the restored site.
- (II) *In-situ* technique It includes volatilization via air venting, leaching with a surfactant, vitrification, isolation and containment with physical barriers. Remediation without excavation of contaminated soil.

*In situ*-techniques are favoured due to their low cost and reduced impact on the ecosystem (Burns *et al.*, 1996). In a recent review on phytoremediation Salt *et al.*, (1998) observed that the most workable subsets of phytoremediation techniques are

1. **Phytoextraction** It is also called phytoaccumulation. The use of pollutant accumulating plants to remove metals or organics from soil by concentrating them in harvestable parts.
2. **Phytodegradation** The use of plants and associated micro-organisms to degrade organic pollutants.
3. **Phytostabilization** The use of plants to reduce the bioavailability of pollutants in the environment.
4. **Rhizofiltration** The use of plant roots to absorb pollutants, mainly metals and nuclear wastes from water and aqueous waste streams.

5. **Phytovolatilization** The use of plants to volatilize pollutants and the use of plants to remove pollutants from air.

Of these phytoextraction is the major promising area where field level results have been shown (Banuelos *et al.*, 1993; Brown *et al.*, 1995). Phytoextraction is fundamentally an agricultural technology to remove inorganic (primarily metal) contaminants from soil which is becoming a challenge for researchers (Thangavel and Subbhuraam, 2004).

Increasing salinity of two important natural resources i.e., water and soil is a major constraint in determining the primary productivity at national and global level. The wastelands of Indian sub-continent are degrading due to the development of salinity either by the use of saline underground water or by some other factors. This degradation is increasing day by day. These habitats are characterized by excess of inorganic salts and their accumulation in upper soil layer. Unlike many other stresses, salt stress is more complex involving many factors likes osmotic stress, ion toxicity, nutrient imbalance and soil reaction effects, which alter morphological, physiological and biochemical attributes of the plants and may lead to early mortality (Qader, 1994).

However, as yet only isolated studies have been carried out to characterize plants which thrive on salinity, hyperaccumulate component ions of salinity and show ameliorating effect on substrate salinity. Nath and Banerjee (1992) studied the ameliorating effect of *Casurina equisetifolia* on saline soil and reported that the ECe, mineral content and pH was reduced by this plant species. Miyamoto *et al.* (1994) utilized the halophytic plant species for soil reclamation as well as fodder production in tropical desert conditions. They reported that chenopods amongst the other plants from a major group that held demonstrated potential for saline soil reclamation.

In another study Khan *et al.* (2000a,b) have identified *Suaeda fruticosa* and *Atriplex griffithii* var. *stocksii* as hyperaccumulator plants and could be successfully cultivated in saline wastelands to reclaim these highly salinized areas. Salinity renders the affected soils physiologically dry. Such soils are poor in organic matter and have a poor water supply capacity, which has a profound effect on vegetation. Although there are many physical and chemical methods to reduce salinity from soil but they are costly and not free from side effects. The key to productivity for such soils is the use of salt tolerant and salt scavenging plant species. Such soils favour the growth of halophytes. Khan *et al.* (2000c) observed that the chenopod, *Haloxylon*

*recurvum*, a stress succulent native of saline soils having a high shoot biomass at high salinity (380 mM NaCl) also accumulated high amount of inorganic ions like Na<sup>+</sup> and Cl<sup>-</sup>.

Efforts have been made for a long time in the direction of reclamation of saline lands, but an appropriate technological development is yet to be achieved in the context of Indian agro-climatic conditions.

For the reclamation and rehabilitation of degraded lands the technology to be developed should be production oriented, economically viable, environmental friendly and suitable for sustainable agricultural production system (Abrol, 1986). Miyamoto *et al.* (1994) and Nathawat (1996) used the term 'biological desalinisation' for this purpose. Biological desalinization is a technique developed recently to reduce or rehabilitate salinity from the salt-affected soils with the help of halophytic plants.

The adaptations of salt hyperaccumulator plants to extreme conditions of arid climate and salinity have not only morphological, physiological or behavioural, but also showed extraordinary individual flexibility of structure and physio-metabolic processes including protein and its degradation (Barnett and Naylor, 1966; Morris *et al.*, 1969). In our laboratory also various salinity and specific proteins have been identified in wheat and cowpea (Champa, 2003; Bishnoi, 2003; Bishnoi *et al.*, 2006a,b). Proline accumulation

occurs in the tissues of plants exposed to a saline substrate (Palfi and Juhasz, 1970) and it has been suggested that proline acts as an endogenous osmotic regulate in halophytes. Mohammad and Sen (1987) observed that proline is not necessarily an indicator of stress condition. Recently Mohammad and Sen (1990) observed that proline accumulation was not governed by environmental factors but some innate factors are responsible for it. Even high salinity at site I induces high proline content in *Salsola baryosma* as compared to site II where it was low salinity.

Protein content of various plant tissues declined under drought or saline conditions, because of increased proteolysis and decreased protein synthesis (Vaadia and Waisel, 1967). *Salsola baryosma* registered higher sugar, protein, proline and mineral contents in the harsh conditions of desert which is the acclimation feature of this plant to extreme conditions of salinity, temperature and water stress (Mohammed and Sen, 1992). In contrast to extensive studies on changes in protein expression as a result of various abiotic stresses including salt and heavy metal stress on crop plants and experimental plants like *Arabidopsis* (Grover *et al.*, 2001), there is a lack of broad base information indicating qualitative changes in protein profiles in response to salt stress in phytoremediating plants. The characterization of salt induced proteins shall be vital for

biotechnological interventions in locating phyto remediating specific salt induced proteins in hyperaccumulators or halophytic plants.

For orienting such scientific phyto remediation efforts towards practical success at field level such basic scientific information is essentially required for growing these species in saline soils having another limitation of water stress.

The present work would therefore be undertaken with the following objectives

1. Identification and characterization of hyper accumulating plants including halophytes native to saline wastelands.
2. To quantify the phyto remediating potential of promising hyperaccumulators keeping in view their salt harvesting potential and concomitant depletion and remediation of salinity.
3. To study the protein profile of some phyto remediating plants.

## CHAPTER – II

# Review of --- --- Literature

Soil salinity occur in many semi-arid to arid regions of the world. Nearly 20% of the world's cultivated area and 40% of the total cultivated area in India are affected by salinity (Zhu, 2001; Suman, 2005). Soil salinity is one of the principle factor responsible for deterioration of soil fertility which inhibits the growth and yields of crop plants (Greenway & Munns, 1980; Tanji, 1990). One way to rehabilitate and reclaim these soils is the planting of salt tolerant forage species (Le Houerou, 1992). The Halophytes have been considered as potential crops for saline areas (Miyamoto *et al.*, 1996). The technology in which plants are used to remove inorganic and organic ions from the soil is known as phytoremediation.

The literature regarding various aspects of plants alongwith their potentiality to remediate or reclaim the soil salinity has been given under the following heads

## **2.1        Survey, collection, identification and characterization of native floras**

Santapau (1956) conducted explorations in Khandala, Purandhar, Mahableshtar, Saurashtra, the Dang forest, North Kanara, Bombay and Salsette Islands. He studied 55,000 plants.

Backer and Brink (1965) studied the 6534 plants in which 4598 wild plants, 413 aliens and neutralized plants and 1523 cultivated plants.

Seymour (1969) studied the 432 plant species which constituted the flora of New England.

Bobrov *et al.* (1970) described the “Flora of the USSR” in which described the families caparidaceae, cruciferae and resedancae having the 691 genera, with a total of 5,987 species.

Collett and Hemsley (1971) surveyed the Simla and adjoining areas. He studied the 498 species of dictos and 133 species of monocots. Blatter and Hallberg (1984) studied the flora of the Indian desert (Jodhpur and Jaisalmer). They were enumerated about 140 species of desert plants.

Bakshi (1984) studied on the vegetation of the district of Murshidabad, Bengal. He analysed the 133 families, 417 genera and 636 species.

Saldanha (1984) covered all the 19 districts of the Karantaka state and studied the 3,400 species of angiosperm distributed among 141 dicot and 29 monocot families.

Manilal (1988) studied the flora of silent valley situated at the south western corner of Nilgiris, in the Palghat District of Kerala South India. He found that the valley was explored 966 species of angiosperms belonging to 599 genera of 134 families.

## **2.2 Use of plants species for reclamation and afforestation in salt affected areas**

*Suaeda fruticosa* can bring about reclamation of saline and alkaline soils (Chaudhri *et al.*, 1964). Afforestation in salt affected with *Prosopis juliflora* is reported to reduce salinity and improve the soil physical properties (Raman *et al.*, 1987).

Sharma *et al.* (1968) studied *Calotropis procera* which is a common plant in arid and semi arid regions of North-West India, reported that growing of *Calotropis procera* in a sodic soil lowered its pH without any significant effect on the EC values. These grasses include Karnal grass (*Diplachne fusca* or *Leptochloa fusca*), rhode grass (*Chloris gayana*),

paragras (*Brachiaria mutica*), *Aleurops lagopoides* *Sporobolus spicatus* and *Cyperus laevigatus*. These species showed high tolerance to alkaline soil conditions (Kumar and Abrol, 1984; Kumar and Abrol, 1996; Kumar, 1988a,b; Kumar, 1996 and Onkware, 1997).

Gallagher (1985) has evaluated several hundred halophytes from salt marshes and salt deserts of the world for developing these as grain and fodder crops and for finding out adequate agronomic practices under saline conditions. Present studies have been made on three forage, one grain and one vegetable halophytic taxa. *Sporobolus virginicus* cultivars have been used for both hay and pasture, *Distichlis spicata* and *Spartina patens* for hay, *Kosteletzkya virginica* for grain resembling millet.

Maliwal *et al.* (1991) reported the effect of *Prosopis juliflora* plantation for the reclamation of saline-sodic soils grown with *Gossypium arboreum* and *Sorghum vulgare*, EC 2.5 of soil decreased from 0.6 to 0.22 dSm<sup>-1</sup>. The pH of soil also decreased from 8.4 to 7.6 upto 30 cm depth of soil.

The halophytes like *Atriplex nummularia*, *Distichlis palmeri*, *Batis maritima* and *Suaeda esteroa* have been used for saline soil reclamation (Miyamoto *et al.* 1996).

Seven Moroccan provenances of *Atriplex halimus* are used for restoration and rehabilitation of saline degraded lands (Wills *et al.*, 1999; Abbad *et al.*, 2004).

### **2.3 Effect of salinity on plant growth, development, biomass and yield**

Large increases in fresh weight and dry weight in *Atriplex nummularia*, *A. inflata*, *Salicornia europaea* and *Suaeda maritima* have been observed under salinity (Black, 1960; Williams, 1960; Greenway, 1968; Yeo, 1974).

Storey and Wyn Jones (1979) reported that fresh weight and growth of both *Atriplex spongiosa* and *Suaeda monoica* was stimulated by low to moderate salinities but inhibited by very high salinities.

Al-Niemi (1981) reported that germination percentage, seedling development, plant height and dry matter per plant of soyabean decreased with increased in NaCl concentration.

Neales and Sharkey (1981) showed that in the halophyte-*Disphyma australe* the leaf number per plant, leaf water and total inorganic content increases upto 200 mol m<sup>-3</sup> NaCl.

Hodson *et al.* (1982) studied the salt-susceptible ecotype of *Agrostis stolonifera*, which showed a 60% increase in dry weight increment by 50 mol m<sup>-3</sup> NaCl in culture solution but whose growth was completely inhibited by 200 mol m<sup>-3</sup> NaCl. The salt-tolerant ecotype, showed maximum growth at 100 mol m<sup>-3</sup> NaCl, but only a 30% inhibition at 200 mol m<sup>-3</sup>.

Pakroo and Kashirad (1981) studied the effect of NaCl induced salinity on growth and nutrient uptake by sunflower in solution culture and found that shoot dry weight, shoot root ratio, plant height, leaf area and transpiration rate decreased with increasing NaCl, it is reflected in more uptake of  $\text{Na}^+$  and  $\text{Cl}^-$  and decreased uptake of Fe, Mn and Zn by the plant.

Al-Charchafchi *et al.* (1988) studied *Haloxylon salicornicum* in arid and semi arid regions in Iraq and reported that it possessed certain morphological and ecophysiological characteristics for drought and salt tolerance.

Francois *et al.* (1990) while working on the effect of salinity on cultivars of guar (*Cyamopsis tetragonaloba*), used irrigation with saline water having EC in the range of 1.3 to 12.4  $\text{dSm}^{-1}$ . The seed yield in all cultivars decreased in concomitant with increase in soil salinity to 10  $\text{dSm}^{-1}$  in 1984 and 7.4  $\text{dSm}^{-1}$  in 1985. Plant dry weight, canopy cover and number of plants per  $\text{m}^2$  at maturity decreased with increasing salinity, leaf  $\text{Cl}^-$ ,  $\text{Na}^+$  and  $\text{Ca}^{2+}$  increased but  $\text{Mg}^{2+}$ ,  $\text{K}^+$  and P decreased with increased salinity.

Mohammed and Sen (1990) observed the effect of different salt concentrations on seed germination of *Salsola baryosma*, *Trianthema trigueta*, *Sesuvium sesuvioides*, *Cressa cretica* and *Zygophyllum simplex* and they informed

that seed germination is controlled by both osmotic as well as ionic factors.

Mahmood *et al.* (1996) studied *Suaeda fruticosa*, *Kochia indica*, *Atriplex crassifolia*, *Sporobolus arabicus*, *Cynodon dactylon*, *Polypogon monspeliensis* and *Desmostachya bipinnata* was tolerant to salinity; its growth was stimulated by a salinity level of 20 dSm<sup>-1</sup>. They also found that root/shoot mass ratio increased with increasing salinity level and this response was quite pronounced in grass species.

Ayala *et al.* (1996) reported that the halophyte *Salicornia bigelovii* shows optimal growth and Na<sup>+</sup> accumulation in 200 mM NaCl and reduced growth under lower salinity conditions.

Khan and Ungar (1996) observed that the seeds of *Haloxylon recurvum* can germinate at very high salt concentration (500 mM), but the rate of germination decreased with increases in salinity.

Ibrahim (1998) studied the effects of water at salinities of 12, 24 or 36 dSm<sup>-1</sup> on the germination and growth of *Atriplex canescens*, *Atriplex lentiformis*, *Atriplex nummularia*, *A. polycarpa* and *A. semibaccata*. He found that seed germination decreased with increasing salinity. However, increased in mineral contents of the plant was well observed without a reduction in yield under high salt concentrations.

Cherian *et al.* (1999) investigated that the *Avicennia marina* shows optimum seedling growth (fresh and dry mass) at 0.34 M NaCl. Salinity decreased the concentration of K<sup>+</sup> in shoot. The peroxidase and acid phosphatase activities were stimulated by salinity, while superoxide dismutase and ATPase showed salt sensitivity.

Gehlot and Sen (1998) revealed that in *Suaeda fruticosa* germination increased upto a certain extent and then started decreasing.

Rao *et al.* (1999) conducted an experimentation on *Salvadora persica*-a non-edible yielding species at 60 dSm<sup>-1</sup> of salinity in the top 30 cm layer indicated a good establishment, growth and profuse multiple shoot formation. Data on shoot, root and leaf biomass during immature phase indicated that total dry biomass decreased with salinity from 25-35 dSm<sup>-1</sup>. Though the leaf area and leaf area index (LAI) decreased with increase in salinity, the plants had put a good multiple shoot formation. Decrease in protein and increase in proline and accumulation of ions like Na<sup>+</sup> and Cl<sup>-</sup> at higher salinity was also shown.

Khan *et al.* (2000c) observed that in *Haloxylon recurvum* the fresh and dry weight of plants increased with an increase in salinity from 0, 180, 360 mol m<sup>-3</sup> NaCl. Succulence of shoots increased at low salinity and decreased at high salinity.

Khan *et al.* (2000a) conducted an experiment on *Suaeda fruticosa*, the plants were grown in saline conditions (200 to 400 mol m<sup>-3</sup> NaCl) had greater fresh and dry weights than those grown in non-saline controls, and 600 to 1000 mol m<sup>-3</sup> NaCl inhibited growth. Maggio *et al.* (2000) conducted an experiment to quantify *Salvadora persica* response to salinity, the seedlings were exposed to 200 mM NaCl for 3 weeks. The presence of NaCl induced a 100% increase in fresh weight and 30% increase in dry weight. Irshad *et al.* (2000) conducted an experiment to study adaption of nine exotic salt-tolerant shrubs on the salty wasteland of the Mardan area, Pakistan. The soil of the site was eroded, moderately to strongly saline with fine texture and highly calcareous with low fertility. ECe ranged from 10 to 22.5 dSm<sup>-1</sup> and pH from 8.3 to 9.2. He found that among all the species, tallest was *Atriplex lentiformis* and performed well in the Mardan area. Wang *et al.* (2001) investigated the fresh weight of *Suaeda salsa* which was markedly stimulated by 0.1M NaCl, 0.4 NaCl and 0.1M KCl and reduced by osmotic stress.

Bilquees *et al.* (2002) studied salt tolerance in *Salicornia rubra* and reported the optimal growth of plant at 200 mM NaCl and growth declined with a further increase in salinity.

Keiffer and Ungar (2002) studied the *Atriplex prostrata*, *Hordeum jubatum*, *Salicornia europaea*, *Spergularia marina* and *Suaeda calceoliformis*, all species reduced soil salinity significantly compared with paired control plots, ranging from 4% in *Hordeum jubatum* to 17% in *Atriplex prostrata*.

Parveen *et al.* (2002) studied growth response of two *Atriplex* species to salinity and hypoxia and found that combined effect of both reduced the growth of both shoot and root. They also reported that *Atriplex lentiformis* showed better tolerance than *Atriplex amnicola*.

Wilson *et al.* (2002) studied the effect of mixed salt salinity on growth and ion relations of a *Chenopodium quinoa* wild and a wheat variety and reported that with respect to salinity effects on growth in *Chenopodium*, no significant reduction in plant height or fresh weight until ECe exceeded 11 dSm<sup>-1</sup>. While both *Chenopodium* and wheat exhibited increasing Na<sup>+</sup> accumulation with increasing salinity levels. K<sup>+</sup>/Na<sup>+</sup> ratio also decreased with increasing salinity in both species.

Suleiman *et al.* (2002) studied the effect of salinity and exogenously applied polyamines on growth and ion relations in spinach and found out a significant reduction of growth as salinity increased in the irrigation water.

Cherian and Reddy (2003) studied salt tolerance in the callus cultures of *Suaeda nudiflora*, a dicotyledonous succulent, halophyte. Growth was significantly inhibited at 50, 100, 150 and 200 mM NaCl. Inorganic ions and proline accumulated in response to salinity.

Ramos *et al.* (2004) reported that *Atriplex nummularia* was able to grow well in medium levels of salinity (100 mM NaCl or KCl) but increasing concentrations of salt induced a progressive decline in length and weight of the plants.

Gonzalez *et al.* (2005) studied the *Cynara cardunculus* with increasing concentration of salts (NaCl and KCl). These salts did not induce a significant decline in the plant weight at 50mM concentration but 100 mM salt concentration caused a deleterious effect on the fresh weight of both roots and shoots.

Amor *et al.* (2005) studied the *Crithmum maritimum*, a local halophyte naturally growing on rocky coasts. The plant growth was significantly improved at moderate salt levels (50 mM NaCl), but was drastically reduced at 200 mM NaCl. The stimulation of biomass production at 50 mM NaCl was associated with enhanced root length and leaf number.

#### **2.4 Physiological mechanism of salt tolerance in plants particularly halophytes**

Jefferies and Rudmik (1984) while studying the physiological, ecological and phylogenetic basis of salt tolerance of halophytic taxa have found that this salt tolerance trait was under polygenic control. These halophytes exhibited a high level of physiological plasticity coping with environmental uncertainty and there is evidence at least in some halophytes of morphogenetic changes in response to salinity.

Flowers (1975) reviewed the physiology of salt tolerance of halophytes to compartmentation of toxic ions in the vacuole, osmoregulation by synthesis of various organic and compatible solutes in the cytoplasm. Decrease in transpiration rate per unit area of leaf to lower the ion input into the leaves and increased succulence.

Guy *et al.*, 1980; Guy and Reid, 1986, Ayala and O'Leary, 1995; Glenn *et al.* 1997 observed that the halophytes can increase their water use efficiency in response to salt, thereby minimizing the amount of water that must be transpired for each unit of growth.

Lipschitz and Waisel, 1982; Schirmer and Breckle, 1982; Kramer, 1984; Yeo and Flowers, 1986; Freitas and Breckle, 1992; Balsamo and Thomson, 1993, 1996; investigated that the halophytes have a diversity of secondary mechanism to handle excess salt. At the tissue level, some halophytes have salt glands, salt bladders or

succulent tissue. Succulence can be a mechanism to dilute excess NaCl in the leaf tissues.

Flowers (1985) studied that the cellular basis of salt tolerance in halophytes depends upon the compartmentation of ions necessary for osmoregulation in vacuoles and upon osmotic adjustment of the cytoplasm by compatible solutes.

Mahmood and Malik (1987) studied the effect of different levels of salinity on seed germination, plant growth and chemical composition of *Atriplex rhagodioides*. Increased biomass yields were obtained in saline treatments upto ECe 15 mScm<sup>-1</sup>, with further increase in salinity, growth was adversely affected. Na<sup>+</sup> and Cl<sup>-</sup> content in plant parts increased, K<sup>+</sup> and Ca<sup>2+</sup> content decreased with increasing salinity. Accumulation of ions against concentration gradient, selective K<sup>+</sup> uptake and partitioning of excess salt in the leaf seem attributable to the high salt tolerance of the species.

Rajput and Sen (1991) observed that the salt accumulation in bladder cells is the primary means of salt exclusion in *Atriplex holocarpa* and *Atriplex vesicaria*, before it reaches a toxic level in the cell sap.

Iyengar *et al.* (1991) studied the salt tolerance mechanism in *Salicornia brachiata* in which salt crystals were present in special trachidial cells. ATPase and

phosphatase activities were found increasing with the increase in salinity. Peroxidase and superoxide dismutase activities also increased upto certain salinity. However, catalase activity decreased with the increase in salinity levels.

Kumar (1996) observed that the grass *Leptocloa fusca* excretes salts through specialized glands so it can tolerate extremely saline and alkaline conditions.

Barkla *et al.*, 1995; Fukuda *et al.*, 1998; Serrano *et al.*, 1999; Hasegawa *et al.*, 2000; Binzel and Ratajczak, 2001; Wang *et al.*, 2001 studied the plant *Suaeda salsa* that this plant must compartmentalize the toxic  $\text{Na}^+$  in the vacuoles. Therefore, membrane bound transport systems regulating cytosolic ion homeostasis and ion accumulation in the vacuole can be considered of crucial importance for adaptation to saline conditions. The capacity of  $\text{Na}^+$  transport from the cytoplasm into the vacuole via the tonoplast  $\text{Na}^+/\text{H}^+$  antiport, which establish an electro chemical  $\text{H}^+$  gradient across (proton motive force) the tonoplast that energizes the transport of  $\text{Na}^+$  against the concentration gradient.

Glenn *et al.* (1999) have reviewed that the salt tolerance mechanisms in halophytes were mainly based on osmotic adjustment, accumulations of inorganic salts, proper working of ion channels and pinocytosis and special lipid

constitution of vacuolar membranes by which  $\text{Na}^+$  leakage back to cytoplasm was prevented.

Khan *et al.* (2000a) investigated that in *Suaeda fruticosa* water potential and osmotic potential of plants became more negative with an increase in salinity.

Sairam and Tyagi (2004) studied that the salinity stress response is multigenic, as a number of processes involved in the tolerance mechanism are affected, such as various compatible solutes/osmolytes, polyamines, reactive oxygen species and antioxidant defence mechanisms ion transport and compartmentalization of injurious ions.

Gonzalez *et al.* (2005) studied the strategies underlying salt tolerance in halophyte *Cynara cardunculus*. In this plant, osmotic adjustment was mainly due to inorganic ions. Water stress promoted  $\text{Na}^+$  but not  $\text{Rb}^+$  ( $\text{K}^+$ ) uptake and translocation to the shoot.

Song *et al.* (2006) studied the osmotic adjustment traits of *Suaeda physophora*, *Haloxylon ammodendron* and *Haloxylon persicum* both in field and under controlled conditions. Inorganic ions especially  $\text{Na}^+$  were more important in osmoregulation for *Suaeda physophora* and *Haloxylon ammodendron* to adapt to saline and arid environment and  $\text{NO}_3^-$  played more important role in

osmoregulation in *Suaeda physophora* and *Haloxylon ammodendron* cultured in NaCl treatment solutions. While organic solutes, especially soluble sugars played more important role in drought adaptation in the xerophyte, *Haloxylon persicum*.

## **2.5 Magnitude of ion regulation in plants particularly with reference to halophytes**

Flowers *et al.* (1977) reviewed that the relative growth and development of various halophytic taxa varied depending upon the salinity in the medium. They advocated that angiospermous halophytes differed from glycophytes by their ability to accumulate ions to high concentration and particularly in the leaf cells. The salt tolerance mechanism in these halophytes was regulated through compartmentation of ions in the vacuoles rather than cytoplasm. The concentration of ions in the cytoplasm remained  $\frac{1}{2}$  to  $\frac{1}{3}$  to that of vacuolar concentrations. Secondly, it was also attributed to salt ion exclusions in the hair or bladders and effective osmoregulation.

Flowers (1985) in and other review on physiology of halophytes brought forth continued increase in biomass of halophytic taxa in concomitant with decrease in transpiration, increased succulence and low stomatal frequency under saline environments, were the main causes of salt tolerance in halophytes.

## 2.6 Soil-plant water relationship under saline soils

Bolanos and Longstreth (1984) experimented that the pressure volume curves for *Alternanthera philoxeroides* (allegation weed) growth in 0-400 mM NaCl were use to determine water potential ( $\psi_w$ ), osmotic potential ( $\psi_s$ ), turgor potential ( $\psi_p$ ) and the bulk elastic modulus ( $\eta$ ) of shoots at different tissue water contents. Values of  $\psi_s$  decreased with increasing salinity and tissue was always lower than rhizosphere. The relationship between  $\psi_p$  and the bulk elastic modulus ( $\eta$ ) increased with salinity. As a result salt stressed plants had larger ranges of positive turgor but smaller ranges of tissue water content over which  $\psi_p$  was positive.

Neales and Sharkey (1981) studied the growth responses of succulent halophyte *Disphyma australe* with increase in external salinity and measured the degree of osmotic adjustment at two salinity levels (i.e., 200 and 500 mol m<sup>-3</sup> NaCl). Even similar studies have been performed in other halophytes mostly on *Atriplex* spp. (Storey and Wyn Jones, 1979) and *Suaeda maritime* (Flowers *et al.*, 1978) and *Suaeda monoica* (Storey and Wyn Jones, 1979).

Mohammed and Sen (1992) investigated soil-plant relationships, metabolic processes and survival of the salt wart-*Suaeda fruticosa* as influenced by salinity. This species exhibited higher sugar and protein contents in rainy season

and higher chlorophyll content under salt stress. Proline accumulation was higher in the winter season. All the elements viz.  $\text{Na}^+$ ,  $\text{K}^+$ ,  $\text{Ca}^{2+}$  and  $\text{Cl}^-$  studied in plant and soil did not follow a definite pattern.

## **2.7 Metabolic and phytochemical accumulation in plants under salinity**

Osmond *et al.* (1969) and Rajput and Sen (1991) studied that different species of chenopodiaceae have different morphological adaptations to salinity as the *Atriplex* species contains salt bladders on its leaves for salt exclusion before it reaches a toxic level in cell sap.

Aslam *et al.* (1979) observed that the Na content increased with ESP level from 15.6 to 23.9 meq/100g dry weight. This was accompanied by a decrease in K, Ca, Mg and Cl contents in *Diplachne fusca*. It was concluded that *D. fusca* was highly tolerant to soil sodicity.

Mohammed and Sen (1992) investigated the metabolic and mineral responses of *Salsola baryosma* (chenopodiaceae)- a halophyte of inland desert salines. The ion analyses of the leaves and soil revealed that the values of all ions ( $\text{Na}^+$ ,  $\text{K}^+$ ,  $\text{Ca}^{2+}$ ,  $\text{Cl}^-$ ) were maximum during harsh summer months at site-I (Pachpadra-salt basin) than site-II (Jodhpur-non-saline)

Munns (1993) discussed the physiology of plant growth in saline soils in relation to improving the salt tolerance of cultivated plants. It is argued that salt taken up by the plant do not directly control plant growth by affecting turgor, photosynthesis or the activity of any one enzyme. Rather, the build up of salt in old leaves hastens their death and the loss of these leaves affects the supply of assimilates or hormones to the growing regions, which in turn affects growth.

Binzel and Reuveni (1995) provided evidence for salt tolerance of plant cells from *in vitro* culture experiments, growth and osmotic adjustment of cells in response to NaCl, distribution and transport in cells exposed to NaCl and cellular metabolism during and after adaptation to NaCl. The various species discussed were *Atriplex nummularia*, tobacco, carrots, barley, *Distichlis spicata* and chinese cabbage.

Miyamoto *et al.* (1996) reported a large accumulation of Na<sup>+</sup> and Cl<sup>-</sup> ions (upto 5-6 mol kg<sup>-1</sup> dry weight) in *Atriplex nummularia*, *Batis maritima* and *Suaeda esteroa* plant tops. Whereas, *Distichlis palmeri* was reported to have higher concentrations of Na<sup>+</sup> and Cl<sup>-</sup> in roots than that in tops. Mg<sup>2+</sup> ions were the next dominant cation absorbed by *Atriplex nummularia* and *Suaeda esteroa*, in both plant tops and below 0.25 mol/kg in roots. The concentrations of Ca<sup>2+</sup> exceeded that of Mg<sup>2+</sup> in *Batis*

*maritima* and were approximately equal to  $Mg^{2+}$  in *Distichlis palmeri*. Both  $Ca^{2+}$  and  $Mg^{2+}$  concentration in tops and roots were highly species dependent. The concentrations of  $K^{+}$  were in the range of 0.25-0.50 mol  $kg^{-1}$  dry weights in both plant tops and roots, whereas, decreased only slightly in plants tops with increasing salinity.

Mahmood *et al.* (1996) have conducted an experiment on some 'chenopods' and reported significant increase in  $Na^{+}$  concentration in plant shoots with increasing salinity levels and significant decrease in  $K^{+}$  and  $Ca^{2+}$  concentration.

Onkware (1997) studied water relations and chemical composition of *Sporobolus spicatus* and *Cyperus laevigatus* under varying levels of salinity induced leaf diffusive resistance, increased concentrations of  $Na^{+}$  and  $Cl^{-}$ , but not of  $K^{+}$ ,  $Ca^{2+}$  and  $Mg^{2+}$ .

Cherian *et al.* (1999) investigated the possible effects of salinity on growth, ion accumulation and enzyme activity in *Avicennia marina*. Salinity decreased the concentration of  $K^{+}$  in shoot.  $Na^{+}/K^{+}$  ratio increased steadily with salinity.

Maggio *et al.* (2000) reported that the concentration of  $Na^{+}$  in leaves of salinized plants was ~40 fold greater than that measured in non-salinized controls,

and this was associated with significant reductions in leaf  $K^+$  and  $Ca^{2+}$  concentration in *Salvadora persica*.

Khan *et al.* (2000b) studied *Atriplex griffithii* var. *Stocksii* that the  $Na^+$  and  $Cl^-$  content in both shoots and roots increased with increases in salinity. Increased treatment levels of NaCl induced decreases in  $Ca^{2+}$ ,  $K^+$  and  $Mg^{2+}$  in plants.

Khan *et al.* (2000a) studied *Suaeda fruticosa* and showed that the increasing salinity increased the  $Na^+$  and  $Cl^-$  concentrations, while the concentrations of  $Ca^{2+}$ ,  $Mg^{2+}$  and  $K^+$  decreased.

Cherian and Reddy (2000) studied the effect of NaCl on growth, ion accumulation and enzyme activity in a halophyte *Suaeda nudiflora*. The accumulation of cations was greater in leaves than in shoot or root.  $Na^+$  and  $Cl^-$  contributed substantially to dry mass. Salinity treatments decreased the concentration of  $K^+$  in leaves, the  $Ca^{2+}$  content and  $Na^+/K^+$  ratio increased steadily with salinity.

Khan *et al.* (2000c) investigated that the root and shoot  $Ca^{2+}$ ,  $Mg^{2+}$  and  $K^+$  content decreased with increased salinity while  $Na^+$  and  $Cl^-$  content increased in *Haloxylon recurvum*. Other similar results were also reported by Khan *et al.* (2001) in *Salicornia rubra* a succulent annual halophyte.

Grieve *et al.* (2001) reported that the  $\text{Ca}^{2+}$  and  $\text{K}^{+}$  decreased whereas  $\text{Na}^{+}$  and total sulphur (S) increased in leaves of all species including *Spinacea oleracea* with increasing salinity. But  $\text{Mg}^{2+}$  in leaves of the composites and the crucifers also increased with salinity, but treatment had no effect on  $\text{Mg}^{2+}$  concentration in chenopods. Increase in salinity caused significant increases in  $\text{Cl}^{-}$  in leaves of crucifers and spinach.

Bilquees *et al.* (2002) studied salt tolerance in *Salicornia rubra* and found that  $\text{Na}^{+}$  and  $\text{Cl}^{-}$  contents of plants increased with an increase in salinity, while  $\text{Ca}^{2+}$ ,  $\text{Mg}^{2+}$  and  $\text{K}^{+}$  content decreased. *Chenopodium quinoa* showed 4-fold and 3-fold increase in leaf and stem  $\text{Na}^{+}$  contents, respectively, with respect to the controls (Wilson *et al.*, 2002). Contrarily, it was observed that  $\text{Na}^{+}$ ,  $\text{Ca}^{2+}$ ,  $\text{Mg}^{2+}$  and  $\text{Cl}^{-}$  contents were increased while  $\text{K}^{+}$  content was decreased in *Spinacea oleracea* with increasing salinity levels (Suleiman *et al.*, 2002).

Gulzar *et al.* (2003) examined the growth water and osmotic relations in the halophytic perennial grass *Usochondra setulosa*. Number of leaves and tillers, root length and shoot length, fresh weight and dry weight of roots and shoots were highest in the non-saline control and decreased with an increase in salinity. Sodium ( $\text{Na}^{+}$ ) and  $\text{Cl}^{-}$

levels increased in shoots while  $K^+$  concentration decreased with increases in salinity.

Abbad *et al.* (2004) reported that with increase of salinity, it generated an accumulation of  $Na^+$  and  $Cl^-$  with a concomitant reduction of  $K^+$ .

Karimi *et al.* (2005) observed that the  $K^+$ ,  $Mg^{2+}$  and  $Ca^{2+}$  contents, water potential, chlorophyll a+b and carotenoids contents, and stomata number and size were reduced at low concentrations of NaCl. In contrast, the  $Na^+$ ,  $Cl^-$  and proline contents increased several times with increasing NaCl concentration in *Kochia prostrata*.

Amor *et al.* (2005) studied the physiological behaviour and antioxidant responses to salinity in *Crithmum masitimum*. The  $Na^+$  and  $Cl^-$  were largely accumulated in shoots with increase in salinity but the  $Ca^{2+}$ ,  $Mg^{2+}$  and  $K^+$  concentrations significantly declined.

## **2.8 Morphological and various modification of plants and other halophytes under saline condition**

Important structures in the salt economy of halophytes are salt glands. They evolved convergently in many different families such as plumbaginaceae, tamaricaceae, primulaceae etc. A similar function of salt recreation is ascribed to bladder trichomes of some chenopodiaceae e.g. *Atriplex* species (Frey-Wissling, 1935).

Excess salt may be secreted by salt glands in some halophytes e.g. *Spartina townsendii* (Skelding and Winterbotham, 1939) and *Limonium* (Ziegler and Luttge, 1967).

Berry and Thomson (1967) showed that the salt which was secreted by the salt glands in *Tamarix aphylla* appeared as small white residue on the surface. Berry (1970) investigated the composition and concentration of salt secreted by the salt glands of *Tamarix aphylla*. He observed that the concentration of the salt glands secretion averaged 0.5 N, a 50-fold increase in concentration over the nutrient solution in which the plants were grown.

Mozafar and Goodin (1970) observed that the concentration of salts in the vasiculated hairs of *Atriplex halimus* L. was measured and was remarkably higher than that of the leaf sap and xylem exudates.

The cellular basis of salt tolerance in halophytes depends upon the compartmentation of ions necessary for osmoregulation in vacuoles and upon osmotic adjustment of the cytoplasm by compatible solutes (Flowers, 1985).

Rajpat and Sen (1991) investigated the comparative studies of salt bladders in *Atriplex holocarpa* F. Muell and *Atriplex vesicaria* Heward ex. Benth showed salt accumulation in bladder cells is the primary means of salt

exclusion in *Atriplex* spp., before it reaches a toxic level in cell sap.

Iyengar *et al.* (1991) was studied the salt tolerance mechanism in *Salicornia brachiata* Roxb, a halophyte growing in salt marshes of Bhavnagar, revealed that in the oblique section salt crystals were present in special trachidial cells.

Popp *et al.* (1993) studied the black mangroves (*Avicenia* spp.) have well developed salt glands that appear to function in salt tolerance by allowing the plant to excrete excess salts onto the leaf surface; yet the equally salt-tolerant red mangroves (*Rhizophroa* spp.) excrete no salt at all.

Glenn *et al.* (1999) studied the salt tolerance mechanism in halophytes. These plants have osmotic adjustment, accumulation of inorganic salts, mainly NaCl, in the vacuole and accumulation of organic solutes in the cytoplasm.

## **2.9 Effect of salinity on Ash content, TDS (Total Dissolved Solids) and CEC (Cation Exchange Capacity)**

Aslam *et al.* (1979) studied *Diplachne fusca* grown in soil with ESP levels of 7, 15, 29, 44, 59. Ash content was not affected by ESP value.

Hyder (1981) studied that the seeds of seven different *Atriplex* species were germinated in the greenhouse

and then transplanted to fields. All species are resistant to prolonged drought and salinity. These were high in protein and ash content.

Bhatti *et al.* (1980) investigated that the maize cv. Neelam and Akbar were sown in pots containing sandy clay loam treated with a mixture of Na salts to give a salinity of 0, 0.5, 1.0, 2.0 or 4.0 meq/100g and given the equivalent of 0, 23 or 45 kg N + 0 or 23 kg P + 23 kg K/ac in 6 combinations. Ash content increased significantly with increasing P, K and salinity but decreased with increasing N application.

Fowler *et al.* (1992) reported that *Salsola iberica* plants when grown under salinity enhanced the mineral ash content.

Glagoleva and Chulanovskaya (1992) investigated the photosynthetic metabolism of 23 species of the chenopodiaceae in relation to soil salinity and tissue ionic composition. The species which were grown at low salinity containing less than 25% ash but at high salinity the ash content was more than 30%.

Ala *et al.* (1994) reported that when *Atriplex amnicola* were grown in sandy loam and silty loam soils with salinity levels of 0, 10 or 20 dS/m. Plant growth decreased in salinity treatments but the Ash content of plants increased.

Kolchevskii (1995) studied the various physiological characteristics of C<sub>3</sub> and C<sub>4</sub> plants grown along

in a gradient of salinity environment. The ash content of plants was higher with increasing soil salinity. Khan *et al.* (2000) reported that in the *Atriplex griffithii* grown at 0, 90, 180 and 360 mM NaCl. The ash content was increased with increasing salinity.

Khan *et al.* (2000a) studied that *Suaeda fruticosa* grown in sand culture in nutrient solution containing 0, 200, 400, 600, 800 or 1000 mol m<sup>-3</sup> NaCl. Ash content increased with increasing salinity, while organic content of plants and tissue water content peaked at 200 mmol m<sup>-3</sup> NaCl and then declined with increasing salinity.

Yurtseven and Baran (2000) studied the effects of saline water irrigation in relation to the amounts of water irrigation canal on broccoli (*Brassica oleracea* botrytis) in relation to yields and mineral contents grown at 0.25-control, 1, 3, 6 and 9 dS/m salinity levels. The biomass yield decreased but the total ash content increased with increasing salinity levels.

Shimizu *et al.* (2003) conducted an experiment to determine the effects of salt treatment on the growth, changes in the crude protein concentration and protein content. These changes were correlated with glycinebetaine (GB) concentrations. They observed that these changes were related to salt tolerance of *Salicornia herbacea*. Fresh weight,

dry weight and ash content increased with increasing salinity.

Salman *et al.* (2003) examined the growth, water and osmotic relations in the halophytic perennial grass *Urochondra setulosa*. Percentage ash content of shoots did not vary with increases in salinity.

Robinson *et al.* (1980) evaluated the effect of salinity on various vegetable crop yields. Soil salinization was artificially created and applied by sprinkler irrigation on crops in a clay and a sandy clay loam soil. Water with a total dissolved solids (TDS) level of 1,350 mg/l produced significantly lower yields of snap beans, carrots and onions than did river water of 875 mg/l TDS.

Glenn *et al.* (1998) studied *Atriplex nummularia* grown with mildly saline or brackish waste water from an electric power plant, it showed that TDS increased with increase in salinity. Anubha *et al.* (2000) showed that the groundwater of Ambala had high TDS at high salinity.

Hernandez *et al.* (2004) studied effect of soil salinity on plant growth. As the EC of the soil increased the value of TDS enhanced. Tripathi and Gehlot (1999) conducted an experiment to determine the effects of gypsum, FYM and phosphorus application on cation exchange capacity (CEC) of wheat roots grown on saline-sodic soil and

water. Root CEC was reduced due to salinity. Soil pH and EC was not related to root CEC.

### **2.10 Effect of salinity on proteins**

Poljakoff and Meiri (1969) have shown that salinity severely reduced the ability of excised pea root tips to incorporate amino acids into protein.

Hall and Flowers (1973) studied an amino acid incorporating microsomal fraction from the leaves of an halophyte-*Suaeda maritima*. There were no differences in the properties of the microsomes isolated from plants grown in saline and non-saline conditions.

Depressed protein synthesis and acceleration in its degradation in plants in response to salt stress (Chandershekhar *et al.*, 1986, Lal and Bhardwaj, 1987).

Singh *et al.* (1987) investigated the salt induced proteins in tobacco at 26 kD. This protein was named as osmotin.

Hurkman *et al.* (1991) observed that in barley accumulation of two 26 kD polypeptides related to germin in response to salt stress.

Claes *et al.* (1990) and Torres Schumann *et al.* (1992) reported salt-induced proteins in rice and tomato.

Lopez *et al.* (1994) has found a 22 kD protein in radish (*Raphanus sativus*) in response to salt stress or water deficit.

Sousa *et al.* (2004) reported that cowpea seedlings subjected to NaCl stress showed increased concentration of 9 proteins, decreased concentration of one and de novo synthesis of one 21.2 kDa protein.

Bishnoi *et al.* (2006a,b) studied the effect of salt and boron stress on two pigeonpea (*Cajanus cajan* L. Mill sp.) genotypes, a salt tolerant (Manak) and a comparatively salt sensitive (ICPL 88039). In NaCl treatment 95.6 kDa proteins in plumule and 67.5 kDa proteins in radicle of Manak appeared. Boron treatment increased 28.3 kDa proteins in plumule and 38.3 and 51.9 kDa proteins in radicle of Manak. However, there was no specific protein in ICPL88039 either in plumule or radicle. Similarly, Champa (2003) studied the effect of NaCl and B on two cultivars of wheat, i.e., KRLI-4 (salt tolerant) and HD-2329 (salt sensitive). In tolerant cultivars (KRLI-4) two proteins of 83.6 and 28.1 kDa in coleoptile and 35 kDa in radicle appeared with B and NaCl+B. 46.6 KD protein was B-specific. Other two proteins 74.2 and 48.8 kDa in HD-2329 were specific to NaCl and were absent in B-treatment. Another 70 kDa protein in coleoptile protein profile of KRLI-4 was expressed in NaCl-treatment, but was absent in B-treatment.

## **2.11      Phytoremediation      potentiality      of      plants/ halophytes for use as plant based technology in saline wastelands**

Bhardwaj (1972) studied Dhaincha (*Sesbania sesquens*) under saline and alkaline wastelands and found that it was an effective salt tolerant leguminous crop, which could be used for reclaiming disturbed soil as well as for providing green manure.

Mohindra (1973) studied the growth of a number of exotic and indigenous grasses and legumes viz. para grass, pusa giant napier, *Dicanthium annulatum*, *Pennisetum orientula*, Rhodes grass, berseem, senji and Lucerne on saline alkali soils having pH between 9.45 and 10.46 and EC in the range of 0.32 and 1.65 dSm<sup>-1</sup>. Rhodes grass and paragrass established successfully.

Losses in crop and plant productivity due to soil salinity at national and global levels are well documented. However, the use of plants for ameliorating such adversities has attracted the attention of agricultural scientists, environmentalist and plant biologists recently (Nathawat and Srivastava, 1996). This changing thrust relating to soil amendments is primarily due to the negative and hazardous effects of chemical amendments for tackling the problem of soil salinity.

Afforestation in saline lands with *Prosopis juliflora* was reported to reduce the salinity and to improve the soil properties (Raman *et al.*, 1987) *Calotropis procera* (a common plant in arid zone) growing in a sodic soil lowered the soil pH

markedly without any significant effect on the ECe values (Sharma *et al.*, 1968). The large scale use of this common weed for soil reclamation can be possible in the areas where it is found in abundance. *Atriplex semibaccata* have salt leaching characteristics from soil (Villers *et al.*, 1995).

Maliwal *et al.* (1991) reported the effect of *Prosopis juliflora* plantation on the reclamation of saline sodic soils. The data on EC showed that the total salt concentrations decreased from 0.60 to 0.22 dSm<sup>-1</sup> under *Prosopis* as compared to fallow land at all the depths. The pH of soil also decreased from 8.4 to 7.6 upto 30 cm depth of soil sampling. However, being a perennial plant, this species require more time to reduce the soil salinity. Hence, the search for annual herb for such purposes is imperative.

Nath and Banerjee (1992) studied the ameliorating effect of *Casuarina equisetifolia* on saline soil and reported that the EC, pH and the mineral content of the soil was adversely affected by this plant species. However, they suggested more studies for conclusive use of domesticated and newly cultivated desert halophytes as the mixed feed for cattle as well as soil bioreclamation. Miyamoto *et al.* (1994) presented a comprehensive review on the potential of utilization of halophytic plant species for soil reclamation as well as fodder production in the same tropic desert condition.

Dagar *et al.* (1993) conducted experiments for the evaluation of plant species, suitable for afforestation in salt affected soils, which has been recently reclaimed and reported that various combinations of *Tectona brandish*, *Alianthes excelsa* and *Temendus indica* with crops like rice, wheat, pearl millet, mustard and lentils were found suitable for this purpose.

Dahiya *et al.* (1993) conducted comprehensive investigation on desalinization potential of plant species in arid and semi arid regions of Haryana and reported that a combination of different dicot plant species with some salinity tolerant grasses may be used for reducing salt content in drought affected areas. Combination of some salt tolerant woody species like *Prosopis juliflora*, *Acacia nilotica*, *Casuarina equisetifolia*, *Tamarix articulata* and grasses like *Leptochloa fusca* showed great potential for amelioration of the soil adversities like pH, EC and high salt concentrations.

Gupta *et al.* (1995) reported that saline alkali soil, Karnal grass (*Diplachne fusca* syn. *Leptochloa fusca*) and paragrass (*Brachiaria mutica*) can successfully reclaim alkali soils. Similar observations have been made in trees as well as grasses also (Kumar, 1996; Kumar and Abrol, 1996).

Arya *et al.* (1996) conducted field experiments to study the performance of *Atriplex lentiformis* in response to different treatments such as gypsum, drainage replacement

of pit soil with good soil. Similarly Arya *et al.* (1998) have also described the improved soil properties, viz. EC, pH and organic matter under the plantation of *Atriplex lentiformis*. Similar reports have also been made by Mahala *et al.* (2001) with some desert halophytes.

## **2.12 Quantification of plant species particularly chenopods for phytoremediation of saline soils**

Dutta (1979) studies *Sporobolus helvolus* a major forage grass of saline tract for its growth and nutrient uptake under various edaphic conditions. Plant height and dry matter production were maximum in soil collected from Pachpadra salt basin and tank silt. But its growth was poor in alluvial soil. In Pachpadra soil the root showed less growth than that of tank silt and alluvial soil.

O'leary (1980) has advocated the reclamation of saline soils by halophytes under non-irrigated conditions but not under irrigated conditions.

Pasternak *et al.* (1985) have found that *Suaeda species* could be selected and developed as an alternative traditional oil seed and fodder crop for regions under saline irrigation.

Siddiqui (1988) reported that *Dactyloctenium aegyptium* (L) Beauv and the mycoflora of the salt affected soils played a significant role in reclamation of the soil.

Nath and Banerjee (1992) studied the amelioration effect of *Casuarina equisetifolia* on saline soil and reported that the EC, pH and the mineral content of the soil was affected by this plant species. However, they suggested more studies for conclusive use of domesticated and newly cultivated desert halophytes as the mixed feed for cattles as well as for soil salinity bioreclamation.

Ahmed *et al.* (1993) conducted a green house experiment on a silt loam soil of Demra series classified as Entisols to determine the effect of salinity (EC-4.0, 8.0 and 16 dSm<sup>-1</sup>) on growth, biomass production and nutrient assimilation of fodder grasses e.g. paragrass (*Brachiara mutica*) napier grass (*Pennisetum purpureum*) and guinea grass (*Panicum maximum*) at different stages of growth (20, 40 and 60 DAT). The growth, fresh biomass and dry matter production decreased with an increase of salinity from 4.0 to 16 dSm<sup>-1</sup> at all growth stages.

Singh *et al.* (1994) reviewed the literature concerning the agroforestry techniques for the rehabilitation of degraded salt affected soil of India and reported that a combination of some salt tolerant woody species like *Prosopis juliflora*, *Acacia nilotica*, *Casuarina equisetifolia*, *Tamarix articulata* and grasses like *Leptochloa fusca* were showing a great potential for amelioration of the soil adversities like pH, EC and high salt concentrations. However, the success was

influenced by the management practices and agro-climatic conditions.

Villiers *et al.* (1995) studied the characteristics of the *Atriplex semibaccata* in relation to the leaching of the salt from soil. He reported that the growth and biomass studies along with certain other physiological characteristics like root/shoot ratio was also important.

Miyamoto *et al.* (1996) carried out an experiment on the potential of utilization of halophytic plant species for soil salinity reclamation as well as fodder production in some tropic desert condition. They reported that among the major natural plant resources of arid and semi-arid desert a large number of species of chenopods and other plants exhibited great capacities for soil reclamation. These include relative tolerance to soil and irrigation water salinity, metabolic and photosynthetic aspects, germination and crop establishment phenomenon, phenological and phenometric observations and biomass production studies. They further estimated the quality of salts annually removed from the soils affected by brackish water irrigation and also the time required for making the soils normal. It was also concluded that these halophytic plants can be raised in conventional style culture system as well as in different multiple culture system. However more remains to be done on the practical utility of these plants with reference to hot desert of Rajasthan.

Mahmood *et al.* (1996) have favoured the utility of native flora of saline waste lands in Pakistan as it can be made productive by growing salt tolerant plants. In this connection some member of chenopodiaceae and other families viz. *Suaeda fruticosa*, *Kochia indica*, *Atriplex crassifolia*, *Sporobolus arabicus*, *Cynodon dactylon*, *Desmostachya bipinnata* and *Polypogon monspeliensis* have been identified.

Miyamoto *et al.* (1996) has recommended the halophytes-*Atriplex nummularia*, *Distichlis palmeri* Fassett, *Batis maritima* L. and *Suaeda esteroa* as potential crops for irrigated production with brackish water or sea water. The plants were grown at an average leaching fraction of approximately 0.3 with diluted or concentrated sea water having salinity levels of 1.2, 10, 20, 40 and 60 g l<sup>-1</sup>. Results indicated that these halophytic species can be grown productively at a leaching fraction of 0.30 or less when salinity of the irrigation water is less than 10 g l<sup>-1</sup>. At higher salinities, frequent irrigation at higher leaching fractions may be required for the optimal growth of these halophytes.

Maggio *et al.* (2000) has suggested the domestication of halophytes particularly *Salvadora persica* as a strategy to expand cultivation onto unfavorable land. Halophytes have been considered for their performance in extremely saline environment and only a few have been characterized in terms of their tolerance and physiological

responses to moderately high levels of salinity and *Salvadora persica* is an evergreen perennial halophyte capable of growing under extreme conditions from very dry conditions to extreme saline soils. It has economic value as a source of oil and other medicinal compounds as well.

## **CHAPTER – III**

# **Materials and Methods**

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The investigations were carried out in Stress Physiology laboratory and screen house of the Department of Botany and Plant Physiology, College of Basic Sciences and Humanities, Chaudhary Charan Singh Haryana Agricultural University, Hisar from June 2004 to October 2005 to investigate the phytoremedial potential/phyto-reclamation of soil salinity by some members of family chenopodiaceae, gramineae and other plant species native to saline wastelands. Extensive survey was made into the chronic saline wastelands of Hisar district and adjoining areas. Plant species that were colonizing and thriving in saline patches were collected.

### **EXPERIMENT -I**

To preserve the collected material on herbarium sheets and their identification and to study the growth and development of some phytoremediating plants under salinity.

### **Field survey collection identification and preparation of Herbarium**

Extensive forays into the chronic saline waste lands of Hisar district and adjoining areas were made. Plant species that were colonizing and thriving on saline patches have been taxonomically identified.

The plant specimens include vegetative as well as flowering and fruiting twigs were taken. The fresh specimen were pressed flat, without folds and rapidly dried in blotting sheets. After the pressed specimens were fully dry, they were securely mounted on white card sheets having the international standard size of the herbarium card sheets of 11.5 x 16.5 inches.

Mounting was done by fixing the specimens using cello tape. The labeling of the herbarium sheet were printed on the right side of bottom of the sheet (Tiagi and Kshetrapal, 2000).

### **Experiment-II**

In order to achieve the objectives of present study the second part of experiment was conducted in screen house and third part in the stress physiology laboratory. Observations of the experiment recorded in this investigation

were taken on plants and soil of all the 36 plants and their native 0-30cm of soil profile. The various constitutive analyses of salt ions in the biomass of the above ground plant parts and soil was done as given in part-2. Plants selected for these investigations are

### **Details of treatments**

(a) Cultivars/plants                      Twenty (20)

1. *Portulaca oleracea* Linn.
2. *Trianthema portulacastrum* Linn.
3. *Aerva tomentosa* Forsk.
4. *Atriplex nummularia* Lindl
5. *Atriplex amnicola* Linn.
6. *Atriplex lentiformis* (Torr) S. Wats.
7. *Chenopodium ambrosoides* Linn.
8. *Suaeda fruticosa* (Linn.) Forsk.
9. *Salicornia brachiata* Robx.
10. *Solanum xanthocarpum* Schrad. et Wendl.
11. *Xanthium strumarium* Linn.
12. *Sesbania sesquens* Merr.
13. *Heliotropium procumbens* Mill
14. *Parkinsonia aculeata* Linn.
15. *Calotropis procera* (Ait.) R. Br.
16. *Prosopis juliflora* (Sw.) DC.
17. *Arundo donax* Linn.
18. *Aeluropes lagopoides* (Linn.) Trin. Ex. Thw.

19. *Cynodon dactylon* (Linn.) Pers.

20. *Setaria indica* (Linn.) Beauv.

(b) Type of salinity Chloride dominated ( $\text{Cl-SO}_4^{2-} = 73$ )

(c) Salinity levels Three

$S_0$  Control (Hoagland's solution)

$S_1$  8.0 dSm<sup>-1</sup> (Hoagland's solution + salinity)

$S_2$  16.0 dSm<sup>-1</sup> (Hoagland's solution + salinity)

(d) Replication Five

(e) Design CRD

## **METHODOLOGY**

Seeds of different experimental plant species were procured from Arid Forest Research Institute (AFRI), Jodhpur (Rajasthan), Central Salt and Marine Chemicals Research Institute (CSMCRI), Bhavnagar (Gujarat) and the local saline wasteland of Hisar.

### **(a) Preparation of nursery**

Firstly seeds were presoaked in water for six hours and sown in the pots having 1:1 mixture of soil and farm yard manure (FYM) and irrigation was given. The pots were irrigated with tap water as and when required till the seedling emergence took place. Sowing of nursery was done in the last week of June, 2004. About twenty days old

seedlings were transplanted in the saline bags. The ECe and pH of the experimental saline bags under each treatment level were recorded at the time of transplanting.

**(b) Preparation of various salinity levels and transplantation**

Further studies were carried out in leak proof polythene bags (12 cm × 8 cm) placed in earthen ware pots of 30 cm diameter in the screen house of Department of Botany and Plant Physiology, College of Basic Sciences and Humanities, CCS Haryana Agricultural University, Hisar. Each sealed polythene bag was filled with 6.0 kg of dry and well sieved yellow dune sandy soil and salinized with the saline solutions of desired levels prepared artificially using mixture of salts i.e. NaCl, MgCl<sub>2</sub>, MgSO<sub>4</sub> and CaCl<sub>2</sub> for chloride-dominated salinity dissolved in the Hoagland's solution. The ratio of different cations and anions were maintained on meq basis as suggested by Datta and Sharma (1990).

Na : (Ca + Mg)                      1:1

Ca : Mg                                      1:3

Cl : SO<sub>4</sub>                                      7:3

1.5 litres of saline solution of desired level was applied to each bag. Five plants were transplanted in each bag at field capacity. The transplanting was done in second week of July, 2004.

### **Observations recorded**

Observations were recorded upto maximum vegetative/flowering stage.

### **Growth parameters**

- 1. Plant height** The plant height was measured from the surface of sand to the apex of the plant i.e. main shoot length using meter scale and expressed in cm.
- 2. Number of leaves** The number of leaves per plant was counted.
- 3. Number of branches** The number of branches per plant was counted.
- 4. Fresh weight** Stem and leaves were separated and weight of the stem and leaves (branches) of each seedlings were measured in grams, respectively.
- 5. Dry weight** The separated plant stem and leaves were oven-dried at 60°C for 48h and finally at 80°C for 24 h or till a constant dry weight was obtained. Total dry weight of whole plant was also calculated by aggregating the dry weight of individual parts. It was recorded in grams.

### **Estimations**

The mineral ions i.e. sodium, potassium, calcium, magnesium' chloride and suphate, total soluble solids, ash content and SAR per unit dry weight of various plant organs, viz., stem and leaves were determined from the oven-dried

material. Except for chloride and sulphate the extraction procedure was common for all mineral ions (USDA, Handbook, 1954).

### **Digestion**

500 mg of oven-dried and well ground material was taken in 50 ml conical flask to which 5 ml of 91 H<sub>2</sub>SO<sub>4</sub> (97-100%) and HClO<sub>4</sub> (60%) mixture was added. The flasks were heated gently on a hot plate till the formation of dense white fumes. When fumes reduced and subsided, at this stage heating was increased and digestion was continued for another 25-30 min to obtain a colourless digest. The digest, thus, obtained was cooled and diluted to 50 ml with distilled 50 ml water. This acid-digest can be used for the estimation of sodium, potassium, calcium and magnesium.

#### **1. Sodium (Na<sup>+</sup>) and potassium (K<sup>+</sup>) estimation**

Sodium and potassium contents were determined in the above acid digest with a flame photometer (Elico make) using standard KCl for potassium and NaCl for sodium. The values were calculated and expressed as mg g<sup>-1</sup> tissue dry weight.

#### **2. Calcium (Ca<sup>2+</sup>) and magnesium (Mg<sup>2+</sup>)**

Calcium and magnesium were estimated by EDTA titration according to the method give in USDA, Handbook (1954) as detailed below

### **Reagents**

- (i) N/100 EDTA solution 1.86 g of EDTA (di-sodium salt) was dissolved in water and volume was made one litre with distilled water.
- (ii) Erichrome Black T indicator (EBT) 4.5 g of hydroxylamine hydrochloride and 0.5 g EBT were dissolved in ethanol and volume was made 100 ml. This solution was prepared freshly before use.
- (iii)  $\text{NH}_4\text{OH-NH}_4\text{Cl}$  buffer 67.5 g of  $\text{NH}_4\text{Cl}$  was dissolved in small volume of distilled water and 570 ml concentrated  $\text{NH}_4\text{OH}$  was added and volume was made to one litre with distilled water.
- (iv) Carbamate crystals

### Procedure

One ml of aliquot was taken in China-dish and 5 ml of distilled water was added. The contents were stirred on a magnetic stirrer on slow speed. Five crystals of carbamate were added into China-dish and then to it, 2 ml of  $\text{NH}_4\text{OH-NH}_4\text{Cl}$  buffer and 4 drops of EBT indicator were added. The content of China dish was titrated with N/100 EDTA till bluish green colour (end-point) from purple red colour appeared. The volume of EDTA solution used was noted and the following calculations were made

$$\text{Ca} + \text{Mg (meq/ml)} = \frac{\text{EDTA used in titration (ml)} \times \text{Normality of EDTA}}{\text{Aliquot taken (ml)}}$$

## **Determination of calcium**

### **Reagents**

- (i) N/100 EDTA (di-sodium salt) solution.
- (ii) Calcon indicator 0.5 g calcon in 100 ml of methanol.
- (iii) 4N NaOH solution 16 g of NaOH was dissolved in 100 ml of distilled water.
- (iv) 1% PVA solution
- (v) 5% Hydroxylamine hydrochloride solution
- (vi) Tri ethanolamine.

### **Procedure**

One ml of aliquot was taken in China dish and to it 5 ml of distilled water was added. After stirring, 1 ml of 5% hydroxylamine hydrochloride solution, 10 drops of triethanolamine, 2 ml of 4N NaOH, 1 ml of PVA solution and 4 drops of calcon indicator were added and mixed. The content was titrated against N/100 EDTA till bluish green colour (i.e. end-point) appeared. Volume of EDTA consumed was recorded.

### **Calculation for calcium**

$$\text{Ca (meq/ml)} = \frac{\text{ml of EDTA used} \times \text{Normality of EDTA}}{\text{Aliquot taken (ml)}}$$

### **Calculation for magnesium**

$$\text{Mg (meq/ml)} = [\text{Ca} + \text{Mg (meq/ml)}] - \text{Ca (meq/ml)}$$

The data for calcium and magnesium were expressed as mg g<sup>-1</sup> tissue dry weight.

## **Sulphate**

The sulphate was estimated by turbidimetric method as suggested by Chesnin and Yien (1950).

### **Digestion for sulphate**

500 mg of oven-dried and well ground material was taken in 50 ml conical flask to which 5 ml of  $\text{HNO}_3$ - $\text{HClO}_4$  (4:1) diacid mixture was added. The flasks were heated gently on a hot plate till the formation of dense white fumes. When fumes reduced and subsided at this stage heating was increased and digestion was continued for another 25-30 min to obtain a colourless digest. The digest thus obtained was cooled and diluted to 50 ml with distilled water.

### **Reagent**

- (i) Gum acacia solution – 0.25% Dissolve 25 g of gum acacia in distilled water and diluted to 100 ml.
- (ii) Barium chloride Grind  $\text{BaCl}_2 \cdot 2\text{H}_2\text{O}$  crystals in a mortar, until they pass through a 20 to 30 mesh sieve, but retained on a 60 mesh sieve.
- (iii) Standard  $\text{SO}_4$  solution Dissolve 0.1815 g of reagent grade  $\text{K}_2\text{SO}_4$  in one litre of distilled water. This is 100 mg/l stock solution of  $\text{SO}_4^{2-}$ . Transfer 1.25, 2.50, 5.0, 7.5, 10.0, 12.5 and 15.0 of the 100 mg/l  $\text{SO}_4^{2-}$ , stock solution in a series of 25 ml volumetric flasks

to obtain 5, 10, 20, 30, 40, 50 and 60 mg/l  $\text{SO}_4^{2-}$ , respectively. Prepare a standard curve by plotting percentage transmittance (T) on Y-axis and concentration on X-axis on a semi-long graph paper. There should be a straight line relationship between concentration and transmittance.

### **Procedure**

Transfer of a 5 ml aliquot of digest to a 25 ml volumetric flask, add 1 ml of gum acacia solution make the volume of mark and shake for one min. Further add 1.0 g of the sieved  $\text{BaCl}_2$  crystals and shake for 1 min. Measure the turbidity in 25 to 30 min., after adding  $\text{BaCl}_2$  crystals, on spectrophotometer using a blue filter at a wavelength of 420 nm. Simultaneously carry out a blank (without sample). Data were expressed as  $\text{mg g}^{-1}$  tissue dry weight.

### **Calculation**

$C \times \text{Dilution factor}$

$C = \text{SO}_4^{2-} \text{ content (mg/l) of from the standard curve against T}$

$T = \text{Transmittance (\%T) as read from spectrophotometer}$

### **Chloride (Cl<sup>-</sup>)**

Chloride was estimated by the ion analyzer (Orion, USA), using chloride specific electrode.

### **Digestion**

500 mg of well ground material was taken in 50 ml conical flask to which 5 ml of one molar  $\text{HNO}_3$ - $\text{KNO}_3$  solution

was added. The solution was stirred for 30 min. on magnetic stirrer and then filtered. Filtrate was used for chloride estimation.

### **Total dissolved solids (TDS)**

Take 1.0 g dry weight of material into a 100 ml conical flask added 100 ml distilled water. Boil and filter the solution. Now make the volume 100 ml and take reading on conductivity meter.

### **Ash content**

Weight the empty crucible and then add the 1.00 g of dry weight of material into the crucible. The crucible with material heated in a furnace at 550°C for 30 min. After cooling weight the crucible.

### **SAR (Sodium Adsorption Ratio)**

The amount of adsorbed sodium is usually expressed as percentage of the cation exchange capacity.

### **Calculation**

$$SAR = \frac{Na^+}{\sqrt{(Ca + Mg)/2}}$$

### **Soil chemical analysis**

#### **pH**

pH was determined in 12 soil suspension with the help of Elico glass electrode on pH meter.

#### **ECe**

Electrical conductivity of saturation soil extract (ECe) was measured by using conductivity bridge and expressed as  $\text{dSm}^{-1}$  at  $25^{\circ}\text{C}$ .

### **Cation Exchange Capacity (CEC)**

#### **Reagents**

- (i) Sodium acetate solution 1N: Dissolve 136 g of sodium acetate trihydrate in water and dilute it to one litre and adjust pH to 8.2 by using NaOH and acetic acid solution.
- (ii) Ammonium acetate solution ( $\text{NH}_4\text{OAC}$ ): Dilute 57 ml of glacial acetic acid and 68 ml of ammonium hydroxide to 800 ml of water. Dilute to one litre and adjust pH to 7.0 by addition of more ammonium hydroxide or acetic acid.

OR

Dissolve 77 g  $\text{NH}_4\text{OAC}$  in one litre distilled water and adjust pH to 7.0 by addition of more ammonium hydroxide or acetic acid.

- (iii) Ethanol, 95%

#### **Procedure**

- (i) Transfer 5 g of soil in a 50 ml stoppered centrifuge tube.
- (ii) Add 30 ml of sodium acetate solution and shake for 5 min.

- (iii) Centrifuge for about 5 min. at about 8000 rpm until the supernatant liquid is clear.
- (iv) Decant and discard the liquid and repeat the shaking and centrifuging three times more with fresh sodium acetate solution.
- (v) Shake the soil with 30 ml of 95% ethanol for 5 min., centrifuge and discard the supernatant.
- (vi) Repeat the ethanol washing three times to remove excessive amounts of sodium acetate.
- (vii) Finally extract the soil. Three lots of 30 ml of  $\text{NH}_4\text{OAC}$  solution, centrifuging and decanting each washing into a 100 ml volumetric flask. Dilute the combined extracts with  $\text{NH}_4\text{OAC}$  to 100 ml.
- (viii) Determine Na concentration in the extract by using flame photometer.

### **Calculations**

Weight of soil taken 5 gm

Volume made after leaching of  $\text{NH}_4\text{OAC}$  100 ml

Conc. of Na in the leachate against reading from standard curve = X ppm

$$\text{CEC} [\text{meq}/100\text{gm soil or } \text{C mol (P}^+) \text{ kg}^{-1}] = \frac{X}{23} \times 2$$

### **Mineral estimation**

Minerals ( $\text{Na}^+$ ,  $\text{K}^+$ ,  $\text{Ca}^{2+}$ ,  $\text{Mg}^{2+}$ ,  $\text{Cl}^-$ ,  $\text{SO}_4^{2-}$ ) of saturation soil extract were determined as previously explained for plant material.

### **Statistical analysis**

Data obtained during experiments were analyzed statistically using factorial complete randomized design (CRD). Treatments were compared with CD values at 5 per cent level of significance.

### **EXPERIMENT-III**

The protein profile of some phytoremediating plants (*Atriplex amnicola*, *A. lentiformis*, *A. nummularia*, *Chenopodium ambrosoides*, *Portulaca oleracea*, *Suaeda fruticosa* and *Setaria indica*) were studied using SDS-PAGE. SDS-PAGE was done using discontinuous buffer system of Laemmli (1970).

### **Stock solutions**

#### 1. Acrylamide – bisacrylamide solution (30%)

|            |         |
|------------|---------|
| Acrylamide | 29.2 gm |
|------------|---------|

|               |       |
|---------------|-------|
| Bisacrylamide | 0.8 g |
|---------------|-------|

|                              |         |
|------------------------------|---------|
| Triple glass distilled water | 70.0 ml |
|------------------------------|---------|

Final volume was made to 100 ml filtered through Whatman No. 1 filter paper and stored at 4°C in dark bottle.

#### 2. 4x resolving gel buffer

(1.5 M Tris-HCl, pH = 8.8)

- |                              |          |
|------------------------------|----------|
| Tris base                    | 18.2 g   |
| Triple glass distilled water | 80.0 ml  |
| Final volume made to         | 100.0 ml |
| Filtered and stored at       | 4.0°C    |
3. 4x Stacking gel buffer  
(0.5M Tris-HCl, pH = 6.8)
- |                              |          |
|------------------------------|----------|
| Tris                         | 6.0 g    |
| Triple glass distilled water | 80.0 ml  |
| Final volume made to         | 100.0 ml |
| Filtered and stored at       | 4.0°C    |
4. 10% SDS
- |                              |          |
|------------------------------|----------|
| SDS                          | 10.0 gm  |
| Triple glass distilled water | 100.0 ml |
| Stored at room temperature   |          |
5. 2x stock sample buffer  
(0.125M Tris-HCl, 4% SDS, 20% glycerol, 0.05% bromophenol blue, 0.3M  $\beta$ -mercaptoethanol, pH 6.8)
- |                                   |        |
|-----------------------------------|--------|
| 0.5M Tris-HCl, buffer (pH 6.8)    | 2.4 ml |
| SDS                               | 0.4 g  |
| Glycerol                          | 2.0 ml |
| 0.5% Bromophenol blue (w/v water) | 1.0 ml |
| $\beta$ -mercaptoethanol          | 1.0 ml |
| Total volume                      | 1.0 ml |
| Stored at room temperature        |        |
6. 1.5% Ammonium per sulphate (APS)

|                              |                            |
|------------------------------|----------------------------|
| APS (Ammonium per sulphate)  | 0.150 g                    |
| Triple glass distilled water | To make 10 ml total volume |

Freshly prepared before use

7. TEMED (N,N,N',N'-tetramethyl ethylene diamine)  
TEMED was used undiluted from the bottle. Stored at cool and dry place, protected from light.

8. 1x Electrode buffer (SDS-Electrophoresis buffer)  
(0.025 M Tris-HCl, 0.192M glycine, 0.1% SDS, pH 8.3)

|                      |           |
|----------------------|-----------|
| Tris                 | 3.0 g     |
| Glycine              | 14.0 g    |
| 10% SDS              | 10.0 ml   |
| Total volume made to | 1000.0 ml |

9. Staining solution

(CBBR-250=0.1%, methanol=40%, glacial acetic acid=10%)

|                              |         |
|------------------------------|---------|
| CBBR-250                     | 0.1 g   |
| Methanol                     | 40.0 ml |
| Glacial acetic acid          | 10.0 ml |
| Triple glass distilled water | 100 ml  |

(to make)

10. Destaining solution

(20% methanol + 10% acetic acid)

|                              |         |
|------------------------------|---------|
| Methanol                     | 200 ml  |
| Acetic acid                  | 100 ml  |
| Triple glass distilled water | 1000 ml |

(To make)

11. **Molecular weight markers** Molecular weight markers of wide range containing 9 proteins (180.0, 116.0, 97.4, 66.0, 48.5, 29.0, 18.4, 14.2 and 6.5 kDa) were used. Molecular weight markers (Sigma chemicals) were prepared in gel loading buffer (approximately 0.2mg per ml of each protein). In one well 5  $\mu$ l of each molecular weight marker was loaded.
12. **Sample preparation** Samples were prepared by crushing 500 mg of fresh leaves in 1.0ml chilled tris buffer (0.1M, pH 7.5) containing 50 mg PVP (insoluble). These were then centrifuged at 10,000 x g at 4°C for 15 min. The pellet was discarded and supernatant containing proteins was preserved at -20°C in deep freezer. The protein quantification was done according to method given by Bradford (1976). The protein extract was transferred to an equal volume of 2 x sample buffer (Laemmli's 2 x sample buffer), heated at 100°C for 3 min., cooled and used for SDS-PAGE. An aliquot containing 50  $\mu$ g of sample protein was loaded in each well.

Electrophoresis was carried out using vertical slab gel electrophoresis apparatus (Model EL-975).

### **Procedure for SDS-PAGE**

Glass plates, spacers, combs and buffer reservoirs of the gel apparatus were thoroughly cleaned with detergent, rinsed and dried. A monomer solution for the appropriate resolving gel was prepared by combining all the reagents given in the above Table 1 except ammonium per sulphate and TEMED. Then ammonium per sulphate (APS) and TEMED were gently mixed into the deaerated monomer solution and the mixture was poured between the gel plates with the help of a beaker, upto the mark delimiting the resolving gel. It was immediately over layered with n-butanol. Polymerization was achieved in approximately 45 min. at room temperature.

**Table 1: Position of stacking and resolving gel for SDS-PAGE**

| <b>Sr. No.</b> | <b>Stock solution</b>                           | <b>Stacking gel (ml)</b> | <b>Resolving gel (ml)</b> |
|----------------|-------------------------------------------------|--------------------------|---------------------------|
| 1.             | Acrylamide-bisacrylamide (30% stock solution)   | 1.3                      | 10.0                      |
| 2.             | 4x stacking gel buffer (0.5M Tris-HCl, pH 6.8)  | 2.5                      | -                         |
| 3.             | 4x Resolving gel buffer (1.5M Tris-HCl, pH 8.8) | -                        | 3.75                      |
| 4.             | 10% SDS                                         | 0.1                      | 0.3                       |
| 5.             | 1.5% APS                                        | 0.5                      | 1.5                       |
| 6.             | TEMED                                           | 0.015                    | 0.015                     |

|    |              |        |        |
|----|--------------|--------|--------|
| 7. | Water        | 5.585  | 14.435 |
|    | Total volume | 10.0ml | 30.0ml |

Top of the resolving gel was thoroughly rinsed with water and water drops removed from above with the help of filter paper strips. Stacking gel solution (10 ml) was prepared as given (table 1) and poured on the top of the resolving gel. A well forming comb was then placed between the gel plates avoiding trapping of bubbles immediately. The stacking gel was allowed to polymerize at room temperature for 30-45 minutes.

Electrophoresis apparatus was assembled and upper and lower reservoir were filled with electrode buffer (pH 8.3). The comb was removed from the stacking gel and the wells were washed 2-3 times with electrode buffer. Prepared samples were then loaded into the wells in the stacking gel using a micropipette. Electrophoresis was carried out at room temperature at a constant current of 15 mA till the samples were in the stacking gel and at 25 mA once the samples entered the resolving gel. The run was continued till the tracking dye reached 5 mm above the bottom edge of the gel.

### **Staining (Coomassie brilliant blue R-250)**

Immediately after the electrophoretic run, the gasket was removed and the glass plates were slid apart with

a spatula. Slab gel was stained overnight in 500 ml of staining solution (stock solution 9). Next morning the staining solution was poured off and replaced with 500 ml of destaining solution (stock solution 10). Finally destaining of the gel was carried out by giving 3-4 changes with destaining solution until the background became transparent. Destaining was carried out at room temperature.

### **Molecular weight determination**

For molecular weight determination, a mixture of the marker proteins (stock solution 11) was also run with electrophoresis simultaneously in the same gel in the wells adjacent to sample wells.

After completion of electrophoresis, staining and background destaining, relative mobilities ( $R_m$  values) were calculated for each of the marker proteins and the resolved proteins by the following formula

$$R_m \text{ value} = \frac{\text{Migration distance of protein band}}{\text{Migration distance of tracking dye}}$$

$R_m$  values of marker proteins were plotted against log of molecular weights of marker proteins using semilogarithmic paper. Molecular weights of different proteins were estimated by matching their  $R_m$  values with appropriate point on the standard curve.

## CHAPTER – IV

# Results

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Results obtained during the course of present experimentation on physiological and molecular characterization of some salinity phytoremediating plants have been presented in this chapter

### **Experiment-I**

#### **5.1.1 Collection and inventorising the plants from saline wastelands of Hisar and adjoining area**

Table 1 shows the list of plants collected from saline wastelands of Hisar and adjoining areas. The plants were fixed on herbarium sheets. The herbarium consisted of 36 plants species belonging to 17 families was prepared (Plates I to IX). These plants were growing on the saline patches of wastelands and belong to different families like chenopodiaceae, gramineae (poaceae), papilionaceae (fabaceae), amaranthaceae, asclepiadaceae, capparidaceae, cyperaceae, boraginaceae, caesalpinaceae, portulacaceae, mimosaceae, salvadoraceae, tamaricaceae, aizoaceae, compositae (asteraceae) and solanaceae.

### 5.1.2 Magnitude of ionic accumulation in biomass of above ground plant parts of different plants collected from saline wastelands of Haryana and adjoining areas (mg g<sup>-1</sup> dry wt.)

Table 2 demonstrated that the magnitude of ionic accumulation in biomass of above ground plant parts. The Na<sup>+</sup> content was maximum in *Suaeda fruticosa*, *Physalis minima* and *Salsola baryosma* e.g. above 200 mg g<sup>-1</sup> dry wt. whereas, it was 150-200 in *Setaria indica*, *Portulaca oleracea*, *Heliotropium procumbens*, *Haloxylon recurvum*, *Capparis aphylla*, *Calotropis procera*, *Aerva tomentosa* and *Atriplex* species. In rest of the plants the Na<sup>+</sup> content was less than 150.

Similarly the Cl<sup>-</sup> content was also maximum in *Suaeda fruticosa* followed by *Haloxylon recurvum* and *Physalis minima*. The Cl<sup>-</sup> content was 145-200 mg g<sup>-1</sup> dry wt. in *Portulaca oleracea*, *Salsola baryosma*, *Capparis aphylla*, *Calotropis procera* and *Atriplex* species. In rest of the genera Cl<sup>-</sup> content was less than 145 mg g<sup>-1</sup> dry wt.

The total ion accumulation was also maximum in *Suaeda fruticosa*, *Physalis minima*, *Salsola baryosma*, *Haloxylon recurvum* and *Atriplex lentiformis* e.g. above 500 mg g<sup>-1</sup> dry weight. The total ions were 400-500 in *Portulaca oleracea*, *Heliotropium procumbens*, *Capparis aphylla*, *Calotropis procera*, *Atriplex nummularia*, *Atriplex amnicola*

and *Aerva tomentosa*. In rest of the plants it was less than 400 mg g<sup>-1</sup> dry wt.

### **5.1.3 Some characteristics of soil samples collected from rhizospheric soil of the plant from wastelands of Haryana and adjoining areas**

Table 3 projected the E<sub>Ce</sub>, pH, SAR (Sodium adsorption ratio) and ionic contents in the soil collected from rhizospheric soil of the plants from saline wastelands. The E<sub>Ce</sub> was maximum in soils from where *Tamarix aphylla*, *Parkinsonia aculeata*, *Eragrostis pilosa*, *Cyperus bulbosus* and *Chenopodium murale* i.e. above 20, whereas, it was 15-20 in *Suaeda fruticosa*, *Solanum xanthocarpum*, *Setaria indica*, *Sesbania sesquens*, *Salsola baryosma*, *Prosopis juliflora*, *Physalis minima* and *Arundo donax*. In rest of the plant soil the E<sub>Ce</sub> was below 15.

The pH was maximum in the rhizospheric soil of *Suaeda fruticosa* and *Amaranthus viridis*. Whereas, the pH was 8.5-9.0 in *Aerva*, *Alternanthera*, *Arundo*, *Atriplex lentiformis*, *Chenopodium murale*, *Cyperus*, *Eriochloa*, *Heliotropium*, *Parkinsonia*, *Physalis*, *Prosopis*, *Salvadora*, *Sesbania*, *Setaria* and *Vernonia*. In rest of the plants the pH was less than 8.5. Likewise, the total ionic content was more in the soil where E<sub>Ce</sub> and pH were also high.

The SAR (sodium adsorption ratio) was more in the rhizospheric soil of *Parkinsonia aculeata* and *Chenopodium*

*murale* i.e. above 10, whereas, it was least in rhizospheric soil of *Calotropis*, *Trianthema*, *Xanthium*, *Amaranthus*, *Aristida*, *Chenopodium ambrosoides* and *Cynodon* (i.e. below 4). In rest of the plants the SAR of the rhizospheric soil was between 4-10.

## **Experiment - II**

Above preliminary observations prompted us to take up exhaustive studies/investigations on 20 potential hyperaccumulator plants in the screen house which constitutes experiment-II (Fig. 1 to 19). These plants were mainly selected on the basis of either the magnitude of ionic accumulation in the above ground parts of the plants (mainly  $\text{Na}^+$  and  $\text{Cl}^-$  contents) or whose rhizospheric soil contained high amount of ECE, SAR and more contents of  $\text{Na}^+$  and  $\text{Cl}^-$  ions. In addition, some plants were selected on the basis of the availability of the seeds/plants during the period of experimentation.

### **5.2.1 Plant height (cm)**

The data presented in Table 4 clearly shows that the height in different halophytic taxa increased with increasing salinity but in other plants the height showed a significant decline with every enhancement of salinity.

At  $8 \text{ dSm}^{-1}$  of salinity the maximum per cent increase in plant height was 52, 30 and 26 in case of *Salicornia brachiata*, *Portulaca oleracea* and *Solanum*

*xanthocarpum* in comparison to their respective controls ( $S_0$ ), whereas, it was 10-17 per cent increase in height at 8 dSm<sup>-1</sup> ( $S_1$ ) in comparison to controls in genera *Trianthema*, *Atriplex*, *Arundo* and *Aleurops*. In rest of the genera like *Aerva*, *Suaeda* and *Calotropis* the increase was to the tune of 2-10 per cent than the controls. In rest of the genera the plant height was decreased with increase in salinity as in case of *Heliotropium procumbens*, *Sesbania sesquens*, *Parkinsonia aculeata*, *Prosopis juliflora*, *Cynodon dactylon* and *Setaria indica*.

Similarity, at 16 dSm<sup>-1</sup> ( $S_2$ ) the maximum per cent increase in plant height was 88, 44.5, 38 and 26 in the *Salicornia brachiata*, *Portulaca oleracea*, *Trianthema portulacastrum* and *Atriplex lentiformis*, respectively in comparison to respective controls ( $S_0$ ). Whereas, it was 10-20 per cent enhancement in plants like *Arundo donax*, *Atriplex amnicola*, *Suaeda frutescens*, *Aleurops lagopoides*, *Xanthium strumarium* and *Aerva tomentosa* in comparison to their respective controls ( $S_0$ ). In rest of the plants the height was declined and maximum decrease was observed in genera like *Solanum xanthocarpum* (64) and *Setaria indica* (49) in comparison to their respective controls ( $S_0$ ). It may be noted here that, in general there was one-fold increase in plant height of members of chenopodiaceae and other hyperaccumulator plants at both the salinity levels.

### 5.2.2 Number of branches per plant

Table 5 presents the number of branches of different hyperaccumulator plants as affected by increasing salinity level from 0-16 dSm<sup>-1</sup>.

The maximum number of branches was observed in the members of chenopodiaceae, *Aerva tomentosa* and *Trianthema portulacastrum*.

At 8 dSm<sup>-1</sup> of salinity the magnitude of increase in number of branches was to the tune of 20-40 per cent than the controls (S<sub>0</sub>) in *Trianthema portulacastrum*, *Salicornia brachiata*, *Aleurops lagopoides*, *Atriplex lentiformis* and *Atriplex nummularia*, whereas, it was 6-20 per cent increase in number of branches in *Portulaca oleracea*, *Aerva tomentosa*, *Atriplex amnicola*, *Chenopodium ambrosoides* and *Suaeda fruticosa* than their respective controls (S<sub>0</sub>). In rest of the genera there was no effect on the number of branches except *Heliotropium* where the decline in branches was observed.

Similarly, at 16 dSm<sup>-1</sup> of salinity the maximum per cent increase in number of branches was observed in *Trianthema portulacastrum* (66.7%), *Atriplex lentiformis* (60%) and *Aleurops lagopoides* (60%) in comparison to their controls (S<sub>0</sub>). The magnitude was enhanced to the tune of 20-42 per cent in *Portulaca oleracea*, *Atriplex nummularia*, *Cynodon dactylon*, *Salicornia brachiata*, *Atriplex amnicola*,

*Chenopodium ambrosoides* than their respective controls ( $S_0$ ) whereas, it was 13 per cent in *Aerva tomentosa* and 18.7 in *Suaeda fruticosa* in comparison to their individual controls ( $S_0$ ).

It may be noted that the number of branches did not differ with either of the salinity levels in comparison to their individual control ( $S_0$ ) in *Solanum*, *Xanthium*, *Sesbania*, *Parkinsonia*, *Calotropis*, *Prosopis*, *Arundo* and *Setaria*.

### **5.2.3 Number of leaves per plant**

Table 6 enumerates that the number of leaves per plant were increased in members of chenopodiaceae, *Portulaca oleracea*, *Trianthema portulacastrum*, *Aerva tomentosa*, *Arundo donax*, *Aleurops lagopoides* and *Cynodon datylon* than their respective controls ( $S_0$ ). In rest of the genera the number of leaves declined with increasing salinity levels.

At 8 dSm<sup>-1</sup> ( $S_1$ ) the maximum per cent increase in number of leaves was seen in *Cynodon* (45.8), *Trianthema* (35) and *Suaeda fruticosa* (35). Whereas it was to the tune of 4-22 per cent in *Atriplex species*, *Portulaca*, *Aerva*, *Arundo* and *Aleurops* in comparison to their respective controls ( $S_0$ ). In rest of the genera, the number of leaves declined and maximum decrease was observed in *Calotropis procera*, *Xanthium strumarium* and *Solanum xanthocarpum*.

Similarly the per cent magnitude of number of leaves was maximum in *Trianthema* (72.6) and *Suaeda fruticosa* (53), *Atriplex lentiformis* (34) and *Aleurops* (31) at 16 dSm<sup>-1</sup> than their controls (S<sub>0</sub>). It was to the tune of 10-25 per cent in genera like *Portulaca*, *Aerva*, *Atriplex amnicola*, and *Arundo donax*. In rest of the genera number of leaves were declined at 16 dSm<sup>-1</sup> than their controls (S<sub>0</sub>). The maximum per cent decline was observed in *Solanum*, *Heliotropium* and *Parkinsonia*. The leaves were absent in *Salicornia brachiata* as it possessed only succulent green shoots.

#### **5.2.4 Fresh weight of stem (g)**

Table 7 illustrated the increase/decrease in fresh weight of plants in response to salinity levels in twenty hyper-accumulator plants selected for the present study.

At 8 dSm<sup>-1</sup> (S<sub>1</sub>) the per cent increase in fresh weight was maximum in *Salicornia brachiata* (165%), *Aleurops lagopoides* (75%) and in *Solanum xanthocarpum* (72%) in comparison to their respective controls (S<sub>0</sub>), whereas, it was in the tune of 40-60 per cent more than the control in *Atriplex lentiformis*, *Suaeda fruticosa*, *Arundo donax* and *Portulaca oleracea*. Likewise, it was to the tune of 10-40 per cent in genera like *Trianthema*, *Aerva*, *Atriplex* and *Cynodon* than their individual controls (S<sub>0</sub>). But in rest of the genera the fresh weight decreased at 8 dSm<sup>-1</sup> than their respective controls (S<sub>0</sub>).

Similarly, at  $16 \text{ dSm}^{-1}$  ( $S_2$ ) the per cent increase in fresh weight was maximum in *Salicornia brachiata* (260), *Aleurops lagopoides* (127) and *Atriplex lentiformis* (117) than their respective controls ( $S_0$ ). It was to the tune of 60 – 90 per cent more than their controls ( $S_0$ ) in *Suaeda*, *Arundo* and *Portulaca*. It was to the extent of 30-60 per cent more in *Trianthema* and *Atriplex amnicola*. However it was only increased upto 2 per cent in *Atriplex nummularia* and 26 per cent in *Aerva* than their controls ( $S_0$ ). In rest of the genera the magnitude of fresh weight was decreased in comparison to their individual controls ( $S_0$ ). The maximum decline in fresh weight was observed in *Setaria* (73 %) and *Sesbania* (65%) than their individual controls ( $S_0$ ).

It may noted that in *Salicornia brachiata*, the fresh weight was 2.6 - 3.6 times more under salinity than its control.

#### **5.2.5 Dry weight of stem (g) per plant**

A perusal of data presented in Table 8 revealed that increasing levels of salinity stress significantly increased the dry weight of halophytes but prominently decreased in other potential hyperaccumulators.

At  $8 \text{ dSm}^{-1}$  the maximum per cent increase was observed in *Solanum* (41) and *Arundo* (44) than their respective controls. The magnitude of increase of dry weight of stem was 0.19 - 0.32 times more than their respective

controls in the member of chenopodiaceae, *Portulaca*, *Aerva*, *Trianthema*, *Cynodon* and *Aleurops*. In rest of the genera the decrease in dry weight was observed at this very salinity level.

Similarly, at 16 dSm<sup>-1</sup> the per cent increase of dry weight was maximum in *Aerva* (97), *Trianthema* (84), *Atriplex lentiformis* (84) and *Arundo* (79) than their own controls (S<sub>0</sub>). It was in the tune of 30-55 per cent in *Atriplex species*, *Portulaca*, *Aleurops*, *Salicornia* and *Suaeda* in comparison to their respective controls (S<sub>0</sub>). In rest of the genera the decline in dry weight was observed. The magnitude of decline was to the tune of 0.2 – 0.5 times in *Setaria*, *Prosopis*, *Parkinsonia*, *Sesbania*, *Heliotropium*, *Solanum* and *Chenopodium*, than their respective controls (S<sub>0</sub>). Likewise, 45-48 per cent declination was observed in case of *Xanthium*, *Calotropis procera* in comparison to their respective control (S<sub>0</sub>). The decline was the least of all the genera at 16 dSm<sup>-1</sup> of salinity in *Cynodon dactylon*.

#### **5.2.6 Fresh weight of leaves (g) per plant**

The data presented in Table 9 shows the effect on fresh weight of leaves with increasing levels of salinity.

At 8 dSm<sup>-1</sup> (S<sub>1</sub>) the magnitude of fresh weight was to the tune of 55-80 per cent more than the respective controls (S<sub>0</sub>) in *Solanum*, *Trianthema*, *Atriplex lentiformis* and *Aleurops*, whereas, it was more to the tune of 10-30 per cent

than their individual controls ( $S_0$ ) in *Arundo*, *Cynodon*, *Atriplex nummularia*, *Portulaca*, *Aerva* and *Suaeda*. However, there was slight increase in the fresh weight of leaves of *Atriplex amnicola*, than control ( $S_0$ ). In rest of the genera decline in fresh weight of leaves was observed.

Likewise at  $16 \text{ dSm}^{-1}$  the increase in magnitude was observed in *Portulaca*, *Trianthema*, *Aerva*, *Atriplex lentiformis*, *Suaeda*, *Arundo* and *Aleurops* in comparison to their respective controls ( $S_0$ ). The maximum per cent increase was observed in *Atriplex lentiformis* (115) than control ( $S_0$ ). In rest of the genera there was a gradual decline in fresh weight of leaves with increment of salinity levels. The maximum per cent decrease was in *Setaria* (75) and *Parkinsonia* (67) than their individual controls.

#### **5.2.7 Dry weight of leaves ( $\text{g plant}^{-1}$ )**

Dry weight of leaves (Table 10) was enhanced in halophytes and two genera of grasses i.e. *Arundo* and *Aleurops*, with increasing levels of salinity in comparison to their respective controls ( $S_0$ ). In rest of the genera, it was decreased with salinity than their individual controls.

Per cent dry weight of leaves registered enhancement in *Solanum xanthocarpum* (74%) and *Aerva tomentosa* (42%) than their individual controls ( $S_0$ ) at  $8 \text{ dSm}^{-1}$  of salinity. Similarly, it was to the tune of 20-40 per cent more in genera like *Atriplex*, *Portulaca*, *Trianthema* and

*Aleurops* than their respective controls ( $S_0$ ). In *Suaeda fruticosa* (9%) and *Arundo donax* (17%) a least increase in dry weight of leaves was registered. There was a maximum decrease in *Xanthium strumarium* i.e. 51.5%. The decline in the dry weight of leaves was 20-400 per cent in *Sesbania*, *Parkinsonia*, *Prosopis*, *Cynodon*, *Setaria*, *Calotropis*, and *Heliotropium* than their individual controls ( $S_0$ ).

Likewise, at  $16 \text{ dSm}^{-1}$  of salinity the maximum per cent increase was observed in *Trianthema portulacastrum* (112%) than its controls ( $S_0$ ). It was to the tune of 60-80 per cent more than the respective controls in *Atriplex lentiformis*, *Atriplex amnicola* and *Aerva tomentosa*, whereas, it was 20-40 per cent more in *Arundo*, *Aleurops*, *Suaeda* and *Portulaca*. The magnitude of decrease at higher salinity in comparison to their respective controls was observed in *Solanum* (63%) and *Xanthium* (62%). Likewise, the decline in dry weight of leaves was to the tune of 40-60 per cent less than their respective controls in *Atriplex nummularia*, *Sesbania sesquens*, *Calotropis procera*, *Parkinsonia aculeata*, *Setaria indica*, *Prosopis juliflora* and *Heliotropium procumbens*, whereas, it was 32 per cent in *Chenopodium ambrosoides*.

#### **5.2.8 Total fresh biomass (g/plant)**

Table 11 illustrated that the total fresh biomass was enhanced with every increment of salinity levels than

controls ( $S_0$ ) in halophytes and some genera of grasses e.g., *Aelurops*, *Arundo* and *Cynodon*.

At  $8 \text{ dSm}^{-1}$  ( $S_1$ ) of salinity the per cent increase in total fresh biomass at  $S_1$  in comparison to their respective controls ( $S_0$ ) was maximum in case of *Salicornia brachiata* (165%). The total fresh biomass (stem + leaves) was enhanced to the extent of 60-75 per cent in *Solanum*, *Aelurops*, and *Atriplex lentiformis*, 35-45 per cent in *Arundo* and *Trianthema*, 10-30 per cent in *Cynodon*, *Atriplex nummularia*, *Portulaca*, *Aerva* and *Suaeda* over their individual controls ( $S_0$ ) whereas, only 5 per cent increase in *Atriplex amnicola* was registered in comparison to its control ( $S_0$ ). On the other hand the decrease was observed in *Setaria* (62%) and *Parkinsonia* (34%) than their individual controls ( $S_0$ ) whereas, it declined to the tune of 10-30 per cent than their respective controls ( $S_0$ ) in *Xanthium*, *Chenopodium*, *Sesbania*, *Heliotropium*, *Calotropis* and *Prosopis*.

Likewise, at  $16 \text{ dSm}^{-1}$  ( $S_2$ ) salinity the maximum per cent increase than its respective controls ( $S_0$ ) was observed in *Salicornia brachiata* (260%). Similarly, the promotion of biomass was to the tune of 75-110 per cent more than their individual controls ( $S_0$ ) in *Atriplex lentiformis*, *Aelurops lagopoides*, *Trianthema portulacastrum* and *Arundo donax*.

Furthermore, the total fresh biomass of *Suaeda* and *Portulaca* enhanced to the extent of 40-45% over that of their respective controls ( $S_0$ ), but it was to the tune of 10-30 per cent more than their controls ( $S_0$ ) in *Aerva tomentosa* and *Atriplex amnicola*. The decline in magnitude of total fresh weight at  $S_2$  than  $S_0$ , was maximum in *Setaria indica* and *Parkinsonia aculeata*. The decline in total fresh weight at  $S_2$  than  $S_0$  was to the tune of 20-40 per cent in genera like *Calotropis*, *Heliotropium*, *Xanthium* and *Atriplex nummularia*, whereas it was 40-60 per cent decline in genera like *Cynodon*, *Parkinsonia*, *Prosopis*, *Sesbania*, *Solanum* and *Chenopodium*.

### **5.2.9 Total dry biomass (g/plant)**

Total dry biomass (Table 12) was enhanced with increasing salinity than the controls ( $S_0$ ) in the members of *Atriplex*, *Salicornia*, *Portulaca*, *Trianthema*, *Aerva*, *Arundo* and *Aelurops* but it declined in rest of the genera.

At 8 dSm<sup>-1</sup> ( $S_1$ ), the total dry biomass registered an increase over that of their respective controls ( $S_0$ ) in genera like, *Solanum xanthocarpum* (62%). *Atriplex*, *Aerva*, *Trianthema*, *Portulaca*, *Arundo* and *Aelurops* (20-40%), whereas, it was to the tune of 10-20 per cent more at  $S_1$  than  $S_0$  in *Suaeda* (11.5%) and *Salicornia* (18%).

Conversely, the magnitude of total dry biomass was declined at  $S_1$  than  $S_0$  in rest of the genera. The decline

in *Xanthium* and *Setaria* was observed to the tune of 15-35 per cent over that of their respective controls ( $S_0$ ).

Similarly, at  $16 \text{ dSm}^{-1}$  ( $S_2$ ) the per cent increase in total dry biomass than their respective controls ( $S_0$ ) was maximum in *Trianthema portulacastrum* (97%). Further, the increase was to the extent of 67.5, 80 and 81 per cent in *Atriplex amnicola*, *Aerva tomentosa* and *Atriplex lentiformis*, respectively.

Likewise, it was 30-55 per cent increase at  $S_2$  than  $S_0$  in *Arundo*, *Aelurops* and *Portulaca*. On the contrary, the decline in magnitude of total dry biomass at  $S_2$  than  $S_0$  was to the tune of 40-60 per cent in rest of the genera, whereas, the per cent decline was 17.5 and 23.0 in *Atriplex nummularia* and *Cynodon dactylon*, respectively.

#### **5.2.10 Water content in stem (g/plant)**

The data in Table 13 presents the water content in stem of different hyperaccumulator plants under salinity levels. It was seen that it enhanced in halophytes and some grasses like *Portulaca*, *Trianthema*, *Aerva*, *Arundo donax*, *Aelurops lagopoids* and *Cynodon dactylon* with increasing salinity levels, whereas, it declined in rest of the genera studied during the present investigation.

At  $8 \text{ dSm}^{-1}$  ( $S_1$ ) percent water content in stem was maximum in *Salicornia brachiata* (229%) than its control ( $S_0$ ). It was 54, 79, 90, 107 and 110 per cent more than the

controls ( $S_0$ ) in *Arundo donax*, *Atriplex lentiformis*, *Suaeda fruticosa*, *Solanum xanthocarpum* and *Aleurops lagopoides* respectively. It was to the tune of 10-45 per cent more than the respective controls ( $S_0$ ) in *Portulaca*, *Cynodon*, *Trianthema*, *Atriplex* species. However, the water content in stem of *Aerva* was only enhanced to 1.12 per cent in comparison to its control ( $S_0$ ). On the other hand magnitude of water content declined at  $S_1$  in comparison to  $S_0$  in rest of the genera.

At higher salinity ( $16 \text{ dSm}^{-1}$ ), the per cent water content in stem was maximum in *Salicornia brachiata* (336%). The per cent stimulation in water content of stem at  $16 \text{ dSm}^{-1}$  than control was 34, 46, 70, 82, 172.5, 176 and 183 per cent increase of other genera like *Atriplex amnicola*, *Trianthema*, *Portulaca*, *Arundo*, *Suaeda*, *Atriplex lentiformis* and *Aleurops lagopoides*, respectively. However, the magnitude of water content in stem was declined in rest of the genera at higher salinity than their respective controls ( $S_0$ ). The maximum decline was observed in *Setaria indica* and *Cynodon dactylon*.

#### **5.2.11 Water content in leaves (g/plant)**

A perusal of data presented in table 14 showed that the water content of leaves significantly increased with increasing levels of salinity in members of chenopodiaceae, *Portulaca*, *Trianthema*, *Aerva*, *Solanum*, *Arundo*, *Aleurops*,

*Cynodon* and decreased in rest of the genera studied during the course of the present investigations in comparison to their respective controls ( $S_0$ ).

At 8 dSm<sup>-1</sup> ( $S_1$ ) salinity the maximum per cent increase in water content in leaves in comparison to their individual controls was observed in *Atriplex lentiformis* (112%), *Aleurops* (96%) and *Solanum* (78%). Similarly, it was to the tune of 35-70 per cent more than controls ( $S_0$ ) in *Trianthema*, *Cynodon* and *Arundo*, whereas, it was 3.5-20.5 per cent more water content in leaves than their respective controls ( $S_0$ ) in *Portulaca*, *Aerva*, *Atriplex nummularia*, *Suaeda* and *Xanthium*.

In rest of the genera the water content declined to the tune of 2-12 per cent than their respective controls ( $S_0$ ) and maximum per cent depletion was observed in *Setaria* (8%) and *Parkinsonia* (39%).

Likewise, at 16 dSm<sup>-1</sup> ( $S_2$ ) the water content in leaves was more than the controls ( $S_0$ ) and it was maximum in *Atriplex lentiformis* (193%) and *Aleurops lagopoides* (160%). The per cent increase in water content of leaves at higher salinity than their individual controls ( $S_0$ ) was 15, 27, 30, 78 and 85 in the genera, *Aerva*, *Suaeda*, *Portulaca*, *Arundo* and *Trianthema*, respectively. However, in rest of the genera it declined. The maximum per cent decline at higher salinity in comparison to their respective controls ( $S_0$ ) was observed in

*Setaria* and *Parkinsonia* i.e. 87 and 71, respectively. The declination was upto 40-60 percent in comparison to their controls ( $S_0$ ) in *Chenopodium*, *Solanum* and *Cynodon*. Likewise, it was 18-40 per cent decline in *Prosopis*, *Calotropis*, *Heliotropium*, *Sesbania* and *Atriplex* species. It must be noted that a slight decline in water content in leaves at  $S_2$  ( $16\text{dSm}^{-1}$ ) than control ( $S_0$ ) was observed in *Xanthium strumarium*.

#### **5.2.12 Total water content in plant (g/plant)**

Table 15 presented here showed that the total water content was promoted with every increment of salinity from  $0\text{-}16\text{ dSm}^{-1}$  in members of *Chenopodiaceae*, *Salicornia*, *Aerva*, *Portulaca*, *Trianthema*, *Solanum*, *Arundo*, *Aleurops* and *Cynodon* and it was decreased in rest of the genera.

At  $8\text{dSm}^{-1}$  of salinity, more total water content magnitude was possessed by *Salicornia brachiata* (229.6%), *Atriplex lentiformis* (109%) and *Aleurops lagopoides* (103%) in comparison to their respective control ( $S_0$ ). It was 3, 19.5, 21, 22, 44, 45, 48 and 78.5 per cent more than their individual controls ( $S_0$ ) in *Aerva*, *Atriplex nummularia*, *Portulaca*, *Suaeda*, *Cynodon*, *Arundo*, *Trianthema* and *Solanum*, respectively. However it was depleted in rest of the genera. The maximum percent depletion in total water content in plant at this very salinity level in comparison to control was observed in *Setaria indica* (67%).

Taking into consideration the higher salinity (16 dSm<sup>-1</sup>) the maximum per cent increase in total water content in plants than their respective controls (S<sub>0</sub>) was observed in *Salicornia brachiata* (336%), *Atriplex lentiformis* (184%) and *Aleurops lagopoides* (172%). Similarly, it was 5, 44, 47, 69 and 80 per cent more than their respective controls (S<sub>0</sub>) in *Aerva*, *Portulaca*, *Suaeda*, *Trianthema* and *Arundo*, respectively.

In rest of the genera, the magnitude of total water content was depleted at higher salinity level (16dSm<sup>-1</sup>) than their controls. The percent depletion in water content was observed to maximum extent in *Setaria* (179%), *Cynodon* (66.5%) and *Parkinsonia* (59%). Similarly, it was 30-50 per cent depletion in comparison to their respective controls in *Prosopis*, *Calotropis*, *Sesbania*, *Heliotropium*, *Solanum* and *Chenopodium*, whereas it was only 3 percent in *Atriplex amnicola*, 18 percent in *Xanthium strumarium* and 21 percent in *Atriplex nummularia* in comparison to their respective controls (S<sub>0</sub>).

#### **5.2.13 Ash content of stem (g g<sup>-1</sup> dry wt.)**

Ash content of stem (Table 16) was enhanced with increasing level of salinity than their controls (S<sub>0</sub>) in all experimental plants. The increment of ash content of stem was more at 16 dSm<sup>-1</sup> than at 8 dSm<sup>-1</sup> of salinity. In general, it was more in *Salicornia brachiata*, *Trianthema*

*portulacastrum* and *Portulaca oleracea*. It was least in *Prosopis juliflora*, *Arundo donax*, *Chenopodium ambrosoides*, *Atriplex amnicola*, *Suaeda fruticosa*, *Aleurops lagopoides* and *Cynodon dactylon*.

At 8 dSm<sup>-1</sup> of salinity the ash content of stem was 38, 41 and 51 percent more than the control (S<sub>0</sub>) in *Sesbania sesquens*, *Setaria indica* and *Calotropis procera*, respectively. Similarly, it was to the tune of 10-30 percent more than their controls (S<sub>0</sub>) in *Salicornia*, *Aerva*, *Parkinsonia*, *Prosopis*, *Arundo*, *Cynodon* and *Atriplex amnicola*, while it was 5-10 percent more ash content of stem in comparison to their controls (S<sub>0</sub>) in *Portulaca*, *Xanthium*, *Heliotropium* and *Aleurops*. However, the ash content of *Solanum xanthocarpum* remained at par with controls (S<sub>0</sub>).

Likewise, at 16dSm<sup>-1</sup> of salinity the magnitude of increase in ash content was maximum in *Sesbania sesquens*, *Prosopis juliflora* and *Cynodon dactylon* i.e 92, 72 and 63 percent, respectively. The per cent promotion in ash content of stem was of the tune of 30-60% than their respective controls (S<sub>0</sub>) *Calotropis*, *Setaria*, *Parkinsonia*, *Arundo*, *Chenopodium*, *Aerva*, *Salicornia*. Whereas, it was 10-30 percent more than the control (S<sub>0</sub>) in *Portulaca*, *Trianthema*, *Solanum*, *Xanthium*, *Heliotropium* and members of *chenopodiaceae*. The ash content of stem in *Aleurops lagopoides* was slightly increased in comparison to control (S<sub>0</sub>), but was less than 8dSm<sup>-1</sup> of

salinity. Overall, the ash content in the above case remained statistically at par in all the treatments.

#### **5.2.14 Ash content of leaves ( $\text{g g}^{-1}$ dry wt.)**

The data presented in Table 17 enumerated the ash content of leaves which showed enhancement with increasing levels of salinity ( $0\text{-}16 \text{ dSm}^{-1}$ ) than their respective controls ( $S_0$ ) except *Parkinsonia aculeata* and *Aleurops lagopoides* where it was diminished at  $16 \text{ dSm}^{-1}$  of salinity than its controls ( $S_0$ ).

The increment of ash content of leaves was  $10\text{-}16$  per cent more at  $8 \text{ dSm}^{-1}$  than controls ( $S_0$ ) in *Atriplex amnicola*, *Calotropis procera*, *Prosopis juliflora* and *Cynodon dactylon*. In rest of the genera, the percent increment of ash content of leaves at  $8 \text{ dSm}^{-1}$  of salinity was  $1\text{-}10\%$ .

Similarly at higher salinity ( $16 \text{ dSm}^{-1}$ ) the ash content of leaves was promoted than the controls to the tune of  $15\text{-}30 \%$  in *Aerva tomentosa*, *Atriplex amnicola*, *Suaeda fruticosa*, *Calotropis procera*, *Prosopis juliflora*, *Arundo donax*, *Cynodon dactylon* and *Seteria indica*, whereas, it was enhanced only from  $4\text{-}15$  per cent more than their respective controls in rest of the genera. It may be noted that in *Aleurops* and *Parkinsonia*, the ash content declined at  $16 \text{ dSm}^{-1}$  of salinity in comparison to their  $S_0$  controls.

#### **5.2.15 Organic matter of stem (g g<sup>-1</sup> dry wt.)**

The results in Table 18 depicted the organic matter in stem of different hyperaccumulator plants under increasing salinity levels (0-16 dSm<sup>-1</sup>).

At 8dSm<sup>-1</sup> of salinity the organic matter in stem was diminished to the tune of 0.5-5.0 per cent than their respective controls (S<sub>0</sub>) in all experimental plants except *Solanum xanthocarpum* where it remained at par with its controls (S<sub>0</sub>).

At higher salinity (16 dSm<sup>-1</sup>) the organic matter in stem was further reduced than their respective controls (S<sub>0</sub>). The reduction was maximum in *Prosopis juliflora* i.e., 30.6% over that of its control (S<sub>0</sub>). Furthermore, a decline of 5-10 percent over their respective controls (S<sub>0</sub>) was observed in case of *Setaria indica*, *Calotropis procera*, *Sesbania sesquens* and *Salicornia brachiata*, whereas, it was merely reduced to 1-5 per cent over their respective control (S<sub>0</sub>) in rest of the experimental plants. It was worth while to note that the decline in organic matter of stem was least in *Aleurops lagopoides* i.e. 0.56%.

#### **5.2.16 Organic matter in leaves (g g<sup>-1</sup> dry wt.)**

The data presented in table 19 showed that the organic matter in leaves was also clearly decreased with increasing levels of salinity. The decline was more at 16 dSm<sup>-1</sup>

of salinity except *Parkinsonia aculeata* where a slight increase in organic matter was observed.

At 8 dSm<sup>-1</sup> of salinity, the decline in organic matter in leaves in comparison to their respective controls (S<sub>0</sub>) was 0.5-3 per cent in all the experimental plants, whereas, it was reduced 1-7 per cent over that of their respective controls (S<sub>0</sub>) at higher salinity (16 dSm<sup>-1</sup>) in all salinity hyperaccumulator plants studied in the course of this investigation.

#### **5.2.17. Ionic status, ECe, pH, CEC, SAR and Na<sup>+</sup>/K<sup>+</sup> ratio of soil before plantation**

Table 20 showed that all the ions (Na<sup>+</sup>, Ca<sup>2+</sup>, Mg<sup>2+</sup>, Cl<sup>-</sup>, SO<sub>4</sub><sup>2-</sup>) were increased with increasing levels of salinity from 0-16 dSm<sup>-1</sup> except K<sup>+</sup> which remained almost at par. ECe, pH, SAR and Na<sup>+</sup>/K<sup>+</sup> ratio were also increased with every increment of salinity levels than the controls (S<sub>0</sub>). As expected the increment in ionic status, ECe, pH, SAR, Na<sup>+</sup>/K<sup>+</sup> was more at 16 dSm<sup>-1</sup> than at 8 dSm<sup>-1</sup> of salinity, but the CEC had remained unchanged or consistent irrespective of salinity levels.

#### **5.2.18 Sodium content in soil after harvesting (µg/g soil)**

The increment in added salinity levels (0, 8 and 16 dSm<sup>-1</sup>) obviously caused an increase in Na<sup>+</sup> content of soil of all plant species (Table 21) in comparison to their respective controls (S<sub>0</sub>).

The  $\text{Na}^+$  content was higher in the soil where *Setaria indica*, followed by *Heliotropium procumbens*, *Xanthium strumarium*, *Calotropis procera*, *Parkinsonia aculeata*, *Prosopis juliflora*, *Solanum xanthocarpum* and *Sesbania sesquens* were growing and the extent of  $\text{Na}^+$  content in the soil of these plants was in the range of 15 to 17 times. Whereas, it was 13 to 14 times more than their respective controls in the soils where *Suaeda frutosa*, *Atriplex species*, *Salicornia brachiata* and *Trianthema portulacastrum* were growing. This clearly showed that soil where halophytic taxa belonging to family chenopodiaceae remained in the soil the  $\text{Na}^+$  content was comparatively less than where other hyperaccumulator plants were growing.

#### **5.2.19 Sodium content in stem ( $\text{mg g}^{-1}$ dry wt.)**

Table 22 shows the  $\text{Na}^+$  content in stem of different hyperaccumulators under various added salinity levels. As expected, the amount of  $\text{Na}^+$  rather sharply enhanced under both the salinity levels and the increment was 3-5 times more at  $8 \text{ dSm}^{-1}$  and 4-8 times more at  $16 \text{ dSm}^{-1}$  in comparison to respective controls ( $\text{S}_0$ ).

Needless to mention here that increment in  $\text{Na}^+$  accumulation in stem was more at  $16 \text{ dSm}^{-1}$  than at  $8 \text{ dSm}^{-1}$  of salinity. The overall accumulation of  $\text{Na}^+$  was in general, more in *Salicornia*, most of the members of chenopodiaceae, *Aerva*, *Portulaca* and *Trianthema*. It was least in case of

*Calotropis procera*, *Prosopis juliflora*, *Parkinsonia aculeata*, *Sesbania sesquens*, *Heliotropium procumbens*, *Xanthium strumarium*, *Chenopodium ambrosoides* and *Setaria indica*.

At 8 dSm<sup>-1</sup> of salinity the accumulation of Na<sup>+</sup> was 5 times more than its controls in *Salicornia brachiata*, 3.5 times in members of chenopodiaceae and 3 times in rest of the experimental plants. It was 345 percent more accumulation of Na<sup>+</sup> than control in *Salicornia*, whereas, it was to the tune of 200-250 per cent in the member of chenopodiaceae, *Aerva*, *Trianthema*, *Portulaca*, *Solanum*, *Xanthium*, *Arundo*, *Cynodon* and *Setaria*. In rest of the genera the accumulation of Na<sup>+</sup> was more to the tune of 150-200 per cent more than their respective controls (S<sub>0</sub>).

Likewise, at 16 dSm<sup>-1</sup> of salinity the percent accumulation of Na<sup>+</sup> was more in most of the members of chenopodiaceae, *Trianthema*, *Aerva*, *Portulaca*, *Salicornia*, *Arundo* and *Aleurops*, where it was accumulated 500-700 percent more at 16 dSm<sup>-1</sup> (S<sub>2</sub>) than their respective controls (S<sub>0</sub>). It was between 300-500 percent more than S<sub>0</sub> in rest of the genera like *Setaria*, *Cynodon*, *Prosopis*, *Parkinsonia*, *Calotropis*, *Sesbania*, *Heliotropium*, *Xanthium*, *Solanum* and *Chenopodium*. In general, the accumulation of Na<sup>+</sup> enhanced 4-8 times more at S<sub>2</sub> than S<sub>0</sub>. It is rather expected also as the salinity S<sub>1</sub> (8 dSm<sup>-1</sup>) is exactly half of S<sub>2</sub> (16 dSm<sup>-1</sup>).

### 5.2.20 Na<sup>+</sup> in leaves (g g<sup>-1</sup> dry wt.)

Table 23 demonstrated the content of Na<sup>+</sup> in leaves of different salt hyperaccumulator plants. It clearly increased with increasing salinity levels from 0-16 dSm<sup>-1</sup>. The increase was more at 16 dSm<sup>-1</sup> than at 8 dSm<sup>-1</sup> of salinity. The overall accumulation of Na<sup>+</sup> was, in general, more in most of the member of chenopodiaceae, *Portulaca oleracea* and *Trianthema portulacastrum* and it was the least in case of *Setaria indica*, *Cynodon dactylon*, *Calotropis procera*, *Parkinsonia aculeata*, *Xanthium strumarium* and *Chenopodium ambrosoides*.

At 8 dSm<sup>-1</sup> of salinity, the accumulation of Na<sup>+</sup> was to the tune of 300-350 per cent more than the controls (S<sub>0</sub>) in leaves either in most of the chenopods or in the genera like *Trianthema* and *Aerva*. Whereas, it was 200-300 per cent more of the Na<sup>+</sup> at 8 dSm<sup>-1</sup> in comparison to their respective controls (S<sub>0</sub>) in leaves of genera like *Portulaca*, *Atriplex*, *Solanum*, *Prosopis*, *Arundo* and *Cynodon*. In rest of the leaves of different genera accumulation of Na<sup>+</sup> was to the tune of 100-200 percent more at 8 dSm<sup>-1</sup> than their individual controls (S<sub>0</sub>).

Similarly the per cent accumulation of Na<sup>+</sup> at 16 dSm<sup>-1</sup> was also more in most of the members of the chenopodiaceae, *Portulaca*, *Trianthema*, *Aerva*, *Solanum*, *Calotropis* and *Prosopis*, where it was accumulated 400-670 per cent more at 16 dSm<sup>-1</sup> than their respective own controls

(S<sub>0</sub>). It was between 300-400 percent more than S<sub>0</sub> in *Atriplex*, *Suaeda*, *Xanthium*, *Sesbania*, *Heliotropium*, *Parkinsonia* and *Arundo*. Likewise, it was 180 to 300 percent more in *Aleurops*, *Cynodon* and *Setaria*. It must be mentioned that in general, the accumulation of Na<sup>+</sup> enhanced 1-3 times more at S<sub>1</sub> and 3-6 times at S<sub>2</sub> levels in comparison to S<sub>0</sub> dSm<sup>-1</sup> (controls) of salinity.

#### **5.2.21 Bioaccumulation of Na<sup>+</sup> in plant (mg/total dry wt. of plants in a pot)**

Table 24 shows the bioaccumulation of Na<sup>+</sup> ions in the total dry biomass of all the plants growing in a pot under various added salinity levels (0-16 dSm<sup>-1</sup>). It clearly showed that the total Na<sup>+</sup> content in the dry biomass of all the plants growing in a pot, were increased to manifolds in comparison to respective plant controls (S<sub>0</sub>). The content was more at 16 dSm<sup>-1</sup> than at 8 dSm<sup>-1</sup> of salinity. The overall accumulation of Na<sup>+</sup> was more in most of the members of chenopodiaceae, *Aerva*, *Trianthema*, *Portulaca*, *Arundo* and *Aleurops*. It was least in case of *Solanum*, *Setaria*, *Parkinsonia*, *Prosopis*, *Calotropis*, *Heliotropium* and *Xanthium*.

At 8 dSm<sup>-1</sup> of salinity the bioaccumulation of Na<sup>+</sup> was to the tune of 310-435 per cent more than the controls (S<sub>0</sub>) in most of the members of chenopodiaceae, *Salicornia brachiata*, *Portulaca oleracea*, *Aerva tomentosa*, *Trianthema portulacastrum*, *Solanum xanthocarpum* and *Arundo donax*, whereas, it was to the extent of 100-300 per cent more in

*Suaeda fruticosa*, *Aleurops lagopoides*, *Cynodon dactylon*, *Calotropis procera* and *Chenopodium ambrosoides*. In rest of the genera the magnitude of accumulation of  $\text{Na}^+$  was 70-100 per cent more than their respective controls ( $\text{S}_0$ ). However, in *Xanthium strumarium* just 15.6 per cent more  $\text{Na}^+$  content was observed in comparison to its control ( $\text{S}_0$ ).

At higher salinity ( $16 \text{ dSm}^{-1}$ ) the bioaccumulation of  $\text{Na}^+$  was to the tune of 900-1300 per cent more than the controls ( $\text{S}_0$ ) in *Trianthema portulacastrum*, *Aerva tomentosa*, *Atriplex amnicola*, *Atriplex lentiformis* and *Salicornia brachiata* whereas was 365-675 per cent more than their respective controls in *Suaeda fruticosa*, *Atriplex nummularia*, *Portulaca oleracea*, *Arundo donax*, *Aleurops lagopoides*. In rest of the genera it was merely 70-165 per cent more than their respective controls ( $\text{S}_0$ ). However it is worth mentioning that in *Solanum xanthocarpum*, only 17 per cent of  $\text{Na}^+$  content was observed in comparison to than its  $\text{S}_0$  controls at  $16 \text{ dSm}^{-1}$ , which was less than even at  $8 \text{ dSm}^{-1}$ . It is because the plants of this genus were salt sensitive and could not survive at this high salinity ( $16 \text{ dSm}^{-1}$ ).

#### **5.2.22 Potassium content in soil after harvesting ( $\mu\text{g g}^{-1}$ soil)**

Table 25 enumerated clearly that with increasing levels of salinity ( $0\text{-}16 \text{ dSm}^{-1}$ ) the content of potassium in soil was increased after harvesting of all experimental plants. The

increment was higher in soil where *Chenopodium ambrosoides* and *Setaria indica* were growing, whereas, the least increment was observed in the soil where *Salicornia brachiata* and *Suaeda fruticosa* were in place. The increment was more at 16 dSm<sup>-1</sup> than at 8 dSm<sup>-1</sup> of salinity.

At 8 dSm<sup>-1</sup> of salinity the K<sup>+</sup> content of soil after harvesting was maximum in *Chenopodium ambrosoides* i.e., 44.6% than controls and least per cent increment was observed in the soil where *Suaeda fruticosa* (6%) and *Salicornia brachiata* (7%) were growing in comparison to the soil of so controls. However, K<sup>+</sup> content was higher to a magnitude of 30-40 per cent more than the control in soils where *Solanum xanthocarpum*, *Xanthium strumarium*, *Heliotropium procumbens*, *Parkinsonia aculeata*, *Arundo donax* and *Aleurops lagopoides*, were growing. Likewise, it was 15-30 per cent more than the control in soils where rest of the genera were growing.

Similarly at 16 dSm<sup>-1</sup> of salinity the maximum per cent increment in K<sup>+</sup> content of soil after harvesting was observed in *Chenopodium ambrosoides* i.e., 88% than the control. It was least in *Suaeda* and *Salicornia*. In rest of the genera it was 45-70 per cent more than their respective controls (S<sub>0</sub>).

#### **5.2.23 Potassium (K<sup>+</sup>) content in stem (mg g<sup>-1</sup> dry wt.)**

Data presented in Table 26 depicted that potassium content in stem was significantly decreased with

increasing levels of salinity (0-16 dSm<sup>-1</sup>) in all the experimental plants. The overall accumulation of K<sup>+</sup> content in stem was more in *Salicornia brachiata* followed by the members of chenopodiaceae, *Portulaca oleracea*, *Trianthema portulacastrum* and *Aerva tomentosa*. It was least in *Parkinsonia aculeata*, *Setaria indica*, *Prosopis juliflora*, *Sesbania sesquens*, *Heliotropium procumbens* and *Calotropis procera*.

At 8 dSm<sup>-1</sup> of salinity the decline in K<sup>+</sup> content of stem was to the magnitude of 45-60 per cent less than their respective controls (S<sub>0</sub>) in *Atriplex* species, *Portulaca*, *Aerva*, *Trianthema*, and *Salicornia*, whereas, it was to the extent of 25-40 per cent less than their individual controls (S<sub>0</sub>). In rest of the genera except *Chenopodium*, *Suaeda* and *Sesbania* where it was 18-19 per cent less than their respective controls (S<sub>0</sub>).

At higher salinity (16 dSm<sup>-1</sup>) the K<sup>+</sup> content was further decreased than their respective controls. (Table 26). The magnitude of decrease was to the tune of 45-60 per cent in the members of chenopodiaceae, *Salicornia*, *Portulaca*, *Aerva*, *Trianthema*, *Heliotropium*, *Parkinsonia* and *Prosopis*, whereas, it was 28-41 per cent less than the control in rest of the experimental plants.

#### **5.2.24 Potassium content in leaves (mg g<sup>-1</sup> dry wt.)**

Table 27 revealed that the K<sup>+</sup> content in leaves was also reduced as the level of salinity enhanced from 0-16 dSm<sup>-1</sup>.

The overall accumulation of  $K^+$  content, in general, was more in the members of chenopodiaceae, followed by *Portulaca oleracea*, *Trianthema portulacastrum* and *Aerva tomentosa*. It was least in *Setaria indica* followed by *Heliotropium procumbens*, *Prosopis juliflora* and *Calotropis procera*.

The reduction in the magnitude of  $K^+$  content in leaves at 8 dSm<sup>-1</sup> of salinity was 25-35 per cent in most of the member of chenopodiaceae, *Trianthema*, *Portulaca*, *Solanum*, *Prosopis* and *Arundo*, whereas, it was 35-45 per cent decline than their respective controls in *Chenopodium*, *Aerva*, *Xanthium*, *Sesbania*, *Heliotropium*, *Parkinsonia*, *Calotropis*, *Aleurops*, *Cynodon* and *Setaria*.

Likewise, at higher salinity (16 dSm<sup>-1</sup>) the  $K^+$  content in leaves was declined than their respective salinity controls ( $S_0$ ) to the magnitude of 40-45 percent in *Sesbania sesquens*, *Xanthium strumarium*, *Parkinsonia aculeata* and *Calotropis procera*, whereas, it was 50-60 per cent less than their individual controls ( $S_0$ ) in rest of the genera.

In general, the accumulation of  $K^+$  content in leaves was reduced 0.6 and 2.2 times at  $S_1$  and  $S_2$  in comparison to  $S_0$ , respectively.

#### **5.2.25 Phytoaccumulation $K^+$ in plants (mg/total dry wt. of plants in a pot)**

The data presented in Table 28 showed that the phytoaccumulation of  $K^+$  content in plant was reduced with

the increasing levels of salinity except *Suaeda fruticosa* and *Solanum xanthocarpum* where  $K^+$  accumulation was increased at  $8 \text{ dSm}^{-1}$  of salinity than their respective controls ( $S_0$ ).

At  $8 \text{ dSm}^{-1}$  of salinity the magnitude of reduction was maximum in *Xanthium strumarium* (67.6%) than its control ( $S_0$ ). Similarly, there was 40-60 percent reduction in *Setaria indica*, *Parkinsonia aculeata*, *Heliotropium procumbens*, *Cynodon dactylon*, *Prosopis juliflora*, *Calotropis procera*, *Sesbania sesquens*, *Salicornia brachiata* and *Chenopodium ambrosoides* in comparison to their respective controls ( $S_0$ ). Whereas, it was merely 10-26 per cent reduction in comparison to their respective controls in rest of the experimental plants.

Likewise, at  $16 \text{ dSm}^{-1}$  of salinity, the magnitude of reduction in phytoaccumulation of  $K^+$  was maximum in *Solanum xanthocarpum* which was 89.5 per cent decrease in comparison to its control.

Similarly, the magnitude of per cent reduction was least of all in case of *Salicornia brachiata* (1.5%) and *Trianthema portulacastrum* (14.3%). However, in rest of the genera like *Prosopis*, *Parkinsonia*, *Calotropis*, *Sesbania*, *Heliotropium*, *Xanthium*, *Chenopodium*, *Cynodon*, *Setaria* and *Atriplex nummularia*, the percent reduction in  $K^+$  content was to the tune of 60-80. In rest of the genera it was 20-50 per cent less than their respective controls ( $S_0$ ).

#### **5.2.26. $\text{Ca}^{2+}$ content in soil after harvesting ( $\mu\text{g g}^{-1}$ soil)**

The  $\text{Ca}^{2+}$  content in soil after harvesting (Table 29) increased with increasing salinity levels (0-16  $\text{dSm}^{-1}$ ) in soil of all experimental plants. The overall calcium ( $\text{Ca}^{2+}$ ) content in soil was more in *Sesbania sesquens* followed by *Setaria indica*, *Calotropis procera*, *Xanthium strumarium* and *Parkinsonia aculeata*. It was least of all in *Salicornia brachiata*, followed by most of the members of chenopodiaceae, *Portulaca oleracea*, *Trianthema portulacastrum* and *Aerva tomentosa*.

At 8  $\text{dSm}^{-1}$  of salinity the  $\text{Ca}^{2+}$  content in soil that remained after harvesting was 262, 272, 277 per cent more than their respective control ( $\text{S}_0$ ) in *Aleurops lagopoides*, *Salicornia brachiata* and *Arundo donax*. It was increased to the tune of 200-250 per cent more than their respective controls in rest of the plants.

Likewise, at higher salinity (16  $\text{dSm}^{-1}$ ) the increment in  $\text{Ca}^{2+}$  content in soil after harvesting was 706, 666, 626 and 605 per cent more than their controls ( $\text{S}_0$ ) in *Salicornia brachiata*, *Arundo donax*, *Aleurops lagopoides* and *Atriplex nummularia*, respectively. Similarly in the rest of the genera it was 540-600 per cent more than their respective controls ( $\text{S}_0$ ).

#### **5.2.27. Calcium ( $\text{Ca}^{2+}$ ) content in stem ( $\text{mg g}^{-1}$ dry wt.)**

The data presented in Table 30 depicted that the  $\text{Ca}^{2+}$  content in stem of all the experimental potential

hyperaccumulator plants decreased with increasing salinity levels (0-16 dSm<sup>-1</sup>) in comparison to their respective controls (S<sub>0</sub>). In general, overall accumulation of Ca<sup>2+</sup> content in stem was more in *Salicornia brachiata* and *Suaeda fruticosa*, it was least of all in *Setaria indica*, *Prosopis juliflora*, *Calotropis procera* and *Parkinsonia aculeata*.

At 8 dSm<sup>-1</sup> of salinity the magnitude of Ca<sup>2+</sup> content in stem was reduced to 46.7 in *Calotropis procera* as compared to its control (S<sub>0</sub>). Likewise the magnitude of reduction was 20-40 per cent in comparison to their respective controls in *Parkinsonia aculeata*, *Setaria indica*, *Salicornia brachiata*, *Prosopis juliflora*, *Cynodon dactylon*, *Aelurops lagopoides*, *Arundo donax*, *Atriplex amnicola* and *Portulaca oleracea*. Mean while it was just 4-20 per cent decline than the controls (S<sub>0</sub>) in rest of the plants. At 8 dSm<sup>-1</sup> salinity the reduction was 1.1-1.8 times less than their controls.

At higher salinity (16 dSm<sup>-1</sup>) the Ca<sup>2+</sup> content in stem was reduced to the tune of 45-60 per cent than their respective controls (S<sub>0</sub>) in *Calotropis procera*, *Prosopis juliflora*, *Arundo donax*, *Cynodon dactylon*, *Setaria indica*, *Aelurops lagopoides*, *Parkinsonia aculeata*, *Salicornia brachiata*, *Chenopodium ambrosoides*, *Atriplex amnicola*, *Atriplex nummularia*, *Aerva tomentosa* and *Portulaca oleracea*,

whereas, it was 33-43 per cent decline than their own controls ( $S_0$ ) in rest of the genera.

It must be mentioned that, in general, the accumulation of  $Ca^{2+}$  in stem was 1.5-2.3 times less at 16 dSm<sup>-1</sup> of salinity than their controls ( $S_0$ ).

#### **5.2.28 $Ca^{2+}$ content in leaves (mg g<sup>-1</sup> dry wt)**

Table 31 presented the  $Ca^{2+}$  content in the leaves which was considerably diminished with the increasing levels of salinity (0-16 dSm<sup>-1</sup>) as compared to that under non-saline conditions (control) in all the experimental plants. The overall accumulation of  $Ca^{2+}$  was more in leaves of *Suaeda fruticosa* followed by *Atriplex* species, *Portulaca oleracea*, *Trianthema portulacastrum* and *Aerva tomentosa*. It was the least of all the hyperaccumulator plants like *Setaria indica* followed by *Xanthium strumarium*, *Parkinsonia aculeata*, *Calotropis procera* and *Sesbania sesquens*.

At 8 dSm<sup>-1</sup> of salinity the accumulation of  $Ca^{2+}$  per cent content in leaves was declined to a magnitude of 20-35 per cent in *Setaria indica*, *Cynodon dactylon*, *Prosopis juliflora*, *Aerva tomentosa*, *Trianthema portulacastrum* and the members of chenopodiaceae. In rest of the plants, it was 10-20 per cent decline than their respective controls ( $S_0$ ). It may be noted that depletion in  $Ca^{2+}$  levels at this very salinity level was 0.12-0.35 times less as compared to controls.

At higher salinity ( $16 \text{ dSm}^{-1}$ ) the accumulation of  $\text{Ca}^{2+}$  content in leaves was decreased to the tune of 28-46 per cent than their individual controls in all the experimental plants studied.

In general, the reduction in  $\text{Ca}^{2+}$  content in leaves with increasing salinity levels from 8-16  $\text{dSm}^{-1}$  was 0.3-0.5 times less than their respective controls ( $S_0$ ).

The trends clearly showed that increasing salinity in the ambient medium drastically reduced the  $\text{Ca}^{2+}$  uptake in the plant parts especially stem and leaves.

#### **5.2.29 Phytoaccumulation of $\text{Ca}^{2+}$ (mg/total dry wt. of plants in a pot)**

Table 32 exhibitd that the bioaccumulation of  $\text{Ca}^{2+}$  in plants was decreased with increasing levels of salinity (0-16  $\text{dSm}^{-1}$ ) in all experimental hyperaccumulator plants selected for the present investigation.

At 8  $\text{dSm}^{-1}$  of salinity the magnitude of bioaccumulation of  $\text{Ca}^{2+}$  was increased in *Solanum xanthocarpum* followed by *Aerva tomentosa*, *Arundo donax* and *Trianthema portulacastrum*. In rest of the plants it was reduced than their controls. It was reduced to the tune of 30-65 per cent than their respective controls ( $S_0$ ) in *Setaria indica*, *Xanthium strumarium*, *Parkinsonia aculeata*, *Prosopis juliflora*, *Sesbania sesquens*, *Calotropis procera*, *Heliotropium procumbens*, *Cynodon dactylon* and *Chenopodium ambrosodies*.

Whereas, in rest of the plant it, was decreased to the magnitude of 0.72-30 per cent than their respective controls (S<sub>0</sub>).

Similarly at 16 dSm<sup>-1</sup> of salinity the phytoaccumulation of Ca<sup>2+</sup> was 35, 21, 11 and 2 per cent more than the controls (S<sub>0</sub>) in *Trianthema portulacastrum*, *Salicornia brachiata*, *Aerva tomentosa* and *Atriplex lentiformis*, respectively. The reduction was the least in *Atriplex amnicola* i.e. 0.39 per cent than its control (S<sub>0</sub>). It was to the tune of 10-30 per cent reduction in bioaccumulation of Ca<sup>2+</sup> than their respective controls in *Arundo donax*, *Portulaca oleracea*, *Suaeda fruticosa* and *Aleurops lagopoides*, whereas, it was to the tune of 55-85 per cent reduction than their respective controls in rest of the plants.

#### **5.2.30 Mg<sup>2+</sup> content in soil after harvesting (µg g<sup>-1</sup> soil)**

The Mg<sup>2+</sup> content in soil (Table 33) was significantly enhanced with every increment in salinity levels (8 and 16 dSm<sup>-1</sup>) in comparison to its controls in all the experimental hyperaccumulator plants. Maximum Mg<sup>2+</sup> content in soil after harvesting was noticed in *Parkinsonia aculeata* followed by *Chenopodium ambrosoides*, *Setaria indica* and *Xanthium strumarium*. It was least in *Salicornia brachiata* followed by the members of chenopodiaceae,

*Portulaca oleracea*, *Trianthema portulacastrum* and *Aerva tomentosa*.

At 8 dSm<sup>-1</sup> of salinity the Mg<sup>2+</sup> content in soil after harvesting was increased to a magnitude of 150-170 per cent more than their respective controls in *Salicornia*, *Aleurops*, *Cynodon*, *Arundo*, *Trianthema*, *Solanum*, *Portulaca* and *Atriplex* species, whereas, in rest of the plants the increment of Mg<sup>2+</sup> content in soil after harvesting was to the tune of 120-150 per cent more than their controls (S<sub>0</sub>).

At 16 dSm<sup>-1</sup> of salinity, the Mg<sup>2+</sup> content in soil after harvesting was obviously more than 8 dSm<sup>-1</sup> of salinity and their respective controls (S<sub>0</sub>) in all the plants studied during the course of this investigation. It was to the tune of 347-470 per cent more than their controls in all the experimental plants. Another pivotal observation was slightly more retention of Mg<sup>2+</sup> in soil where *Chenopodium*, *Solanum*, *Xanthium*, *Sesbania*, *Heliotropium*, *Parkinsonia*, *Calotropis*, *Prosopis*, *Arundo*, *Aleurops*, *Cynodon* and *Setaria* were going and it was comparatively less in case of soil where *Salicornia*, *Suaeda*, *Atriplex*, *Aerva*, *Trianthema* and *Portulaca* were growing.

#### **5.2.31 Magnesium (Mg<sup>2+</sup>) content in stem (µgg<sup>-1</sup> dry wt.)**

Table 34 reported that the Mg<sup>2+</sup> content in stem was reduced as the salinity levels increased from 0-16 dSm<sup>-1</sup> than their controls (S<sub>0</sub>) in all the experimental plants. The

overall accumulation of  $Mg^{2+}$  content in stem was maximum in *Salicornia brachiata* and most of the members of chenopodiaceae. It was least in *Setaria indica* and *Parkinsonia aculeata*.

At 8 dSm<sup>-1</sup> of salinity the magnitude of reduction in  $Mg^{2+}$  content in stem was to the tune of 40-60 per cent less than their respective controls ( $S_0$ ) in *Prosopis juliflora*, *Parkinsonia aculeata*, *Calotropis procera*, *Chenopodium ambrosoides* and *Sesbania sesquens*. In rest of the genera, it was 20-40 per cent reduction than their respective controls ( $S_0$ ).

At higher salinity (16 dSm<sup>-1</sup>) the  $Mg^{2+}$  content in stem was declined 40-60 per cent in all experimental plants. In general, the reduction in  $Mg^{2+}$  content of stem was 1.3-2.4 times at  $S_1$  and  $S_2$  than  $S_0$  in all plants studied in the present investigation.

#### **5.2.32 $Mg^{2+}$ content in leaves (mg g<sup>-1</sup> dry wt.)**

$Mg^{2+}$  content in leaves (Table 35) was decreased with the every increment of salinity levels (0-16 dSm<sup>-1</sup>) than their controls ( $S_0$ ). The reduction was more at 16 dSm<sup>-1</sup> than 8 dSm<sup>-1</sup> of salinity. The overall accumulation of  $Mg^{2+}$  content in leaves was more in *Suaeda fruticosa* followed by *Atriplex* species, *Protulaca oleracea*, *Trianthema portulacastrum* and *Aerva tomentosa*. It was least in case of *Setaria indica*, *Prosopis juliflora*, *Calotropis procera*, *Cynodon dactylon*, *Sesbania sesquens*, *Xanthium strumarium* and *Parkinsonia aculeata*.

At 8 dSm<sup>-1</sup> of salinity, the Mg<sup>2+</sup> content in stem was reduced to greater magnitude than their respective controls (S<sub>0</sub>) in *Chenopodium ambrosoides* (32%). It was to the tune of 20-30 per cent reduction in Mg<sup>2+</sup> content in leaves than their controls (S<sub>0</sub>) in most of the members of chenopodiaceae, *Portulaca*, *Trianthema*, *Aerva*, *Arundo*, *Aleurops*, *Cynodon*, *Prosopis* and *Sesbania*. In rest of the genera, it was 7-20 per cent reduction in Mg<sup>2+</sup> content than their respective controls.

Similarly at higher salinity (S<sub>2</sub>) i.e. 16 dSm<sup>-1</sup> the per cent Mg<sup>2+</sup> content in leaves was reduced in *Suaeda fruticosa* (45%) and *Atriplex lentiformis* (41%) than their respective controls (S<sub>0</sub>). Likewise, there was 30-40 per cent decline in Mg<sup>2+</sup> content than their respective controls in most of the members of chenopodiaceae, *Portulaca*, *Trianthema*, *Aerva*, *Solanum*, *Calotropis*, *Arundo*, *Cynodon* and *Aleurops*. Whereas, it was depleted to 15-30 per cent than their controls in case of *Setaria*, *Prosopis*, *Parkinsonia*, *Heliotropium*, *Sesbania* and *Xanthium*. The leaves were absent in case of *Salicornia brachiata*.

#### **5.2.33 Phytoaccumulation of Magnesium (Mg<sup>2+</sup>) (mg/total dry wt. of plants in a pot)**

Phytoaccumulation of Magnesium (Mg<sup>2+</sup>) was reduced with increasing levels of salinity (8 dSm<sup>-1</sup> and 16 dSm<sup>-1</sup>) than controls in all the plants (Table 36). The

reduction was more at 16 dSm<sup>-1</sup> than 8 dSm<sup>-1</sup> of salinity. The bioaccumulation was increased in case of *Aerva tomentosa*, *Atriplex lentiformis*, *Salicornia brachiata* and *Trianthema portulacastrum*.

At 8 dSm<sup>-1</sup> of salinity, the per cent bioaccumulation of Mg<sup>2+</sup> content was reduced to a maximum extent in case of *Xanthium strumarium* (60.9%) and *Parkinsonia aculeata* (59.7%). The per cent reduction in Mg<sup>2+</sup> content was to a magnitude of 32-42 in comparison to respective controls (S<sub>0</sub>) in case of *Chenopodium ambrosoides*, *Solanum Xanthocarpum*, *Sesbania sesquens*, *Heliotropium*. However, it was 2-25 per cent reduction in comparison to their respective controls (S<sub>0</sub>) in rest of the experimental hyperaccumulator plants.

Similarly at 16 dSm<sup>-1</sup> of salinity the reduction was maximum in *Solanum Xanthocarpum* (85%) than controls. Likewise, it was to the tune of 45-75 per cent decline than their own controls (S<sub>0</sub>) in case of *Atriplex nummularia*, *Chenopodium ambrosoides*, *Xanthium strumarium*, *Sesbania sesquens*, *Heliotropium procumbens*, *Parkinsonia aculeata*, *Calotropis procera*, *Prosopis juliflora*, *Cynodon dactylon* and *Setaria indica*, whereas it was 2-25 per cent decline was noticed in rest of the genera in comparison to their respective controls (S<sub>0</sub>).

#### **5.2.34 Chloride ( $\text{Cl}^-$ ) content in soil**

Table 37 illustrated that the chloride ( $\text{Cl}^-$ ) content in soils was enhanced with the increasing levels of salinity (8 and 16  $\text{dSm}^{-1}$ ) than their non-saline controls ( $\text{S}_0$ ). The per cent increment of  $\text{Cl}^-$  content in soil after harvesting was more at 16 than at 8  $\text{dSm}^{-1}$  of salinity. The overall  $\text{Cl}^-$  content in soil after harvesting was more in *Setaria indica* followed by *Heliotropium procumbens*, *Prosopis juliflora* and *Xanthium strumarium*. Contrary to the above, the per cent  $\text{Cl}^-$  content in *Salicornia brachiata* and members of family chenopodiaceae declined more than the rest of the genera.

At 8  $\text{dSm}^{-1}$  of salinity the increment in  $\text{Cl}^-$  content in soil than control was 12-16 times in all experimental plants while at 16  $\text{dSm}^{-1}$  of salinity the increment was 20-34 times more than their respective controls in all experimental hyperaccumulator plants.

#### **5.2.35 Chloride ( $\text{Cl}^-$ ) content in stem ( $\text{mg g}^{-1}$ dry wt)**

The data presented in Table 38 showed that the  $\text{Cl}^-$  content in stem was increased with increasing levels of salinity than their controls in all the experimental plants. The enhancement was seen more at 16  $\text{dSm}^{-1}$  than 8  $\text{dSm}^{-1}$  of salinity. The overall  $\text{Cl}^-$  content was maximum in *Salicornia brachiata* and most of the members of chenopodiaceae. It was least in *Setaria indica* followed by *Calotropis procera*,

*Prosopis juliflora*, *Xanthium strumarium*, *Heliotropium procumbens*, *Parkinsonia aculeata* and *Sesbania sesquens*.

At 8 dSm<sup>-1</sup> (S<sub>0</sub>) of salinity the enhancement in Cl<sup>-</sup> content in stem was 130-175 per cent more than their respective controls (S<sub>0</sub>) in *Salicornia brachiata*, most members of chenopodiaceae, *Portulaca oleracea*, *Trianthema portulacastrum*, *Aerva tomentosa*, *Sesbania sesquens*, *Prosopis juliflora* and *Setaria indica* whereas, 80-125 per cent more Cl<sup>-</sup> content was observed in rest of the genera studied for this experiment. Another interesting observation was that the Cl<sup>-</sup> content registered 1.82 to 2.71 fold increase over their respective controls.

Likewise at 16 dSm<sup>-1</sup> (S<sub>2</sub>) of salinity the per cent increment in Cl<sup>-</sup> content in stem was maximum in *Salicornia brachiata* (422%) followed by *Setaria indica* (326%), *Parkinsonia aculeata* (319%) and *Chenopodium ambrosoides* (311%). It was least of all in case *Cynodon dactylon* (192%). However, in rest of the plant genera the increment was to the tune of 200-300 per cent more than their respective controls (S<sub>0</sub>).

In general, the enhancement of Cl<sup>-</sup> content in stem was 2.9-5.2 times more at S<sub>2</sub> than their individual controls (S<sub>0</sub>).

#### **5.2.36 Chloride (Cl<sup>-</sup>) content in leaves (mg g<sup>-1</sup> dry wt.)**

Chloride content in leaves (Table 39) was enhanced with increasing levels of salinity than their

respective controls. Obviously, the enhancement in  $\text{Cl}^-$  content in leaves was more at  $16 \text{ dSm}^{-1}$  than at  $8 \text{ dSm}^{-1}$  of salinity. The overall accumulation of  $\text{Cl}^-$  was, in general more in case of *Salicornia brachiata* followed by most of the member of chenopodiaceae, *Portulaca oleracea*, *Trianthema portulacastrum* and *Aerva tomentosa*, whereas, it was least in *Setaria indica* followed by *Parkinsonia aculeata*, *Sesbania sequens*, *Heliotropium procumbens*, *Calotropis procera*, *Xanthium strumarium* and *Prosopis juliflora*.

At  $8 \text{ dSm}^{-1}$  of salinity the accumulation of  $\text{Cl}^-$  was to the tune of 100-125 per cent more than their respective controls ( $S_0$ ) in leaves, whereas, it was 60-100 per cent more of  $\text{Cl}^-$  at  $8 \text{ dSm}^{-1}$  in comparison to controls ( $S_0$ ) in leaves of rest of the experiental plants. Likewise, the per cent accumulation of  $\text{Cl}^-$  at  $16 \text{ dSm}^{-1}$  ( $S_2$ ) was also more in most of the member of chenopodiaceae, *Aerva*, *Trianthema*, *Portulaca* and *Prosopis*, where it was accumulated 250-325 per cent more than their respective own controls ( $S_0$ ). It was 170-250 per cent more than  $S_0$  in *Atriplex nummularia*, *Solanum*, *Xanthium*, *Sesbania*, *Heliotropium*, *Parkinsonia*, *Calotropis*, *Arundo*, *Aleurops*, *Cynodon* and *Setaria*.

It is worthwhile to mention that, in general, the accumulation of  $\text{Cl}^-$  enhanced 1.6-3.0 times more at 8 and

2.7-4.24 times more at 16 dSm<sup>-1</sup> of salinity levels as compared to controls (S<sub>0</sub>).

**5.2.37 Phytoaccumulation of chloride (Cl<sup>-</sup>) content in above ground plant parts (mg/total dry wt. of plants in a pot)**

Table 40 presented that the bioaccumulation of Cl<sup>-</sup> content in plants was increased with increasing salinity than their controls in all experimental plants except *Solanum xanthocarpum* and *Xanthium strumarium*, where the Cl<sup>-</sup> content declined at 16 dSm<sup>-1</sup> and 8 dSm<sup>-1</sup> of salinity levels, respectively.

The overall accumulation of Cl<sup>-</sup> was more in *Suaeda fruticosa* followed by *Aerva tomentosa*, *Atriplex nummularia*, *Trianthema portulacastrum*, *Portulaca oleracea*, *Salicornia brachiata*, *Atriplex amnicola* and *Atriplex nummularia*. It was least in case of *Solanum xanthocarpum*, followed by *Heliotropium procumbens*, *Prosopis juliflora* and *Parkinsonia aculeata*.

At 8 dSm<sup>-1</sup> of salinity the accumulation of Cl<sup>-</sup> in a plant was increased to the tune of 150-300 per cent more than their respective controls in case of *Salicornia*, *Solanum*, *Portulaca*, *Aerva*, *Trianthema*, and *Atriplex* species, whereas, in rest of the plant it was 10-150 per cent more than their respective controls (S<sub>0</sub>) except *Xanthium strumarium* where it

was declined to more than 10 per cent in comparison to its control ( $S_0$ ).

Similarly the per cent accumulation of  $Cl^-$  was maximum in *Salicornia brachiata* (1059%) and *Trianthema portulacastrum* (651%). It was least in *Xanthium strumarium* (30%), followed by *Sesbania sesquens* (40%), *Calotropis procera* (55%), *Heliotropium procumbens* (64%) and *Parkinsonia aculeata* (65%). Other categories include 500-600 per cent more  $Cl^-$  than their respective controls ( $S_0$ ) in case of *Atriplex lentiformis*, *Atriplex amnicola* and *Aerva tomentosa*. Whereas, it was 300-400 per cent more  $Cl^-$  than their controls in ( $S_0$ ) in *Portulaca oleracea*, *Suaeda fruticosa*, *Arundo donax* and *Aelurops lagopoides*. In rest of the genera the magnitude of accumulation of  $Cl^-$  was 80-170 per cent more than their controls ( $S_0$ ). It must be mentioned that the  $Cl^-$  content in comparison to  $S_0$  was 27 per cent less in *Solanum xanthocarpum*. It could be ascribed to more sensitivity of this plant to higher salinity ( $16\text{ dSm}^{-1}$ ). Another interesting fact was that the phytoaccumulation of  $Cl^-$  was 1.14-3.95 times at  $8\text{ dSm}^{-1}$  and 0.73-11.9 times more at  $16\text{ dSm}^{-1}$  in comparison to controls ( $S_0$ )

#### **5.2.38 Sulphate ( $SO_4^{-2}$ ) content in soil after harvesting ( $\mu\text{g g}^{-1}$ soil)**

Table 41 depicted that the sulphate content in soil was enhanced with every increment of salinity levels than

their respective controls. The increment was more at 16 dSm<sup>-1</sup> than at 8 dSm<sup>-1</sup> of soil salinity. In general, the accumulation of SO<sub>4</sub><sup>-2</sup> was more in *Sesbania sesquens*, *Parkinsonia aculeata*, *Calotropis procera*, *Heliotropium procumbens*, and *Setaria indica*, whereas it was the least in case of *Suaeda fruticosa*, *Salicornia brachiata* and *Atriplex* species.

At 8 dSm<sup>-1</sup> of salinity the increment in SO<sub>4</sub><sup>-2</sup> content in soil after harvesting was 1000-1120 per cent more than their respective controls in *Salicornia* and most of the members of chenopodiaceae. Furthermore, it was 900-1000 percent more of SO<sub>4</sub><sup>-2</sup> in comparison to controls (S<sub>0</sub>) in genera like *Portulaca*, *Aerva*, *Trianthema*, *Solanum*, *Parkinsonia*, *Prosopis*, *Arundo*, *Aleurops* and *Cynodon*. In rest of the genera, it was 780-900 percent more SO<sub>4</sub><sup>-2</sup> in soil after harvesting than their respective control treatments (S<sub>0</sub>).

Similarly, at 16 dSm<sup>-1</sup> of salinity the accumulation of SO<sub>4</sub><sup>-2</sup> in soil after harvesting was 2000-2700 per cent more than their respective controls in case of *Cynodon dactylon*, *Aleurops lagopoides*, *Arundo donax*, *Prosopis juliflora*, *Parkinsonia aculeata*, *Solanum xanthocarpum*, *Salicornia brachiata*, *Suaeda fruticosa*, *Portulaca oleracea*, *Trianthema portulacastrum*, *Aerva tomentosa* and *Atriplex* species. In rest of the plants it was 1700-2000 percent more than their respective controls.

In general, the accumulation of  $\text{SO}_4^{-2}$  varied in the soil after harvesting of hyperaccumulator plants from individual control ( $\text{S}_0$ ) from 8.8 to 12.2 and 18.4 to 27.5 times more at 8 and 16  $\text{dSm}^{-1}$  of salinity, respectively.

#### **5.2.39 Sulphate ( $\text{SO}_4^{-2}$ ) content in stem ( $\text{mg g}^{-1}$ dry wt.)**

Sulphate ( $\text{SO}_4^{-2}$ ) content in stem (Table 42) was declined as the salinity levels were increased from 8 and 16  $\text{dSm}^{-1}$  of salinity than their respective controls. In general, the accumulation was more in *Salicornia brachiata* followed by *Suaeda fruticosa* and *Atriplex* species as compared to other plants. It was the least of all plants in *Setaria indica*, *Sesbania sesquens* and *Xanthium strumarium*.

At 8  $\text{dSm}^{-1}$  of salinity, the maximum per cent decrease in  $\text{SO}_4^{-2}$  content in stem was 36, 34 and 31.7 in case of *Aleurops lagopoides*, *Cynodon dactylon* and *Arundo donax* respectively, whereas, it was least in *Sesbania sesquens* (0.5%). The per cent decrease was 20-30 in case of *Portulaca*, *Trianthema*, *Aerva*, *Solanum*, *Calotropis*, *Prosopis*, *Setaria* and *Atriplex amnicola* in comparison to their respective controls ( $\text{S}_0$ ). In rest of the genera it was 10-20 per cent decline than their individual controls ( $\text{S}_0$ ).

Similarly, the accumulation of sulphate was 44, 43.6 and 41.4 per cent less in stem than their respective controls ( $\text{S}_0$ ) in *Arundo donax*, *Cynodon dactylon* and

*Solanum xanthocarpum*, respectively at 16 dSm<sup>-1</sup> of salinity, whereas, it was least in *Atriplex nummularia* i.e. 17%. The accumulation of SO<sub>4</sub><sup>-2</sup> in stem was reduced to the tune of 30-40 percent than their individual controls (S<sub>0</sub>) in *Suaeda fruticosa*, *Salicornia brachiata*, *Xanthium strumarium*, *Sesbania sesquens*, *Calotropis procera*, *Prosopis juliflora* and *Setaria indica*. In rest of the cases, it was 20-30 per cent decline in comparison to their controls (S<sub>0</sub>).

#### **40. Sulphate (SO<sub>4</sub><sup>-2</sup>) content in leaves (mg g<sup>-1</sup> dry wt.)**

The sulphate content in leaves (Table 43) was reduced as the salinity levels increased from 0-16 dSm<sup>-1</sup> than non-saline condition (control). In general, the accumulation was more in most of the members of chenopodiaceae and least in *Setaria indica*, *Prosopis juliflora*, *Parkinsonia aculeata* and *Calotropis procera* as compared to other plants. The decline in SO<sub>4</sub><sup>-2</sup> content was more at 16 dSm<sup>-1</sup> than 8 dSm<sup>-1</sup> of salinity. Leaves were absent in *Salicornia brachiata*.

At 8 dSm<sup>-1</sup> of salinity the per cent accumulation of SO<sub>4</sub><sup>-2</sup> content in leaves was 15-30 per cent less than their respective controls (S<sub>0</sub>) in most of the plants except *Chenopodium ambrosoids*, *Suaeda fruticosa*, *Xanthium strumarium*, *Parkinsonia aculeata*, *Calotropis procera* and *Setaria indica*, where it was just 5-15 per cent decline in comparison to their respective controls.

Similarly, the accumulation of  $\text{SO}_4^{-2}$  at 16 dSm<sup>-1</sup> was decreased to the tune of 30-40 per cent than their controls in *Portulaca*, *Trianthema*, *Aerva*, *Atriplex*, *Heliotropium*, *Parkinsonia*, *Arundo*, *Aleurops* and *Cynodon*. Likewise it was to the magnitude of 20-30 per cent reduction than their respective controls in rest of the plants except *Suaeda fruticosa* where the decline was noticed upto 18.4 per cent in comparison to its control ( $\text{S}_0$ ).

It is worthwhile mentioning here that in general, the accumulation of  $\text{SO}_4^{-2}$  was declined 0.73-0.94 times less at 8 or 16 dSm<sup>-1</sup> of salinity over that of their controls ( $\text{S}_0$ ).

**5.2.41. Phytoaccumulation of  $\text{SO}_4^{-2}$  in plant (mg/total dry wt. of plants in a pot)**

The data enumerated in Table 44 revealed that the total accumulation of  $\text{SO}_4^{-2}$  in total dry weight of above ground parts of plants in a pot declined with increasing levels of salinity from 0-16 dSm<sup>-1</sup>. The accumulation of  $\text{SO}_4^{-2}$ , in general, was reduced more at 16 dSm<sup>-1</sup> ( $\text{S}_2$ ) than at 8 dSm<sup>-1</sup> of salinity. The accumulation of  $\text{SO}_4^{-2}$  was maximum in the members of chenopodiaceae, *Portulaca oleracea*, *Aerva tomentosa* and *Trianthema portulacastrum*, whereas, it was that least of all experimental plants in case of *Heliotropium procumbens*, *Salicornia brachiata*, *Parkinsonia aculeata*, *Prosopis juliflora* and *Setaria indica* as compare to other plants at 8 dSm<sup>-1</sup> of salinity.

At 8 dSm<sup>-1</sup> of salinity, the accumulation of SO<sub>4</sub><sup>-2</sup> was 25-26 per cent less than the controls in case of *Chenopodium*, *Solanum*, *Xanthium*, *Sesbania*, *Heliotropium*, *Parkinsonia*, *Calotropis*, *Prosopis*, *Cynodon* and *Setaria*, whereas, it was 1-25 per cent less than their respective controls in rest of the genera. However, in case of *Portulaca oleracea*, *Aerva tomentosa* and *Atriplex lentiformis*, there was an increase in SO<sub>4</sub><sup>-2</sup> content at 8 dSm<sup>-1</sup> of salinity in comparison to their respective controls (S<sub>0</sub>).

Similarly, the accumulation of SO<sub>4</sub><sup>2-</sup> content in plant was 50-70 per cent less than the controls (S<sub>0</sub>) in case of *Chenopodium*, *Xanthium*, *Sesbania*, *Heliotropium*, *Parkinsonia*, *Calotropis*, *Prosopis*, *Cynodon* and *Setaria* whereas it was 83.6 and 39 percent less than their controls in *Solanum xanthocarpum* and *Atriplex nummularia*, respectively. In rest of the genera, the decline was 1-15 percent in comparison to their respective controls (S<sub>0</sub>). It is worthwhile to mention here that accumulation of SO<sub>4</sub><sup>2-</sup> was enhanced than their controls (S<sub>0</sub>) in case of *Trianthema portulacastrum*, *Aerva tomentosa*, *Atriplex amnicola*, *Atriplex lentiformis* and *Salicornia brachiata*.

#### **5.2.42. Na<sup>+</sup>/K<sup>+</sup> ratio in soil after harvesting**

Table 45 showed that the Na<sup>+</sup>/K<sup>+</sup> ratio in soil after harvesting was enhanced with increasing levels of salinity. The increment was more at 16 dSm<sup>-1</sup> than at 8 dSm<sup>-1</sup> of

salinity. Another pivotal observation was that the  $\text{Na}^+/\text{K}^+$  ratio was also enhanced in all the treatments- $\text{S}_0$ ,  $\text{S}_1$  and  $\text{S}_2$  in comparison to the  $\text{Na}^+/\text{K}^+$  ratio before plantation of hyperaccumulator plants. This might occur due to more accumulation of other ions in the plant parts from the ambient saline environment resulting in enhanced  $\text{Na}^+/\text{K}^+$  ratio in soil after harvesting.

At  $8 \text{ dSm}^{-1}$  of salinity the  $\text{Na}^+/\text{K}^+$  ratio was 500-600 per cent more than their controls in case of *Salicornia brachiata*, *Suaeda fruticosa*, *Atriplex* species, *Trianthema portulacastrum*, *Cynodon dactylon* and *Setaria indica*, whereas, it was to the tune of 400-500 per cent more than the control in rest of the genera.

Similarly, the  $\text{Na}^+/\text{K}^+$  ratio in soil after harvesting was more than their respective controls at  $16 \text{ dSm}^{-1}$  of salinity. It was to the tune of 900-1060 per cent more than their respective controls in most of the members of chenopodiaceae, *Salicornia* and *Trianthema*. Likewise, it was to the magnitude of 800-900 per cent more than their respective controls ( $\text{S}_0$ ) in *Portulaca*, *Aleurops*, *Cynodon*, *Setaria*, *Prosopis*, *Sesbania* and *Calotropis*. In rest of the genera the magnitude was 625-700 per cent more than their individual controls ( $\text{S}_0$ ).

In general, the increment of  $\text{Na}^+/\text{K}^+$  ratio was 4-5 fold and 8.0-11.5 times, more than their respective controls at 8 and 16  $\text{dSm}^{-1}$  of salinity, respectively.

#### **5.2.43. $\text{Na}^+/\text{K}^+$ ratio in stem (mg/plant)**

The data presented in Table 46 depicted that the  $\text{Na}^+/\text{K}^+$  ratio in stem was increased with every increment of salinity (8 and 16  $\text{dSm}^{-1}$ ) than their controls ( $\text{S}_0$ ). The enhancement of  $\text{Na}^+/\text{K}^+$  ratio in stem was more at 16  $\text{dSm}^{-1}$  of salinity than 8  $\text{dSm}^{-1}$ . The overall  $\text{Na}^+/\text{K}^+$  ratio was more in *Portulaca oleracea*, *Trianthema portulacastrum*, *Aerva tomentosa* and most of the members of chenopodiaceae, whereas it was least in *Calotropis procera*, *Chenopodium ambrosoides*, *Xanthium strumarium*, *Sesbania sesquens* and *Heliotropium procumbens*.

At 8  $\text{dSm}^{-1}$  of salinity the  $\text{Na}^+/\text{K}^+$  ratio in stem was maximum in *Salicornia brachiata* and *Atriplex amnicola* i.e., 756 and 621 per cent more than their controls respectively. It was to the magnitude of 450-560 percent more than their respective controls ( $\text{S}_0$ ) in case of *Atriplex* species, *Aerva tomentosa*, *Portulaca oleracea*, *Trianthema portulacastrum* and *Cynodon dactylon*, whereas, it was to the tune of 200-300 per cent more in rest of the genera.

Similarly at 16  $\text{dSm}^{-1}$  of salinity the  $\text{Na}^+/\text{K}^+$  ratio in stem was to the tune of 1000-1900 percent more than their controls in case of most of the members of

chenopodiaceae, *Aerva*, *Portulaca*, *Trianthema* and *Parkinsonia*. In rest of the genera it was to the magnitude of 600-1000 per cent more than their individual controls ( $S_0$ ).

It must be mentioned here that in general, the  $Na^+/K^+$  ratio was approximately 3-6 at 8 dSm<sup>-1</sup> and 7 to 20 times more at 16 dSm<sup>-1</sup> of salinity than their controls ( $S_0$ ).

#### **5.2.44 $Na^+/K^+$ ratio in leaves**

The data presented in Table 47 detailed that the  $Na^+/K^+$  ratio in leaves was increased with increasing levels of salinity (8 and 16 dSm<sup>-1</sup>) than their respective controls ( $S_0$ ). The increment in  $Na^+/K^+$  ratio in leaves was more at 16 dSm<sup>-1</sup> than at 8 dSm<sup>-1</sup> of salinity. The leaves were absent in *Salicornia brachiata*.

At 8 dSm<sup>-1</sup> ( $S_1$ ) of salinity the maximum per cent enhancement in  $Na^+/K^+$  ratio in leaves was 599, 568 and 512 per cent more than their respective controls ( $S_0$ ) in case of *Aerva tomentosa*, *Trianthema portulacastrum* and *Portulaca oleracea*, respectively. Moreover, it was to the tune of 350-450 per cent more in comparison to their respective controls in the members of chenopodiaceae, *Solanum xanthocarpum*, *Heliotropium procumbens*, *Arundo donax* and *Cynodon dactylon*. In rest of the genera, it was to the magnitude of 240-340 per cent more than their individual controls ( $S_0$ ).

At 16 dSm<sup>-1</sup> of salinity, the  $Na^+/K^+$  ratio in leaves was to the tune of 900-1325 per cent more in case of

members of chenopodiaceae, *Aerva*, *Trianthema*, *Portulaca*, *Calotropis*, *Prosopis*, *Arundo* and *Solanum*, whereas, it was to the magnitude of 500-800 per cent more than their respective controls ( $S_0$ ) in rest of the genera. In general, the Na/K ratio in leaves was 3.4 to 6.9 fold increase at 8 dSm<sup>-1</sup> and 7.4 to 14.2 times increase at 16 dSm<sup>-1</sup> of salinity in comparison to controls ( $S_0$ ).

#### **5.2.45 Na<sup>+</sup>/K<sup>+</sup> ratio in plant**

Na<sup>+</sup>/K<sup>+</sup> ratio in plant (Table 48) was enhanced with every increment of salinity levels than their non-saline control. The increment in Na<sup>+</sup>/K<sup>+</sup> ratio was more at 16 dSm<sup>-1</sup> than at 8 dSm<sup>-1</sup> of salinity. The overall Na<sup>+</sup>/K<sup>+</sup> ratio was in general, more in *Atriplex* species, *Trianthema portulacastrum*, *Portulaca oleracea*, *Aerva tomentosa* and *Arundo donax* and it was least in case of *Salicornia brachiata* and *Setaria indica*.

At 8 dSm<sup>-1</sup> of salinity, the Na<sup>+</sup>/K<sup>+</sup> ratio was to the tune of 400-600 per cent more than their respective controls ( $S_0$ ) in *Portulaca*, *Trianthema*, *Aerva*, *Atriplex* species and *Cynodon*, whereas it was 756 per cent more than their controls in case of *Salicornia brachiata*. Likewise, it was to the magnitude of 265-400 per cent more in rest of the plants.

Similarly, the per cent Na<sup>+</sup>/K<sup>+</sup> ratio in plant at 16 dSm<sup>-1</sup> ( $S_2$ ) was also more in most of the members of chenopodiaceae, *Aerva*, *Trianthema* and *Portulaca*, whereas,

in rest of the genera it was to the tune of 590-920 per cent more than their respective controls ( $S_0$ ).

It must be mentioned here that in general, the Na/K ratio enhanced 3.7-6.8 times more at  $S_1$  and 7 to 16 fold more at  $S_2$  levels as compared to  $S_0$  (Control) in whole of the dry matter content of the above ground parts of the plants growing in a pot.

#### **5.2.46 Total ionic content in soil after harvesting**

The data presented in table 49 depicted that the sum total of ionic contents in soil after harvesting of plants were increased with increasing levels of salinity than their respective controls ( $S_0$ ). The increment in total ions were more at  $16 \text{ dSm}^{-1}$  than at  $8 \text{ dSm}^{-1}$  of salinity. The sum total of ions, in general, were more in case of *Setaria indica*, *Prosopis juliflora*, *Parkinsonia aculeata*, *Calotropis procera*, *Heliotropium procumbens*, *Sesbania sesquens* and *Xanthium strumarium*, whereas, it was least in case of members of chenopodiaceae. It clearly showed the inherent mechanism of ion regulation particularly in members of chenopodiaceae and other hyperaccumulator plants.

At  $8 \text{ dSm}^{-1}$  of salinity the accumulation of total ions in soil were 5.8-6.8 times more than their respective controls in all the plants, whereas the total ions were 11.5-14.3 times more than their respective controls ( $S_0$ ) at 16

dSm<sup>-1</sup> of salinity in all experimental plants studied during the course of present investigation.

#### **5.2.47 Phytoaccumulation of total ions (mg/plant) in plants**

Table 50 presents the phytoaccumulation of sum total of ions together in plants were enhanced with every increment of salinity levels in most of the hyperaccumulators. The overall accumulation of sum total of ions were, in general, more than their respective controls (S<sub>0</sub>) in *Atriplex lentiformis*, *Atriplex amnicola*, *Trianthema portulacastrum*, *Aerva tomentosa*, *Portulaca olercea* and *Suaeda fruticosa*. It was decreased than their controls in *Solanum xanthocarpum*, *Xanthium strumarium*, *Sesbania sesquens*, *Heliotropium procumbens*, *Parkinsonia aculeata*, *Calotropis procera* and *Prosopis juliflora*.

At 8 dSm<sup>-1</sup> of salinity the phytoaccumulation of sum total of all ions together were 70-140 per cent more than their individual controls (S<sub>0</sub>) in case of most of the members of chenopodiaceae, *Portulaca*, *Aerva*, *Trianthema*, *Solanum* and *Arundo*, whereas, the sum total of ions were 51, 42 and 21 per cent more in *Aleurops*, *Salicornia* and *Cynodon*, respectively. In *Chenopodium*, *Prosopis* and *Calotropis* the magnitude was 5, 4 and 1 per cent more than their respective controls (S<sub>0</sub>). But in *Xanthium*, *Sesbania*,

*Heliotropium* and *Parkinsonia* the magnitude of sum total of ions were declined than their controls ( $S_0$ ).

Similarly the phytoaccumulation of sum total of ions together at  $16 \text{ dSm}^{-1}$  of salinity were to the tune of 250-350 per cent more than their controls ( $S_0$ ) in *Atriplex lentiformis*, *Atriplex amnicola*, *Aerva tomentosa*, *Trianthema portulacastrum* and *Salicornia brachiata*. Whereas, it was to the extent of 130-200 per cent more than their controls ( $S_0$ ) in *Portulaca oleracea*, *Suaeda fruticosa*, *Arundo donax* and *Aelurops lagopoides*. Similarly, it was to a magnitude of 40 and 14.6 per cent more than their controls ( $S_0$ ) in *Atriplex nummularia* and *Cynodon dactylon*, respectively. But a decline in magnitude was also observed from 4-24 per cent less than their individual controls ( $S_0$ ) in case of *Chenopodium*, *Solanum*, *Xanthium*, *Sesbania*, *Heliotropium*, *Parkinsonia*, *Calotropis*, *Prosopis* and *Setaria*.

#### **5.2.48 Phytoaccumulation of sum total of ions (mg/total dry weight of plants in a pot)**

Table 51 illustrated that the phytoaccumulation of sum total of ions were enhanced with every increment of salinity levels than their respective controls ( $S_0$ ) except for few plants like *Chenopodium ambrosoides*, *Solanum xanthocarpum*, *Xanthium strumarium*, *Sesbania sesquens*, *Heliotropium procumbens*, *Parkinsonia aculeata*, *Calotropis procera*, *Prosopis juliflora*, *Cynodon dactylon* and *Setaria*

*indica*. In general, the sum totals of ions were present more in case of most of the members of chenopodiaceae, *Aerva tomentosa*, *Trianthema portulacastrum* and *Portulaca oleracea*.

At 8 dSm<sup>-1</sup> of salinity the phytoaccumulation of sum total of ions were 70-140 per cent more in the members of chenopodiaceae, *Portulaca*, *Aerva*, *Trianthema* and *Solanum* in comparison to their controls (S<sub>0</sub>), whereas, it was to the magnitude of 51, 21, 5, 4 and 1.2 per cent more in case of *Aleurops*, *Cynodon*, *Chenopodium*, *Prosopis* and *Calotropis* than their controls (S<sub>0</sub>), respectively. But there was a decline in their magnitude than their controls (S<sub>0</sub>) in case of *Xanthium*, *Sesbania*, *Heliotropium* and *Parkinsonia*.

Similarly the phytoaccumulation of sum total of ions were maximum in *Salicornia brachiata* and *Trianthema portulacastrum* i.e. 454 and 345 per cent more than their controls respectively at 16 dSm<sup>-1</sup> of salinity. The accumulation of total ions were to the tune of 100-300 per cent more than their controls (S<sub>0</sub>) in *Suaeda fruticosa*, *Atriplex lentiformis*, *Atriplex amnicola*, *Aerva tomentosa*, *Portulaca oleracea*, *Arundo donax* and *Aleurops lagopoides*. Likewise, it was 68.5 per cent more than their controls (S<sub>0</sub>) in *Atriplex nummularia*. In *Solanum*, *Chenopodium*, *Xanthium*, *Sesbania*, *Heliotropium*, *Parkinsonia*, *Calotropis*, *Prosopis*,

*Cynodon* and *Setaria*, the decline in magnitude than their controls was also observed.

#### **5.2.49 Total dissolved solids in stem ( $\mu\text{s/ppm}$ )**

Total dissolved solids (TDS) in stem (Table 52) were enhanced with increasing levels of salinity than their controls. The increment was more at 16 than 8  $\text{dSm}^{-1}$  of salinity. The overall accumulation of total dissolved solids (TDS) was, in general, more in most of the members of chenopodiaceae, whereas, it was the least in case of *Calotropis procera*, *Setaria indica*, *Prosopis juliflora*, *Parkinsonia aculeata*, *Xanthium strumarium*, *Sesbania sesquens*, *Heliotropium procumbens* and *Solanum xanthocarpum*.

At 8  $\text{dSm}^{-1}$  of salinity the accumulation of TDS was to the tune of 50-60 per cent more than their respective controls ( $S_0$ ) in the members of chenopodiaceae, whereas, it was 17-32 per cent more in rest of the genera.

Similarly, the accumulation of TDS at 16  $\text{dSm}^{-1}$  of salinity was to the magnitude of 75-105 per cent more in members of chenopodiaceae, *Aerva*, *Trianthema*, *Portulaca*, *Arundo*, *Aleurops* and *Cynodon*. In rest of the genera the magnitude of increase was 40-70 per cent more than their controls.

In general, the accumulation of TDS varied between 0.07-0.75 fold at 8  $\text{dSm}^{-1}$  and 0.6-1.02 times more

at 16 dSm<sup>-1</sup> of salinity in comparison to their respective controls (S<sub>0</sub>).

#### **5.2.50 Total dissolved solids (TDS) in leaves (μS/ppm)**

Table 53 demonstrated that the total dissolved solids (TDS) in leaves of different salt hyperaccumulator plants registered an upward trend with increasing levels of salinity (0-16 dSm<sup>-1</sup>). The increase was more at 16 dSm<sup>-1</sup> than at 8 dSm<sup>-1</sup> of salinity. The overall accumulation of TDS was in general, more in most of the members of chenopodiaceae, *Portulaca oleracea*, *Trianthema portulacastrum* and *Aerva tomentosa*, it was the least of all the plants in case of *Setaria indica*, *Parkinsonia aculeata*, *Calotropis procera*, *Prosopis juliflora*, *Xanthium strumarium*, *Heliotropium procumbens*, *Sesbania sesquens* and *Solanum xanthocarpum*.

At 8 dSm<sup>-1</sup> of salinity, the accumulation of TDS in leaves was 47-87 per cent more than their respective controls in *Saueda*, *Protulaca*, *Trianthema*, *Aerva*, *Arundo*, *Aleurops* and *Cynodon* whereas, it was to the tune of 10-20 per cent more than their respective controls in rest of the experimental plants.

Similarly, the per cent accumulation of TDS at 16 dSm<sup>-1</sup> of salinity was also more in most of the members of chenopodiaceae, *Aerva*, *Trianthema*, *Portulaca*, *Arundo*,

*Aleurops* and *Cynodon*. In rest of the genera, it was 25-45 percent more than their respective controls ( $S_0$ ).

In general, the accumulation of TDS was 0.12-0.87 fold more at 8 dSm<sup>-1</sup> and 0.25-1.22 times more at 16 dSm<sup>-1</sup> of salinity than their controls ( $S_0$ ).

#### **5.2.51 Sodium Adsorption Ratio (SAR) in soil after harvesting**

Table 54 showed that the sodium adsorption ratio (SAR) in soil after harvesting was enhanced with increasing levels of salinity than their controls ( $S_0$ ). The enhancement in SAR was higher at 16 dSm<sup>-1</sup> than at 8 dSm<sup>-1</sup> of salinity.

At 8 dSm<sup>-1</sup> of salinity sodium adsorption ratio (SAR) was enhanced to a magnitude of 350-415 per cent more than their respective controls ( $S_0$ ) in *Suaeda fruticosa*, *Trianthema portulacastrum*, *Setaria indica*, *Calotropis procera*, *Heliotropium procumbens*, *Sesbania sesquens* and *Atriplex* species, whereas, it was to the tune of 300-350 per cent more than their controls ( $S_0$ ) in rest of the plants.

Similarly the SAR was increased in soil after harvesting to the tune of 500-565 per cent more than their controls ( $S_0$ ) in case of *Setaria indica*, *Aleurops lagopoides*, *Calotropis procera*, *Heliotropium procumbens*, *Sesbania sesquens*, *Suaeda fruticosa*, *Portulaca oleracea*, *Trianthema portulacastrum* and *Atriplex* species, whereas, it was

enhanced to a magnitude of 480-500 per cent more than their controls in rest of the genera.

In general, the SAR ranged between 3.13-4.14 folds at 8 dSm<sup>-1</sup> and 4.8-5.65 times more at 16 dSm<sup>-1</sup> of salinity in comparison to their respective controls (S<sub>0</sub>).

#### **5.2.52 Cation exchange capacity (CEC) in soil after harvesting**

Table 55 presented here clearly showed that the cation exchange capacity (CEC) in soil after harvesting was not affected by the levels of salinity. The CEC was almost the same both at 8 and 16 dSm<sup>-1</sup> of salinities in all the experimental plants.

#### **5.2.53 pH**

Table 56 illustrated that the pH of soil was enhanced with every increment of levels. The increment was more at 16 dSm<sup>-1</sup> of salinity than at 8 dSm<sup>-1</sup> of salinity. The overall pH in general, was more in *Setaria indica*, *Parkinsonia aculeata*, *Sesbania sesquens*, *Xanthium strumarium*, *Calotropis procera*, *Prosopis juliflora* and it was least of all in case of members of family chenopodiaceae, *Aerva tomentosa*, *Portulaca oleracea* and *Trianthema portulacastrum*.

At 8 dSm<sup>-1</sup> of salinity the pH of soil after harvesting was to the tune of 4-9 per cent more than their controls (S<sub>0</sub>) in all the experimental plants.

Similarly the pH was 12.5-19.0 per cent more at 16 dSm<sup>-1</sup> of salinity than their respective controls in all the experimental plants.

It is interesting to note that pH varied between 0.05 to 0.09 folds more at 8 dSm<sup>-1</sup> and 0.13 to 0.19 times more at 16 dSm<sup>-1</sup> of salinity in comparison to respective controls (S<sub>0</sub>).

#### **5.2.54 ECe of soil**

ECe of soil after harvesting was enhanced with increasing levels of salinity (0-16 dSm<sup>-1</sup>) than their respective controls in all the experimental plants (Table 57). The increment was more at 16 dSm<sup>-1</sup> of salinity in comparison to 8 dSm<sup>-1</sup> of salinity. In general the more ECe was observed in case of *Setaria indica*, *Prosopis juliflora*, *Heliotropium procumbens*, *Calotropis procera*, *Sesbania sesquens*, *Parkinsonia aculeata* and *Xanthium strumarium* whereas, it was least in case of member of chenopodiaceae, *Portulaca oleracea*, *Aerva tomentosa* and *Trianthema portulacastrum*.

At 8 dSm<sup>-1</sup> of salinity the ECe was enhanced to a magnitude of 1000-1400 per cent more than their respective controls S<sub>0</sub> in case of most members of chenopodiaceae, *Aerva*, *Trianthema*, *Portulaca*, *Arundo*, *Aelurops* and *Cynodon*, whereas, it was to the tune of 800-1000 per cent more than their controls (S<sub>0</sub>) in rest of the genera.

Similarly the ECe of soil after harvesting at 16 dSm<sup>-1</sup> of salinity was to the tune of 2000-3015 per cent more than their respective controls in case of members of chenopodiaceae, *Aerva*, *Trianthema*, *Portulaca*, *Heliotropium*, *Arundo*, *Aleurops* and *Cynodon*.

It must be mentioned that in general, the enhancement in ECe was increased between 8-13 folds at 8 dSm<sup>-1</sup> and 17-30 folds at 16 dSm<sup>-1</sup> in comparison to their respective controls (S<sub>0</sub>).

#### **5.2.55 Percent (%) decrease in ECe**

Table 58 demonstrated that the per cent (%) decrease in ECe was maximum at control than at 8 and 16 dSm<sup>-1</sup> of salinity. As the levels of salinity increase, the per cent decrease in ECe was declined. The overall per cent decrease in ECe was more in the members of chenopodiaceae, *Aerva tomentosa*, *Portulaca oleracea*, *Trianthema portulacastrum*, *Arundo donax*, *Aleurops lagopoides* and *Solanum xanthocarpum*. The per cent decrease in ECe was least of all the plants in case of *Setaria indica*, *Prosopis juliflora*, *Heliotropium procumbens* and *Calotropis procera*.

It is worthwhile to note that per cent decrease in ECe of soil after harvesting of plants varied between 1.7-4.5 at 16 dSm<sup>-1</sup>, 3.9-9.6 at 8 dSm<sup>-1</sup> and 17-51 at 0 dSm<sup>-1</sup> of salinity in comparison to ECe of soil just before plantation.

**5.2.56 Per cent (%) remediation in terms of total estimated ionic accumulation after harvesting the plants *vis-a-vis* total estimated ionic accumulation under various added salinity levels before plantation.**

Table 59 illustrated that the per cent (%) remediation in terms of total estimated ionic accumulation after harvesting was decreased with increasing levels of salinity from 0-16 dSm<sup>-1</sup>. The per cent remediation was more at control (0 dSm<sup>-1</sup>) in comparison to different levels of salinity (8 and 16 dSm<sup>-1</sup>).

The overall percent remediation was more in case of most of the members of chenopodiaceae, *Portulaca oleracea*, *Trianthema portulacastrum* *Solanum xanthocarpum*, *Aerva tomentosa*, *Arundo donax*, *Aleurops lagopoides* and *Cynodon dactylon*, whereas, it was the least of all in case of *Setaria indica*, *Calotropis procera*, *Sesbania sesquens*, *Prosopis juliflora*, *Parkinsonia aculeata*, *Heliotropium procumbens*, *Xanthium strumarium* and *Chenopodium ambrosoides*.

Per cent remediation varied between 3-7 at 16 dSm<sup>-1</sup> and 6.5-16.3 at 8 dSm<sup>-1</sup> of salinity and 20-30 at 0 dSm<sup>-1</sup> of salinity. In fact, there is no remediation at 0 dSm<sup>-1</sup> (S<sub>0</sub>) since there are no toxic ions involved, but only mineral ions are preferentially absorbed. However, the actual

remediation took place at 8-16 dSm<sup>-1</sup> of salinity where uptake of toxic salt ions also took place alongwith mineral ions due to addition of Hoagland solution in the medium.

### **Experiment – III**

#### **Protein profile of Phytoremediating plants**

Figure 20 showed the protein profile in *Chenopodium ambrosoides*, *Portulaca oleracea*, *Suaeda fruticosa* and *Setaria indica* under salinity (S<sub>2</sub> = 16 dSm<sup>-1</sup>) and control (S<sub>0</sub>) through SDS-PAGE. In *Chenopodium ambrosoides* under non-saline (control) treatment a total of 12 protein bands were observed whereas under salinity (S<sub>2</sub>-16 dSm<sup>-1</sup>) the number of bands were increased to 18. In *Chenopodium ambrosoides* seven new proteins were synthesized (i.e. 167.9, 74.9, 63.1, 56.2, 19.9, 17.7 and 10.0 kDa) and one protein at S<sub>2</sub> (59.5 kDa) disappeared in comparison to control. It is worth while to mention here that the density of six proteins which appeared under salinity was quite thicker as compared to the control (S<sub>0</sub>). *Portulaca oleracea* was having 19 proteins bands under control (S<sub>0</sub>) while 22 protein bands were present under highest salinity treatment (S<sub>2</sub>) which clearly showed that the three new proteins were synthesized (i.e. 105.2, 15.8 and 26.6 kDa) under salinity than its control (S<sub>0</sub>). In case of *Suaeda fruticosa* the protein profile showed that a total of 17 protein bands appeared in control (S<sub>0</sub>), while 20 protein bands were

seen under  $16 \text{ dSm}^{-1}$  salinity. This indicated that in *Suaeda fruticosa* three new proteins were synthesized under salinity in comparison to its control (i.e. 56.2, 15.8 and 14.1 kDa). Likewise, in *Setaria indica* two proteins disappeared at  $S_2$  (i.e. 118.9 and 8.4 kDa) under  $16 \text{ dSm}^{-1}$  of salinity with respect to its control ( $S_0$ ). The total number of protein bands in *Setaria indica* were 15 in control and 13 under  $16 \text{ dSm}^{-1}$  of salinity. It might be assumed from the above findings that the *de novo* synthesis of various proteins and their consequent disappearing of proteins might be related to hyperaccumulation of salt ions in salinity tolerant plants.

Figure 21 showed the protein profile in *Setaria indica*, *Atriplex nummularia*, *A. amnicola* and *A. lentiformis* under salinity ( $S_2=16 \text{ dSm}^{-1}$ ) and control ( $S_0$ ) through SDS-PAGE. In *Setaria indica* a total of 15 protein bands were observed under control ( $S_0$ ), while 13 under salinity ( $S_2$ ). In *Setaria indica* two proteins (i.e. 118.9 and 8.4 kDa) disappeared under salinity ( $S_2$ ) in comparison to its control ( $S_0$ ). Whereas, in case of *Atriplex nummularia de novo* synthesis of two proteins (i.e. 51.8 and 22.1 kDa) were found under salinity ( $S_2$ ) which were absent in control ( $S_0$ ). Similarly the total number of bands in *Atriplex nummularia* were 17 under control and 19 under salinity ( $S_2$ ). Which means that two protein bands were freshly synthesized under salinity. *Atriplex amnicola* showed 15 bands under ( $S_0$ ) and

20 bands under salinity. In this six proteins (i.e. 44.6, 26.6, 25.1, 19.9, 12.5 and 10.0 kDa) were newly synthesized but another protein (i.e. 29.8 kDa) disappeared under salinity with respect to their control. However, in case of *Atriplex lentiformis* one protein (i.e. 10.0 kDa) was newly synthesized ( $S_2$ ) and one protein (i.e. 22.1 kDa) disappeared under salinity in comparison to control ( $S_0$ ). Therefore, it must be noted here that the total number of protein bands under salinity ( $S_2$ ) and under control ( $S_0$ ) in *Atriplex lentiformis* remained 16.

## CHAPTER – V

# Discussion

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Phytoremediation is the use of plants to bioremediate contaminated soil, water and air and it has recently emerged as a more cost effective, noninvasive, and publicly acceptable way to address the removal of environmental contaminants (Boyajian and Carreira, 1997; Singh *et al.*, 2003).

Halophytes have been considered as potential crops for saline areas. These species of halophytes are able to avoid ion toxicity and maintain water uptake in the presence of high salt concentrations (Flowers *et al.*, 1977; Munns, 2002). Two mechanisms of cellular adaptation to salinity are the accumulation of osmo-protectants, such as glycine-betaine or betaine-quarternary ammonium compounds or proline (especially present in glycophytes) and the control of ion movements allowing high inorganic ion concentrations (especially present in halophytes) (Bohnert *et al.*, 1995). These halophytic species like *Atriplex halimus*

(Chenopodiaceae) were used for restoration and rehabilitation of saline degraded lands (Abbad *et al.*, 2004).

In the present investigation, 20 different plant species were used for the phytoremediation of salinity. The results have been discussed to establish the cause and effect relationship by looking into the general trends on the basis of existing evidences in published literature on this subject. In addition, in-depth discussion with several scientists working on allied fields and personal scientific communications received from various organizations including Central Arid Zone Research Institute (CAZRI), Jodhpur, Arid Forest Research Institute (AFRI), Jodhpur, Central Salt and Marine Chemicals Research Institute (CSMCRI), Bhavnagar (Gujarat), Birla Institute of Scientific and Industrial Research, Jaipur (Rajasthan) indicated that scanty scientific information is available on native flora of saline wastelands which is mainly constituted of glycophytes. While the use of halophytes for saline soil reclamation/amelioration/desalination seems to have entered the realm of economic feasibility towards biosalt production in some countries like India, Pakistan and Morocco. Commercial production of halophytes with brackish water and sea water is still at its exploratory stage (e.g. Barrett *et al.*, 1986; Squires and Ayoub, 1994). Nevertheless, the efforts have been made to discuss the results of experimentation of

present study on some hyperaccumulator members of chenopodiaceae, poaceae, asclepiadaceae, tamaricaceae and others in the light of the available literature on the subject

**1. Collection, identification and characterization of native flora of saline wastelands**

Native flora of saline wastelands is almost consistent except for minor variations depending upon the magnitude of salinity. We did extensive survey of the saline wastelands in Haryana (Hisar) and parts of Rajasthan. We observed that inspite of variation in the levels of salinity, the native flora remained almost the same in these locations in north-west India. Generally, *Suaeda fruticosa*, *Salsola baryosma*, *Haloxylon recurvum* and *Atriplex* species grew in high salinity, whereas, the members belonging to families like poaceae, tamaricaceae, boraginaceae capparidaceae etc. occurred under marginal saline wastelands. These flora have also been mentioned in the inventory of saline wastelands of Sen and co-workers (1982). Such studies have also been made for different parts of Rajasthan by Das and Sarup (1951), Agarwal (1974) and Charan *et al.* (1978). They have listed different floras depending upon the ECe and pH of soil. They also analysed the biomass of plants native to saline lands in concomitant with the analysis of rhizosperic soil. These analyses have been helpful in our case also to find out potential salt hyper accumulator plants on the basis of the

amount of toxic salt ions in the above ground plant parts (Tables 1, 2 and 3).

**2. Growth, development, fresh/dry weight of plants, biomass yield in various chenopods and other plants varies with levels of salinity**

The data presented in Table 4 show that plant height was increased with increasing levels of salinity in most of the members of Chenopodiaceae, *Portulaca oleracea*, *Trianthema portulacastrum*, *Aerva tomentosa*, *Arundo donax* and *Aleurops lagopoides*, but in *Atriplex nummularia*, *Solanum xanthocarpum* and *Calotropis procera* an increase upto 8 and subsequent decrease at 16 dSm<sup>-1</sup> of salinity was observed. Whereas, the plant height was not affected at 8 but decreased at 16 dSm<sup>-1</sup> of salinity in *Chenopodium ambrosoides*, *Cynodon dactylon* and *Setaria indica*. In rest of the genera, the plant height was decreased with increasing levels of salinity.

Similarly, the number of branches (Table 5) were also increased with every increment of salinity in members of Chenopodiaceae, *Aerva*, *Trianthema*, *Portulaca*, *Aleurops* and *Cynodon*, whereas in rest of the genera the number of branches were not affected by salinity except *Heliotropium procumbens*, where a decrease in number of branches with increasing levels of salinity, was noticed.

Likewise, the number of leaves (Table 6) were also increased with the enhancement of salinity in most of the members of Chenopodiaceae, *Aerva*, *Trianthema*, *Portulaca*, *Arundo*, *Aleurops* and *Sesbania* but the number of leaves increased upto 8 dSm<sup>-1</sup> of salinity in *Atriplex nummularia*, *Cynodon dactylon* and *Setaria indica* and decreased thereafter at 16 dSm<sup>-1</sup> of salinity. However, the number of leaves were decreased with increasing levels of salinity in rest of the plants.

Total fresh/dry biomass (Table 11 and 12) was enhanced with the every promotion of salinity in most of the members of Chenopodiaceae, *Aerva*, *Trianthema*, *Portulaca*, *Arundo* and *Aleurops*, whereas, it was reduced upto 8 dSm<sup>-1</sup> of salinity in *Atriplex nummularia*, *Solanum* and *Cynodon* and decreased subsequently at 16 dSm<sup>-1</sup> of salinity. In rest of the plants it decreased with the enhancement of salinity levels.

These results are in accord with the observations of Neales and Sharkey (1981) in *Disphyma australe* where an increase in growth, leaf number per plant and leaf fresh weight has been observed by the increment of salinity to a level of 200 mol m<sup>-3</sup> NaCl. Ala *et al.* (1994) observed that the plant growth, shoot volume and plant biomass was increased upto 10 dSm<sup>-1</sup> but decreased at 20 dSm<sup>-1</sup> of salinity. Mahmood *et al.* (1996) showed that the plant growth increased with increasing salinity in *Suaeda fruticosa*, but

increased upto 5 dSm<sup>-1</sup> only in *Cynodon dactylon* and *Polypogon monspeliensis*. The growth of *Kochia indica*, *Atriplex crassifolia* and *Desmostachya bipinnata* decreased gradually with increase in salinity. In *Avicennia marina* the growth, total fresh and dry mass increased with increase in salinity (Cherian *et al.*, 1999). Even Cherian and Reddy (2000) in *Suaeda nudiflora* have recorded similar behaviour of plant growth, fresh and dry mass. Rao *et al.* (1999) studied that the total plant biomass, shoot length, root length and number of multiple shoots declined with increase in salinity from 25-35 to 45-55 dSm<sup>-1</sup> in *Salvadora persica*. Khan *et al.* (2000a,b,c) studied the growth and development of *Atriplex griffithii*, *Suaeda fruticosa* and *Haloxylon recurvum* under various levels of salinity. They observed that the growth and dry mass was increased with increasing salinity in *Atriplex griffithii* but inhibited only at 360 mM NaCl. In *Suaeda fruticosa* the growth and shoot dry weight was increased upto 400 m mol m<sup>-3</sup> NaCl, but decreased at higher salinity. Whereas, the growth fresh and dry weight of plants increased with an increase in salinity in *Haloxylon recurvum*. Similar results have been obtained by Shimizu *et al.* (2003) in *Salicornia herbacea*. Salman *et al.* (2003) in *Urochondra setulosa* showed that the number of leaves, plant height, fresh and dry weight were the highest in the non-saline and decreased with an increase in salinity. Gonzalez *et al.* (2005)

in *Cynara cardunculus* observed the plant growth and the weight of plant decreased at 100 mM NaCl or KCl. Similar results have been obtained by Ramos *et al.* (2004) in *Atriplex nummularia* and Abbad *et al.* (2004) in *Atriplex halimus*, where the growth, fresh and dry biomass increased upto 2% NaCl, but decreased at 3% NaCl concentrations. Amor *et al.* (2005) showed that the plant growth, leaf number and biomass production was stimulated upto 50 mM NaCl and thereafter, it decreased at 200 mM NaCl. Karimi *et al.* (2005) showed an increase in plant growth, fresh and dry matter upto 150 mM in *Kochia prostrata* but subsequently it decreased at 200 mM of NaCl.

### **3. Soil-water relationship and magnitude of salt resistance of different hyperaccumulator plants at different levels of salinity**

The water content (Table 15) was increased with the increasing levels of salinity in most of the members of Chenopodiaceae, *Aerva*, *Trianthema*, *Portulaca*, *Arundo* and *Aleurops*, but increased upto 8 dSm<sup>-1</sup> of salinity only in *Atriplex nummularia*, *Solanum xanthocarpum* and *Cynodon dactylon* and decreased at 16 dSm<sup>-1</sup> of salinity. In rest of the plants the water content was reduced with the enhancement of salinity.

High salt levels are partially compensated with high water storage in plant organs, thus diluting salt

concentrations. This mechanism was found in the stem succulent *Salicornia europaea* (Greenway, 1968; Chapman, 1974) and in other stem-succulents as *Arthrocnemum*, *Anabasis*, *Allenrolfea*, *Halocenemum* etc. Exactly similar was true in case of leaf-succulents also e.g. *Aster*, *Helimocnemis*, *Halogeton*, *Nitraria*, *Salsola*, *Suaeda* etc. The increase in water content can be a good reason for tissue succulence (Storey and Wyn Jones, 1979) and salinity promotes succulence in a number of halophytes (Reddy *et al.*, 1992; Ayala and O'Leary, 1995). The plant water content was also increased with salinity in *Suaeda nudiflora* (Cherian and Reddy, 2000).

The increase in water content could be attributed to osmoregulation or osmotic compensation or osmotic adjustment. Increase in succulence (dilution mechanism of salt tolerance), increasing ionic content, presence of less frequency of stomata on leaves, presence of hair or bladder or trichomes on the leaves, sunken stomata, presence of cuticle and all help in reducing the transpiration especially in halophytes. These are some of the characteristic morpho-physiological adaptations in halophytes (Flowers *et al.*, 1977; Wyn Jones, 1981; Richardson and McCree, 1985).

Leaf or stem succulence (i.e. high water content) is an adaptive feature, which contributes to the regulation of internal ion concentrations in many halophytes (Short and

Colmer, 1999). Similarly, leaf succulence degree in *Atriplex amnicola* (Aslam *et al.*, 1986); stem succulence degree in *Sarcocornia natalensis* (Naidoo and Rughuuanan, 1990); succulence in halophyte *Disphyma australe* (Neales and Sharkey, 1981); *Avicennia marina* (Cherian *et al.*, 1999); and in *Suaeda physophora* and *Haloxylon ammodendron* (Song *et al.*, 2006) in wake of high concentrations of NaCl were the acclimation factors of these halophytes to hostile saline external environment conditions in arid and semi arid regions.

This fact was also observed in the present investigations, which showed that the water content was the highest in *Salicornia brachiata*, *Atriplex lentiformis*, *Aleurops*, *Arundo*, *Trianthema* and *Suaeda* at higher salinity (i.e. 16 dSm<sup>-1</sup>).

Tissue water content increased in *Suaeda fruticosa* upto 200 mol m<sup>-3</sup> NaCl, but decreased with further increase in salinity and in case of *Haloxylon recurvum*, it enhanced at low salinity and declined at 360 mol m<sup>-3</sup> NaCl (Khan *et al.*, 2000a,c). Similar results were observed by Karimi *et al.* (2005) in *Kochia prostrata* where the water content was stimulated upto 150 mM but got depleted at 200 mM NaCl. In the present investigation we also observed similar results in *Atriplex nummularia*, *Solanum xanthocarpum* and *Cynodon dactylon* where an increase in water content upto 8 dSm<sup>-1</sup>

and then further decline at  $16 \text{ dSm}^{-1}$  of salinity was observed. Conversely in *Atriplex amnicola* there was decline in water content with the increment of salinity. These results are in agreement with Salman *et al.* (2003) who showed that the maximum succulence was found at 0 mM NaCl (control) and decreased with increasing salinity in *Urochondra setulosa*. Water potential, osmotic potential and stomatal conductance became more negative with an increase in salinity. Similar results were also obtained in present investigation in *Chenopodium*, *Xanthium*, *Sesbania*, *Heliotropium*, *Parkinsonia*, *Calotropis*, *Prosopis* and *Setaria*, where the water content decreased with the enhancement of salinity. These results clearly put forth the sensitivity of these genera to saline environment.

#### **4. The magnitude of computed salt ion phytoaccumulation varies with different salt hyper accumulator plants**

The  $\text{Na}^+$  and  $\text{Cl}^-$  content in stem and leaves (Table 22, 23, 38 and 39) was increased with increasing levels of salinity, but at the same time the  $\text{K}^+$ ,  $\text{Ca}^{2+}$ ,  $\text{Mg}^{2+}$  and  $\text{SO}_4^{2-}$  content in stem and leaves (Table 26, 27, 30, 31, 34, 35, 42 and 43) was decreased with increasing levels of salinity.

Phytoaccumulation of  $\text{Na}^+$  and  $\text{Cl}^-$  content per pot (Table 24 and 40) was also increased with the increment of salinity except *Solanum xanthocarpum* where  $\text{Cl}^-$  content

decreased at 16 dSm<sup>-1</sup> of salinity and in *Xanthium strumarium* where Cl<sup>-</sup> content declined at 8 dSm<sup>-1</sup> of salinity in comparison to their respective controls. Phytoaccumulation of K<sup>+</sup> (Table 28) was also declined with the enhancement of salinity except *Suaeda fruticosa* and *Solanum xanthocarpum* where an increase at 8 dSm<sup>-1</sup> of salinity was observed. Phytoaccumulation of Ca<sup>2+</sup> per pot declined with the increasing levels of salinity (Table 32) except *Trianthema* and *Aerva* where it depicted an increase with salinity, but in *Atriplex lentiformis* and *Salicornia brachiata* an increase in Ca<sup>2+</sup> content at 16 dSm<sup>-1</sup> of salinity in comparison to their respective controls was also observed. Phytoaccumulation of Mg<sup>2+</sup> decreased with increasing levels of salinity (Table 36) except *Aerva tomentosa* where the phytoaccumulation of Mg<sup>2+</sup> enhanced with the increment of salinity. However, this enhancement was observed also in *Solanum xanthocarpum* at 8 dSm<sup>-1</sup> of salinity in comparison to their controls, whereas, in *Trianthema*, *Salicornia* and *Atriplex lentiformis* the phytoaccumulation of Mg<sup>2+</sup> was increased at 16 dSm<sup>-1</sup> of salinity in comparison to control.

Phytoaccumulation of SO<sub>4</sub><sup>2-</sup> in plants per pot (Table 44) was also declined with the increment of salinity except *Aerva tomentosa* and *Atriplex lentiformis* where it was increased with the enhancement of salinity. But in *Portulaca* the phytoaccumulation was increased at 8 dSm<sup>-1</sup> of salinity,

whereas it consistently kept on increasing even upto 16 dSm<sup>-1</sup> of salinity in *Trianthema*, *Salicornia* and *Atriplex amnicola*.

The ratio of Na<sup>+</sup>/ K<sup>+</sup> in stem, leaves and above ground parts in plants (Table 46, 47 and 48) was stimulated with increasing levels of salinity. These results are in consonance with Aslam *et al.* (1979) in *Diplachne fusca*, where an increase in Na<sup>+</sup> and decrease in K<sup>+</sup>, Ca<sup>2+</sup>, Mg<sup>2+</sup> contents was observed with increasing salinity and concomitantly the Cl<sup>-</sup> content was decreased with increasing level of salinity. Khan *et al.* (2000b) in *Atriplex griffithii*, *Suaeda fruticosa* and *Haloxylon recurvum* showed similar results in the sense that the Na<sup>+</sup> and Cl<sup>-</sup> content in both shoots and roots was enhanced with increase in salinity, but Ca<sup>2+</sup>, K<sup>+</sup> and Mg<sup>2+</sup> content was declined with increasing levels of salinity. Similar results were obtained by Storey and Wyn Jones (1979) in *Atriplex spongiosa* and *Suaeda monoica*; and Mahmood *et al.* (1996) in *Suaeda fruticosa*, *Kochia indica*, *Atriplex crassifolia*, *Sporobolus arabicus*, *Cynodon dactylon*, *Polypogon monspeliensis* and *Desmostachya bipinnata*. Maggio *et al.* (2000) revealed that most of the Na<sup>+</sup> concentration was centred in the leaves of *Salvadora persica* under salinity and it was 40-fold greater than the non-salinized controls with significant reductions in leaf K<sup>+</sup> and Ca<sup>2+</sup> concentrations. Keiffer and Ungar (2002) observed that the Na<sup>+</sup> and Cl<sup>-</sup> contents were higher than other ions in

saline conditions in *Atriplex prostrata*, *Hordeum jubatum*, *Salicornia europaea*, *Spergularia marina* and *Suaeda calceoliformis*.

Likewise, Salman *et al.* (2003) indicated that the  $\text{Na}^+$  and  $\text{Cl}^-$  levels increased in shoots while  $\text{K}^+$  concentration decreased with increase in salinity in *Urochondra setulosa*. Our results are also in agreement with the results obtained by Shimizu *et al.* (2003) in *Salicornia herbacea*, Remos *et al.* (2004) in *Atriplex nummularia* and Abbad *et al.* (2004) in *Atriplex halimus*.

Amor *et al.* (2005) also showed that the  $\text{Na}^+$  and  $\text{Cl}^-$  were largely accumulated in shoots. The accumulation of  $\text{Na}^+$  and  $\text{Cl}^-$  was increased with the increasing levels of salinity while the concentrations of  $\text{Ca}^{2+}$ ,  $\text{Mg}^{2+}$  and  $\text{K}^+$  were declined. Our results were also in concord with Gonzalez *et al.* (2005) in *Cynara cardunculus* and Karimi *et al.* (2005) in *Kochia prostrate*. Even Cherian and Reddy (2003) showed that the  $\text{Na}^+/\text{K}^+$  ratio was increased with the addition of NaCl concentrations in the medium.

## **5. Physiological basis of salt resistance in different chenopods and potential hyper-accumulator plants**

The results presented (Tables 50 and 51) especially on phytoaccumulation of total ions (mg per plant dry weight or mg per total dry weight of plants in a pot),

showed that ionic accumulation increased with increasing levels of salinity except *Xanthium strumarium*, *Sesbania sesquens*, *Heliotropium procumbens*, *Parkinsonia aculeata* and *Setaria indica*. In these latter plants, the total ions accumulation was declined with the increment of salinity, whereas in *Chenopodium ambrosoides*, *Solanum xanthocarpum*, *Calotropis procera* and *Prosopis juliflora* there was a decline in total ions accumulation at higher salinity only (i.e. 16 dSm<sup>-1</sup>). These results are in accordance with various review articles of different research workers on diverse plants (Flowers *et al.*, 1977; Greenway and Munns, 1980; Flowers, 1985; Cheeseman, 1988; Chinnusamy *et al.*, 2005; Shisong Ma *et al.*, 2006), who have studied the physiological basis of salt tolerance of both glycophytes and halophytes. They indicated that *Salicornia brachiata* - is an obligate halophyte (Enhalophyte), whose growth and development increased under saline conditions (Joshi *et al.*, 1982; Iyengar *et al.*, 1991; Reddy *et al.*, 1993). Likewise *Suaeda fruticosa* and *Aelurops lagopoides* have been adjudged as halophytes, whereas *Aerva persica*, *Portulaca oleracea*, *Sesbania bispinosa* and *Setaria verticillata* as facultative halophytes; and *Trianthema portulacastrum*, *Prosopis juliflora*, *Heliotropium marifolium* and *Calotropis procera* as glycophytes (Rajpurohit, 1980).

In our studies, we have also observed a high degree of salt resistant in *Suaeda fruticosa*, *Atriplex* species, *Aerva*, *Portulaca*, *Trianthema*, *Aleurops* and *Arundo* especially under high salinity (16 dSm<sup>-1</sup>). At the same time, the plants like *Sesbania*, *Heliotropium*, *Chenopodium*, *Solanum*, *Xanthium*, *Parkinsonia*, *Prosopis*, *Cynodon* and *Setaria* have reduced growth at higher salinity in comparison to their controls. This clearly indicated that the members of Chenopodiaceae alongwith *Aerva*, *Portulaca*, *Trianthema*, *Aleurops* and *Arundo* have also got characteristics of salt tolerance. In addition they hyperaccumulate salt ions and their reclamation potential of soil salinity is also evidently proved beyond doubt in our experimentation. As far as the physiology of salt tolerance is concerned, halophytes are a diverse group of plants with varying degree of salt tolerance (Flowers *et al.*, 1975). There are mainly two types of mechanisms of salt resistance (i) avoidance (ii) tolerance. In general the salt avoidance mechanism includes (i) exclusion of salt at root level. (ii) Excretion (pores in the leaves) as in *Leptochloa fusca*. (iii) Extrusion i.e. by trichomes, glands, vesicle and hairs. (iv) Dilution of cell sap (increased absorption of water along with salt ions as in case of cotton and *Atriplex*). (v) Shedding of leaves as in case of cotton.

Some halophytes have salt glands. These were observed in *Tamarix aphylla* (Berry and Thomson, 1967;

Berry, 1970), salt bladders in *Atriplex* spp. (Rajput and Sen, 1991), vesiculated hairs in *Atriplex halimus* (Mozafar and Goodin, 1970), salt crystals were present in special tracheidial cells in *Salicornia brachiata* (Iyengar *et al.*, 1991) and *Leptochloa fusca* have specialized glands for salt excretion (Kumar, 1996). Succulence can be a mechanism to dilute excess NaCl in the leaf tissue (Kramer, 1984). Non-halophytes also increase water use efficiency in response to salt stress (Osmond *et al.*, 1980; Richards, 1992).

The salt tolerance mechanisms include sequestration of NaCl into vacuoles to remove the excess of salts present in cytoplasm of cell. The Na<sup>+</sup> uptake into the vacuole is mediated by Na<sup>+</sup>/ K<sup>+</sup> antiporters in the tonoplast and in the stalk cells of the glands. Tonoplast antiporter activity of salt-tolerant higher plants has been identified in roots or leaves of the halophytes - *Atriplex nummularia* (Harsidim *et al.*, 1990), *Plantago maritima* (Staal *et al.*, 1991), *Atriplex gmelini* (Matoh *et al.*, 1989) as well as glycophytes such as barley (Garbarino and Dupont, 1988, 1989) and cotton (Harsidim *et al.*, 1990).

The cellular basis of salt resistance (tolerance) in halophytes depends upon the effective compartmentation of ions in vacuoles which is necessary for osmoregulation. Osmotic adjustment by *de novo* synthesis of compatible solutes in the cytoplasm can also prevent loss of turgor and

hence ensures continuity of growth of plants. These mechanisms of salt resistance have been adequately explained in *Suaeda maritima* (Flowers, 1985); *Haloxylon recurvum*, *Atriplex griffithii*, and *Suaeda fruticosa* (Khan *et al.*, 2000a,b,c); *Atriplex nummularia* (Ramos *et al.*, 2004); *Kochia prostrata* (Karimi *et al.*, 2005); *Cynara cardunculus* (Gonzalez *et al.*, 2005) and in *Suaeda physophora*, *Haloxylon ammodendron* and *Haloxylon persicum* (Song *et al.*, 2006).

**6. The members of Chenopodiaceae and other hyper accumulator plants of present investigation could be used for domestication of the disturbed saline soils**

The foregoing results (Table 3,4,5) on morphological parameters, water content of the plants (Tables 13, 14, 15) the accumulation of toxic ions (Tables 22, 23, 24, 26, 27, 28, 30, 31, 32, 34, 35, 36, 38, 39, 40, 42, 43, 44) like  $\text{Na}^+$  and  $\text{Cl}^-$  in concomitant with the decline of essential nutrients like  $\text{K}^+$ ,  $\text{Ca}^{2+}$ ,  $\text{Mg}^{2+}$  and  $\text{SO}_4^{2-}$  in the above ground plant parts, the total ionic accumulation in plant dry weight clearly putforth that the chenopods like *Suaeda fruticosa*, *Salicornia brachiata*, *Atriplex nummularia*, *Atriplex lentiformis*, *Atriplex amnicola* and other hyper accumulators like *Aerva tomentosa*, *Portulaca oleracea*, *Trianthema portulacastrum*, *Aleurops lagopoides* and *Arundo donax*, which have been studied during the course of the present

investigation, have shown the potentiality of enhancement in growth under salinity and these plants could be adjudged as saline hyper accumulators. It showed that the salinity favour their growth, development and their simultaneous biomass production. So these hyperaccumulator plants can be used for domestication and their further transplantation on to the disturbed saline and alkaline soils for reclamation was plausible. On the contrary *Chenopodium ambrosoides*, *Solanum xanthocarpum*, *Xanthium strumarium*, *Heliotropium procumbens*, *Sesbania sesquens*, *Prosopis juliflora*, *Parkinsonia aculeata* and *Cynodon dactylon* could only be planted in areas with low salinity, however, *Calotropis procera* and *Setaria indica* could not be used for plantation in the saline wastelands. Out of these hyper accumulator plants *Salicornia brachiata* can not be used for cultivation onto the disturbed saline lands because it has a lot of water content with increase in salinity and the dry biomass is very low. Moreover, geographically this plant belongs to coastal areas of Gujarat (Iyengar *et al.*, 1991; Reddy *et al.*, 1993) which is being continuously bathed by the waves/tides of sea water.

In this context various plants like *Prosopis juliflora*, Karnal grass (*Leptochloa fusca*); rhodegrass (*Chloris gayana*); para grass (*Brachiara mutica*); *Aelurops lagopoides*, *Sporobolus spicatus*, *Cyperus laevigatus* have been used as fodder plants (Maliwal *et al.*, 1991; Kumar and Abrol, 1996;

Kumar, 1996; Onkware, 1997). Kumar (1988a,b) has recommended *Diplachne fusca*, *Panicum laevifolium*, *Panicum antidotale*, *Chloris gayana* and *Cynodon maritimus* for soil salinity and alkalinity reclamation.

Even *Spinacea oleracea* could be grown at marginal saline lands (Garg and Gupta, 1997) and alkali lands as it yielded higher biomass and could be used as potential vegetable crops (Sharma *et al.*, 2001). Mahmood *et al.* (1996) have ascribed high tolerance of chenopods to their ability for internal ion regulation and exhibited wide range of tolerance to salinity. Most of these plants *Suaeda fruticosa*, *Kochia indica*, *Atriplex crassifolia*, *Sporobolus arabicus*, *Cynodon dactylon*, *Polypogon monspeliensis*, *Desmostachya bipinnata* may be utilized for enhancing productivity of salt affected land. Sharma *et al.* (1968) studied *Calotropis procera* and found that it was suitable for alkaline soil as it markedly lowered down the pH value of soil.

Gallagher (1985) have evaluated several halophytes which could be developed for grain fodder and vegetable crops under saline conditions. *Sporobolus virginicus* has been used for hay and pasture, *Distichis spicata* for hay, *Kosteletzkya virginica* for grain, *Atriplex triangularis* for substituted vegetable.

Khan *et al.* (2000a) have recommended *Suaeda fruticosa* for fodder purposes. Chaudhari *et al.* (1964)

reported that *Suaeda fruticosa* could be used as soda ash a commercial product locally called saji. Agarwal *et al.* (1950) recommended *Sesbania aculeata* and *Brachiaria mutica* as green manures for the reclamation of alkaline soils.

*Haloxylon ammodendron* and *H. persicum* have traditionally been used as livestock feed and fire wood and these are crucial plant species in protecting desert lands in China (Tobe *et al.* 2000 and Song *et al.* 2006). Even *Atriplex halimus* has qualities of palatability and is appreciated fodder for camels, bovines and caprines during drought (Kinet *et al.* 1998).

**7. Magnitude of decrease of soil salinity by the members of chenopodiaceae and other plants through higher accumulation of ions**

The results presented in Table 21, 25, 29, 33, 37 and 49) clearly showed the comparison of the data of  $\text{Na}^+$ ,  $\text{K}^+$ ,  $\text{Ca}^{2+}$ ,  $\text{Mg}^{2+}$ ,  $\text{SO}_4^{2-}$  and  $\text{Cl}^-$  ions before plantation and after harvesting of different hyper accumulator plants. It has clearly showed that the increase in salinity levels obviously enhanced manifold increase in  $\text{Na}^+$  and  $\text{Cl}^-$  in the soils. At the same time  $\text{K}^+$ , remained almost constant before plantation. However,  $\text{Ca}^{2+}$ ,  $\text{Mg}^{2+}$  and  $\text{SO}_4^{2-}$  although increase to a lesser extent in comparison to  $\text{Na}^+$  and  $\text{Cl}^-$  but with the harvesting

of different plant species the increasing salinity levels do increase  $\text{Na}^+$  and  $\text{Cl}^-$  manifold in plants as well.

On the contrary  $\text{K}^+$ , content increased with increasing salinity levels after harvesting. In addition,  $\text{Ca}^{2+}$ ,  $\text{Mg}^{2+}$  and  $\text{SO}_4^{2-}$  also increased with every increment in salinity levels. The data with respect to ionic contents in the soils where different plant species were growing showed that the magnitude of increase of  $\text{Na}^+$ ,  $\text{K}^+$ ,  $\text{Ca}^{2+}$ ,  $\text{Mg}^{2+}$ ,  $\text{Cl}^-$ ,  $\text{SO}_4^{2-}$  and total ionic content in the soils was reduced in comparison to the data of these ions before plantation of the different plant species. It is clearly evident in these tables (21, 25, 29, 33, 37, 41 and 49) that  $\text{Na}^+$ ,  $\text{K}^+$ ,  $\text{Ca}^{2+}$ ,  $\text{Mg}^{2+}$ ,  $\text{SO}_4^{2-}$ ,  $\text{Cl}^-$  and the sum total of ionic contents were increased in different plant species.

The content of  $\text{Na}^+$ ,  $\text{K}^+$ ,  $\text{Ca}^{2+}$ ,  $\text{Mg}^{2+}$ ,  $\text{Cl}^-$ ,  $\text{SO}_4^{2-}$  and total ionic content remained much less in soil where *Suaeda fruticosa*, *Salicornia brachiata*, *Atriplex lentiformis*, *Atriplex amnicola*, *Atriplex nummularia*, *Aerva tomentosa*, *Portulaca oleracea*, *Trianthema portulacastrum*, *Aleurops lagopoides*, *Arundo donax* and *Cynodon dactylon* were growing. But in case of *Chenopodium ambrosoides*, *Solanum xanthocarpum*, *Xanthium strumarium*, *Sesbania sesquens*, *Prosopis juliflora*, *Heliotropium procumbens*, *Parkinsonia aculeata*, *Calotropis procera* and *Setaria indica* the different contents of ions like

$\text{Na}^+$ ,  $\text{Cl}^-$ ,  $\text{Ca}^{2+}$ ,  $\text{Mg}^{2+}$ ,  $\text{SO}_4^{2-}$ ,  $\text{K}^+$  and the total ions remained higher in the soil after harvesting of the above mentioned plant species. On the contrary, sharp hyperaccumulation of different ions mainly  $\text{Na}^+$  and  $\text{Cl}^-$  into the biomass of different plant species like *Salicornia brachiata*, *Suaeda fruticosa*, *Atriplex* species, *Aerva tomentosa*, *Trianthema portulacastrum*, *Portulaca oleracea*, *Aleurops lagopoides* and *Arundo donax* could characterize them as potential hyperaccumulators. However, *Atriplex nummularia*, *Solanum xanthocarpum* and *Cynodon dactylon* were observed moderate accumulators. Likewise, less accumulation of these ions (Table 22, 23, 26, 27, 30, 31, 34, 35, 39, 42, 43) in case of *Chenopodium ambrosoides*, *Xanthium strumarium*, *Sesbania sesquens*, *Parkinsonia aculeata*, *Heliotropium procumbens*, *Prosopis juliflora*, *Calotropis procera* and *Setaria indica* led to more contents of all these ions in the soil after harvesting of these different plant species.

Another interesting fact brought forth by this investigation was with respect to contents of  $\text{K}^+$  before plantation which did not differ much at different salinity levels (table 20). However, after harvesting of plant species there was increase in  $\text{K}^+$  content, with increase in salinity levels (Table 25). This clearly showed that there was a direct competition between  $\text{Na}^+$  and  $\text{K}^+$  under increased levels of salinity. The results clearly showed that there is preferential

absorption of  $\text{Na}^+$  and  $\text{Cl}^-$  ions which led to the competitive inhibition of  $\text{K}^+$  ions in the plants studied, thereby, causing increase in  $\text{K}^+$  with every increment of salinity levels in the soil after harvesting of these plant species.

This type of preferential absorption of  $\text{Na}^+$  and  $\text{Cl}^-$  and competitive inhibition of  $\text{K}^+$  has already been reported in various plants by different research workers (Naidoo and Raghuunanan, 1990; Al-Zahrani; Hajar, 1998 and Cherian and Reddy, 2000).

This preferential absorption of  $\text{Na}^+$  and  $\text{Cl}^-$  by different halophytes also inhibited the accumulation of other nutrients as well like N,  $\text{K}^+$ , P,  $\text{Ca}^{2+}$ ,  $\text{SO}_4^{2-}$  as reported by Epstein (1972), Flowers (1972), Glenn and O'Leary (1984), Cramer *et al.* (1985), McNulty (1985), Naidoo and Raghuunanan (1990), Khan *et al.* (2000), and Khan *et al.* (2001).

#### **8. Role of organic matter, ash content and TDS (Total Dissolved Solids) of different plant species in reclamation of saline soils**

The ash content of stem and leaves (Tale 16, 17) was increased with the increasing levels of salinity in all the experimental plants except *Parkinsonia aculeata* and *Aleurops lagopoides* where a slight decrease occurred in ash content of leaves at  $16 \text{ dSm}^{-1}$  of salinity. The overall ash content was more in most of the members of

Chenopodiaceae, *Portulaca oleracea*, *Trianthema portulacastrum* and *Aerva tomentosa* due to the accumulation of more salt ions.

The organic matter (Table 18 and 19) of stem and leaves of different plant species was decreased with increasing levels of salinity in all the experimental plant species. The organic matter was maximum in less accumulators of ions like *Setaria indica*, *Prosopis juliflora*, *Calotropis procera* etc. which is exactly opposite to the trends of ash contents in plants.

The total dissolved solids (TDS) (Tables 52 and 53) was enhanced with every increment of salinity levels in all the experimental plants. The trends of TDS are same as that of ash content. The TDS was more in members of Chenopodiaceae, *Portulaca oleracea*, *Trianthema portulacastrum*, *Aerva tomentosa*, *Arundo donax* and *Aelurops lagopoides* due to the hyperaccumulation of salt ions in these plants. However, the TDS were less in *Chenopodium ambrosoides*, *Solanum xanthocarpum*, *Xanthium strumarium*, *Sesbania sesquens*, *Parkinsonia aculeata*, *Heliotropium procumbens*, *Calotropis procera*, *Prosopis juliflora*, *Cynodon dactylon* and *Setaria indica* and incidentally these plants accumulated meagre amount of ions in their biomass.

These results were consistent with findings of many research workers like Choudhari *et al.* (1964) in *Suaeda fruticosa*; Waisel and Ovadia (1972) in *Suaeda monoica* and Joshi (1982) in *Suaeda nudiflora* and *Salicornia brachiata*.

Likewise, the ash content was high under salinity in seven different *Atriplex* species (Hyder, 1981). Bhatti *et al.* (1980) observed that the ash content was also increased significantly with enhancement of P, K and salinity in maize. Exactly similar trends were observed in *Salsola iberica* (Fowler *et al.*, 1992) and 23 species of Chenopodiaceae (Glagoleva and Chulanovskaya, 1992). Ala *et al.* (1994) showed that the ash content of plants increased with concomitant decrease in organic matter content under salinity in comparison to control in *Atriplex amnicola*. Kolchevskii *et al.* (1995) studied 14 species of C<sub>3</sub> and C<sub>4</sub> plants and showed that the ash content was higher under increasing soil salinity. The ash content was also higher under salinity in *Atriplex nummularia*, *Distichlis palmeri*, *Batis maritima* and *Suaeda esteroa* (Miyamoto *et al.*, 1996). The ash content of plants increased and the organic content of plants was significantly reduced with the increment of salinity in *Suaeda fruticosa*, *Atriplex griffithii* var. *Stocksii* (Khan *et al.*, 2000b) and in *Salicornia herbacea* (Shimizu *et al.*, 2003) as well. Gonzalez *et al.* (2005) studied that the

total solute concentration in plants increased with salinity and this was mainly due to the increase in the amount of internal inorganic ions in a salt tolerant halophyte *Cynara cardunculus*.

**9. Use of chenopods and other hyperaccumulator plants for phytoremediation and their use as plant based green technology for reclamation of saline soils**

Tables 56, 57, 58 and 59 showed that pH, ECe and their magnitude was clearly decreased on comparison of data before plantation and after harvesting of chenopods and other hyper accumulators. Likewise, per cent remediation in terms of total estimated ionic accumulation in the harvestable biomass in the plant in comparison to the total estimated ionic concentrations left in the soil at various added salinity levels was promising particularly at both levels of salinity. Rather per cent remediation was more at 8 than at 16 dSm<sup>-1</sup> in all members of Chenopodiaceae and hyper accumulators.

To elaborate the above results further, it was shown that ECe and pH was decreased after harvesting of plants at every increment of added salinity levels in comparison to before plantation of different plant species. The magnitude of decrease was well pronounced in the soil where the members of Chenopodiaceae, *Aerva tomentosa*,

*Portulaca oleracea*, *Trianthema portulacastrum*, *Aleurops lagopoides* and *Arundo donax* were growing, however, it was the least of all in the soil from where *Chenopodium ambrosoides*, *Solanum xanthocarpum*, *Xanthium strumarium*, *Heliotropium procumbens*, *Sesbania sesquens*, *Parkinsonia aculeata*, *Prosopis juliflora*, *Calotropis procera*, *Cynodon dactylon* and *Setaria indica* were harvested. Even per cent remediation occurred more in most of the members of Chenopodiaceae, *Aerva*, *Trianthema*, *Portulaca*, *Aleurops* and *Arundo* in comparison to *Chenopodium*, *Solanum*, *Xanthium*, *Heliotropium*, *Sesbania*, *Cynodon*, *Parkinsonia*, *Prosopis*, *Calotropis* and *Setaria*. Thus, it drives home the point that the members of Chenopodiaceae, *Aerva*, *Trianthema*, *Portulaca*, *Aleurops* and *Arundo* have the potential to ameliorate markedly the soil salinity and pH. These results are in consonance with the findings of various research workers who have used *Atriplex semibaccata* having salt leaching characteristics from soil (Villers *et al.*, 1995); *Atriplex lentiformis* (Arya *et al.*, 1996, 1998) improved soil properties like EC, pH and organic matter under saline conditions; *Atriplex holocarpa*, *Atriplex hortensis* and *Atriplex vesicaria* possessed hair and bladders which accumulate salt ions against the concentration gradient (Rajput and Sen, 1991; Sen and Rajpurohit, 1982). *Suaeda fruticosa* and *Atriplex nummularia* and *Atriplex stocksii* could be used for

enhancing productivity of saline wastelands for use as pasture fodder plant (Mahmood *et al.*, 1996; Khan *et al.*, 2000a,b,c). In a significant observation on saline lands in Pakistan, *Suaeda fruticosa* could remove 2646 kg ha<sup>-1</sup> NaCl in a year (Chaudhary *et al.*, 1964). Even, *Salicornia brachiata* could be used as salt hyperaccumulator and for production of biosalt (Reddy *et al.*, 1993), Mohammed and Sen (1992) have adjudged *Salsola baryosma* as an hyper accumulator plant of saline wastelands. In addition, *Suaeda nudiflora* has also been used as a substitute vegetable crop in some areas in India (Cherian and Reddy, 2000, 2003). In the same way, *Salvadora persica* occurred in saline black soil which could be used for phytoreclamation onto unfavourable land (Rao *et al.*, 1999; Maggio *et al.*, 2000). Moreover, *Avicennia marina* (Forstk.) is a dominant vegetation in saline wetlands along the tropical and sub-tropical coasts and has the potentiality to check the gushing tidal waves as has been proved in the recent tsunami disaster (Cherian *et al.*, 1999; various news paper reports, 2004). Likewise *Haloxylon recurvum* is a dominant flora in Rajasthan and around Karachi in Pakistan (Gehlot and Sen, 1996; Khan and Ungar, 1996).

Even other grasses have also been identified like rhodes grass (*Chloris gayana*), guinea grass (*Panicum maximum*), para grass (*Brachiaria mutica*), *Panicum leavifolium* and *Sesbania sesquens* (Dhaincha), which could

be used extensively for desalinization and detoxification of saline wastelands of Haryana (Dahiya *et al.*, 1993). Similarly, Neales and Sharkey (1981) have identified succulent halophytes like *Disphyma australe* which could hyperaccumulate salinity ions.

Robinson *et al.* (2003) used *Populus deltoides*, Eucalyptus and willow clones on the Kopu site for phytoremediation and to improve degraded environments. Abbad *et al.* (2004) used seven Moroccan provenances of *Atriplex halimus* for restoration and rehabilitation of saline degraded lands. Suman (2005) used forage grasses like *Brachiaria mutica*, *Leptochloa fusca*, *Setaria sphacelata*, *Chloris gayana*, *Sorghum sudanensis* and *Panicum maximum* to improve salt-affected soils.

**10. The *de novo* synthesis of proteins in members of Chenopodiaceae and other hyper accumulator plants throw light on proteins responsible for hyper accumulation of salt ions in the above ground biomass of salt resistant plants**

The last part of this investigation drives comparison of protein profile of five potential hyper accumulators i.e. *Suaeda fruticosa*, *Portulaca oleracea*, *Atriplex lentiformis*, *Atriplex amnicola* and *Atriplex nummularia* with that of moderate salt accumulators like *Chenopoidum ambrosoides* and least salt accumulator *Setaria*

*indica* through SDS-PAGE (Fig. 20 and 21). In *Chenopodium ambrosoides* 7 new proteins were synthesized (i.e. 167.9, 74.9, 63.1, 56.2, 19.9, 17.7 and 10.0 kDa) and one protein of 59.5 kDa disappeared under salinity in comparison to control. In *Setaria indica* two proteins disappeared at 16 dSm<sup>-1</sup> of salinity (i.e. 118.9 and 8.4 kDa). On the contrary, three new proteins each were synthesized in *Portulaca oleracea* (i.e. 105.2, 15.8 and 26.6 kDa) and in *Suaeda fruticosa* (i.e. 56.2, 15.8 and 14.1 kDa) under salinity. Likewise in *Atriplex nummularia* *de novo* synthesis of two proteins (i.e. 51.8 and 22.1 kDa) and 6 proteins (i.e. 44.6, 26.6, 25.1, 19.9, 12.5 and 10.0 kDa) in *Atriplex amnicola* took place and in addition to disappearance of one protein (i.e. 29.8 kDa) under salinity. On the other hand in *Atriplex lentiformis* one protein (i.e. 10.0 kDa) appeared and another (i.e. 22.1 kDa) disappeared under salinity in comparison to control.

Depressed protein synthesis or acceleration in its degradation in plants in response to salt stress has been reported by number of research workers (Chandershekhar *et al.*, 1986; Lal and Bhardwaj, 1987). *Sporobolus spicatus* had high concentrations of proteins under high salinity (Boutton *et al.*, 1988).

Similar results were obtained in tobacco where a 26 kDa protein named as osmotin was found (Singh *et al.*,

1987) in response to salinity. In barley accumulation of two 26 kDa polypeptides related to germin in response to salt stress was observed (Hurkman *et al.*, 1991). Likewise, a 22 kDa protein was found in radish (*Raphanus sativus*) in response to salt stress (Lopez *et al.*, 1994). Salt induced proteins have also been identified in rice (Claes *et al.*, 1990) and tomato (Torres Schumann *et al.*, 1992). Similarly, decrease in protein content in concomitant with increase in proline accumulation in *Salvadora persica* (Rao *et al.*, 1999) and *Suaeda nudiflora* (Cherian and Reddy, 2003) has been observed. Sreenivasulu *et al.* (2000) reported that with 200 mM NaCl treatment tolerant cultivar Prasad of foxtail millet responded with the induction of 17 kDa and 22 kDa polypeptide bands which were not expressed in the sensitive cultivar Lepakshi. Sousa *et al.* (2004) reported that cowpea seedlings subjected to NaCl stress showed increased concentration of 9 proteins, decreased concentration of one and *de novo* synthesis of one 21.2 kDa protein. Bishnoi *et al.* (2006) have clearly shown that NaCl treatment induced 95.6 kDa proteins in plumule and 67.5 kDa proteins in radicle of a salt-tolerant (Manak) cultivar of *Cajanus cajan*.

### **Concluding remarks**

On, the basis of foregoing discussion, it may be inferred that various Chenopods viz. *Suaeda fruticosa*, *Atriplex* species, *Salicornia brachiata* and other plants like

*Aerva tomentosa*, *Portulaca oleracea*, *Trianthema portulacastrum*, *Aleurops lagopoides* and *Arundo donax* were hyperaccumulators of salt ions from the soils. Similarly, *Solanum xanthocarpum*, *Xanthium strumarium*, *Sesbania sesquens*, *Heliotropium procumbens*, *Parkinsonia aculeata*, *Prosopis juliflora* and *Cynodon dactylon* were moderate accumulators of salt ions. Contrary to this, *Setaria indica*, *Calotropis procera*, *Chenopodium ambrosoides* are least accumulators. Phytoremediation magnitude was higher at 16 dSm<sup>-1</sup> than at 8 dSm<sup>-1</sup> of salinity. The above mentioned two categories - hyperaccumulators and moderate hyperaccumulator plants could be used in highly saline and marginal saline lands, respectively for phytoreclamation of salinity, which could provide effective, sustainable and low cost plant based technology for greening of saline wastelands, amelioration of physical and chemical nature of top layers of soil especially in arid and semi-arid tracts of India. These can provide fodder, substituted vegetables, grain, fire wood and oil yielding and economically viable plants for livestock and rural people and stabilize the consistently ever eroding saline lands. Another feasibility in the near future is the production of bio-salt from these hyperaccumulator plants.

In effect plants use sun's energy to remove salt ions from soil to the above ground portions during phytoremediation. So transpiration mediated and active uptake of salt ion is the cornerstone of phytoremediation.

Secondly, the various halophytic taxa especially occurring in saline wastelands could be extensively cultivated depending upon their economic utility and for saline soil reclamation. This technology involves the repeated cropping of these hyperaccumulator plants until the soils have reached acceptable levels for the farmer to cultivate his regular crops.

Nevertheless, further extensive studies are needed especially with several native saline flora and indigenous halophytes in small micro-plots and in natural saline wastelands to find out their relative efficacy to extract salts from saline soils. This shall constitute a significant component of a comprehensive technology of bioremediation of salt affected soils.

Further, molecular and biochemical studies are required to identify and characterize the various proteins involved in the hyperaccumulation of ions in halophytes. Likewise, biotechnological approaches for rapid multiplication of potential hyperaccumulators for their plantations onto the saline wastelands for quick and effective phytoremediation of soil salinity could be undertaken in the near future.

## CHAPTER – VI

# Summary

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Present investigation entitled, “Physiological and molecular characterization of some salinity phytoremediating plants” was conducted on *Salicornia brachiata*, *Suaeda fruticosa*, *Atriplex lentiformis*, *Atriplex amnicola*, *Atriplex nummularia*, *Portulaca oleracea*, *Aerva tomentosa*, *Trianthema portulacastrum*, *Chenopodium ambrosoides*, *Solanum xanthocarpum*, *Xanthium strumarium*, *Sesbania sesquens*, *Heliotropium procumbens*, *Parkinsonia aculeata*, *Prosopis juliflora*, *Arundo donax*, *Aelurops lagopoides*, *Cynodon dactylon*, *Setaria indica* and *Calotropis procera* under screen house conditions with various added salinity levels i.e. 0, 8 and 16 dSm<sup>-1</sup>. The objectives were - (i) to generate the scientific information for the identification of hyperaccumulating plants native to saline wastelands, (ii) to gather information on growth development and the hyperaccumulating potential of ionic components of salinity with an aim to ameliorate/ rehabilitate soil salinity and (iii) to study protein profiles of

some hyperaccumulating plants with a view to identify specific proteins involved in hyperaccumulation of salt ions.

The seeds were procured from reliable sources and stored in cloth bags under insect free ambient conditions for subsequent experimentation. The experiments were conducted with aforementioned specific objectives following the standard procedures. The salient features of experimental findings are summarized below

1. Thirty six plant species belonging to 17 families were collected from the saline wastelands of Hisar and adjoining areas. These plants were fixed on herbarium sheets. The above ground plant parts and the rhizospheric soil were analysed for various mineral salt ions to find out potential hyperaccumulator plants.
2. Out of 36 plant species, 20 plant species on the basis of ionic accumulation in their above ground biomass viz-a-viz in their rhizospheric soil, were selected as potent hyperaccumulator plants.
3. The simulated salinity stress enhanced the plant height, number of branches per plant and number of leaves per plant with increasing levels of salinity (0, 8 and 16 dSm<sup>-1</sup>) in *Portulaca oleracea*, *Trianthema portulacastrum*, *Aerva tomentosa*, *Atriplex nummularia*, *Atriplex lentiformis*, *Atriplex amnicola*,

*Suaeda fruticosa*, *Salicornia brachiata*, *Arundo donax*, *Aelurops lagopoides* and In rest of the experimental plants a concomitant decline in these parameters were observed. But in *Atriplex nummularia*, *Solanum xanthocarpum*, the plant height was increased upto 8 dSm<sup>-1</sup> only and then declined. However, on *Xanthium strumarium* the plant height was increased at 16 dSm<sup>-1</sup> of salinity only. The maximum per cent increase in plant height was observed in *Salicornia brachiata*. The number of branches was also increased in *Cynodon dactylon* at 16 dSm<sup>-1</sup> and in *Chenopodium ambrosoides* at all the salinity levels. In rest of the plant species including *Arundo donax*, the number of branches was similar under salinity and control except *Heliotropium procumbens* where, a decrease in number of branches was observed. The number of leaves were also increased in *Sesbania, sesquens* at all levels of salinity but in *Atriplex nummularia*, *Cynodon dactylon* and *Setaria indica* the increase in number of leaves was observed only at 8 dSm<sup>-1</sup> of salinity. The maximum per cent increase in number of branches and number of leaves was observed in *Trianthema portulacastrum*.

4. The fresh and dry weight of stem and leaves, total fresh and dry weight above ground biomass was also

increased with every increment of salinity in *Portulaca oleracea*, *Trianthema portulacastrum*, *Aerva tomentosa*, *Suaeda fruticosa*, *Salicornia brachiata*, *Atriplex lentiformis*, *Atriplex amnicola*, *Arundo donax* and *Aleurops lagopoides*, but in *Atriplex nummularia*, *Cynodon dactylon* and *Solanum xanthocarpum* these parameters were increased upto 8 dSm<sup>-1</sup> of salinity only. The fresh/dry weight of stem in *Atriplex nummularis* was increased at 16 dSm<sup>-1</sup> of salinity only. In *Atriplex amnicola* the decrease in fresh weight of leaves at 16 dSm<sup>-1</sup> of salinity was observed. Total fresh biomass in per cent was maximum in *Salicornia brachiata* and *Atriplex lentiformis*, while per cent increase in the total dry biomass was maximum in *Trianthema portulacastrum*. Furthermore, the maximum per cent decrease in total fresh biomass was observed in *Setaria indica* and the maximum per cent decrease in total dry biomass was observed in *Sesbania sesquens* and *Solanum xanthocarpum*.

5. Water content in stem, leaves and total water content in the above ground plant parts, was enhanced with every increment of soil salinity (0, 8 and 16 dSm<sup>-1</sup>) in *Portulaca oleracea*, *Trianthema portulacastrum*, *Aerva tomentosa*, *Atriplex lentiformis*, *Suaeda fruticosa*, *Salicornia brachiata*,

*Arundo donax*, and *Aleurops lagopoides*. Whereas in *Atriplex nummularia*, *Solanum xanthocarpum* and *Cynodon dactylon*, the increase in these parameters was upto 8 dSm<sup>-1</sup> of salinity, but subsequently it declined at 16 dSm<sup>-1</sup> of salinity.

Further, a decrease in all these parameters mention above, whether leaf or stem, were observed in *Atriplex amnicola*, *Chenopodium ambrosoides*, *Xanthium strumarium*, *Sesbania sesquens*, *Heliotropium procumbens*, *Parkinsonia aculeata*, *Calotropis procera*, *Prosopis juliflora* and *Setaria indica* but the water content in stem was increased at all the levels of salinity. In *Aerva tomentosa* the water content of stem was increased upto 8 dSm<sup>-1</sup> of salinity and then diminished at 16 dSm<sup>-1</sup>. The per cent increase in total water content was maximum in *Salicornia brachiata* and *Atriplex lentiformis*.

6. Ash content and TDS (Total Dissolved Solids) in stem and leaves was increased with increasing levels of salinity in all the experimental plants except *Parkinsonia aculeata* where a decline in ash content of leaves at 16 dSm<sup>-1</sup> of salinity was observed. The maximum per cent increase in ash content of stem was observed in *Sesbania sesquens* and least in *Aleurops lagopoides*. The per cent increase in ash content of leaves was maximum in *Cynodon dactylon*

and least in *Heliotropium procumbens*. The increase in TDS of stem was maximum in *Salicornia brachiata* and *Suaeda fruticosa* and in leaves of *Atriplex lentiformis* and *A. amnicola*. The organic matter in stem and leaves was declined with the enhancement of salinity in all the experimental plants except *Parkinsonia aculeata* where an increase in organic matter in leaves was observed at 16 dSm<sup>-1</sup> of salinity.

7. It was observed that the pH, electrical conductivity (ECe) at the soil saturation extract, sodium adsorption ratio (SAR), different ionic contents like Na<sup>+</sup>, K<sup>+</sup>, Ca<sup>+</sup>, Mg<sup>2+</sup>, Cl<sup>-</sup>, SO<sub>4</sub><sup>2-</sup>, Na<sup>+</sup>/K<sup>+</sup> ratio and total amount of ions were enhanced in the soil before plantation and after harvesting of different plant species. However, the cation exchange capacity (CEC) of the soil remained same both in the control as well as in saline medium (8 and 16 dSm<sup>-1</sup>). After harvesting maximum increase in the above mentioned parameters at all salinity levels were observed in the soil where *Setaria indica*, *Prosopis juliflora*, *Parkinsonia aculeata*, *Calotropis procera*, *Heliotropium procumbens*, *Sesbania sesquens*, *Xanthium strumarium* and *Chenopodium ambrosoides* were growing and a moderate enhancement was observed in *Arundo donax*, *Aeluropes lagopoides*,

*Cynodon dactylon*, *Atriplex nummularia*, and *Solanum xanthocarpum*. However, minimum increase was observed in *Suaeda fruticosa*, *Atriplex lentiformis*, *Salicornia brachiata*, *Atriplex amnicola*, *Portulaca oleracea*, *Trianthema portulacastrum* and *Aerva tomentosa*, thereby showing their potential utilization for soil salinity reclamation.

8. Content of  $\text{Na}^+$  and  $\text{Cl}^-$  was enhanced with the increasing levels of salinity in stem and leaves of all the experimental plants but the  $\text{Mg}^{2+}$ ,  $\text{Ca}^{2+}$ ,  $\text{K}^+$  and  $\text{SO}_4^{2-}$  was declined with every increment of salinity. In *Salicornia brachiata* stem, the highest  $\text{Na}^+$  and  $\text{Cl}^-$  was observed, it is followed by *Suaeda fruticosa*, *Atriplex lentiformis*, *Atriplex amnicola*, *Portulaca oleracea*, *Trianthema portulacastrum*, *Aerva tomentosa* and *Atriplex nummularia*. In rest of the plants the ionic content was least in comparison to the above mentioned plants.  $\text{Na}^+/\text{K}^+$  ratio was also increased with increasing levels of salinity in all the experimental plants.
9. Phytoaccumulation of ions per plants as well as in all plants in a pot were also enhanced with increasing levels of salinity in *Suaeda fruticosa*, *Salicornia brachiata*, *Atriplex lentiformis*, *Atriplex amnicola*, *Atriplex nummularia*, *Portulaca oleracea*, *Trianthema*

*portulacastrum*, *Aerva tomentosa*, *Arundo donax*, *Aleurops lagopoides* and *Cynodon dactylon* whereas, in case of *Solanum xanthocarpum*, *Chenopodium ambrosoides*, *Calotropis procera* and *Prosopis juliflora* it was increased upto 8 dSm<sup>-1</sup> of salinity only. However, the accumulation of sum total of ions in *Xanthium strumarium*, *Sesbania sesquens*, *Parkinsonia aculeata*, *Heliotropium procumbens* and *Setaria indica* was declined at all the salinity levels in comparison to its control (So).

10. The per cent decrease in ECe and per cent (%) remediation in terms of total estimated ionic accumulation after harvesting the different plant species in comparison to total estimated ionic accumulation under various added salinity levels before plantation, showed that more remediation occurred in the soil where *Suaeda fruticosa*, *Salicornia brachiata* followed by *Atriplex lentiformis*, *Atriplex amnicola*, *Atriplex nummularia*, *Portulaca oleracea*, *Arundo donax*, *Trianthema portulacastrum*, *Aleurops lagopoides*, *Aerva tomentosa*, *Cynodon dactylon* and *Solanum xanthocarpum* were growing. However, per cent remediation was least of all in saline soil where *Setaria indica*, *Calotropis procera*, *Sesbania sesquens*, *Heliotropium procumbens*,

*Parkinsonia aculeata*, *Xanthium strumarium*, *Prosopis juliflora* and *Chenopodium ambrosoides* were growing.

11. In SDS-PAGE the protein profiles of hyperaccumulators like *Suaeda fruticosa* the *de novo* synthesis of three protein bands (56.2, 15.8 and 14.1 kDa) took place. Similarly, in *Portulaca oleracea* also three new protein bands (105.2, 26.6 and 15.8 kDa) were observed likewise in *Atriplex nummularia* two new protein bands (51.8 and 22.1 kDa) and in *Atriplex lentiformis* one protein band (10.0 kDa) were clearly seen at 16 dSm<sup>-1</sup> of salinity. In the same fashion, in *Atriplex amnicola* six new protein bands (44.6, 26.6, 25.1, 19.9, 12.5 and 10 kDa) were synthesized under salinity. However, in *Atriplex lentiformis* one protein band (22.1 kDa) and in *Atriplex amnicola* one protein band (29.8 kDa) disappeared. However, in two least accumulator plant species *Setaria indica* two protein bands (118.9 and 8.4 kDa) and in *Chenopodium ambrosoides* one protein band (59.5 kDa) disappeared altogether. Whereas, in *Chenopodium ambrosoides* seven new proteins (i.e. 167.9, 74.9, 63.1, 56.2, 19.9, 17.7 and 10.0 kDa) were freshly synthesized. The *de novo* synthesis and disappearing of these protein bands in these hyperaccumulators could be involved in hyperaccumulation of toxic salt ions.

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## **ABSTRACT**

|                                   |                                                                                                                                                                                                      |
|-----------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Title of thesis                   | : <b>Physiological and molecular characterization of some salinity phytoremediating plants</b>                                                                                                       |
| Name of the degree holder         | : <b>SUSHMA RANI</b>                                                                                                                                                                                 |
| Admission No.                     | : 2002BS72D                                                                                                                                                                                          |
| Title of degree                   | : Doctor of Philosophy                                                                                                                                                                               |
| Name and address of Major Advisor | : <b>Dr. S.C. GOYAL</b><br>Associate Professor<br>Department of Botany & Plant Physiology<br>College of Basic Sciences & Humanities<br>CCS Haryana Agricultural University,<br>Hisar 125004, (India) |
| Degree awarding University        | : CCS Haryana Agricultural University, Hisar                                                                                                                                                         |
| Year of award of degree           | : 2006                                                                                                                                                                                               |
| Major subject                     | : Botany                                                                                                                                                                                             |
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| Number of words in the abstract   | : Approx. 500                                                                                                                                                                                        |

**Keywords:** *Phytoremediation, Salinity, growth, development, ion accumulation, proteins, hyperaccumulators*

Thirty six (36) plant species belonging to 17 families were collected from saline wastelands of Hisar and adjoining areas. Out of these 20 potential hyperaccumulator plant species were selected on the basis of plant biomass and rhizospheric soil analyses. In general the plant height, number of branches, number of leaves, fresh and dry biomass of above ground plants and water content were increased with every increment of salinity levels (0, 8 and 16 dSm<sup>-1</sup>) in most of the members of chenopodiaceae (*Atriplex lentiformis*, *Atriplex amnicola*, *Suaeda fruticosa* and *Salicornia brachiata*), *Portulaca oleracea*, *Trianthema portulacastrum*, *Aerva tomentosa*, *Arundo donax* and *Aelurops lagopoides*, whereas, these parameters were increased upto 8 dSm<sup>-1</sup> of salinity in *Atriplex nummularia*, *Solanum xanthocarpum* and *Cynodon dactylon*, but decreased at 16 dSm<sup>-1</sup> of salinity as compared to their respective controls. However, above mentioned parameters were reduced with the enhancement of salinity in *Chenopodium ambrosoides*, *Xanthium strumarium*, *Sesbania sesquens*, *Heliotropium procumbens*, *Parkinsonia aculeata*, *Calotropis procera*, *Prosopis juliflora* and *Setaria indica* in comparison to their respective controls. The ash content, total dissolved solids (TDS), Na<sup>+</sup> and Cl<sup>-</sup> were enhanced, but the organic

matter,  $K^+$ ,  $Ca^{2+}$ ,  $Mg^{2+}$ ,  $SO_4^{2-}$  were declined with the increment of salinity in comparison to their respective controls in all experimental plants. The ECe, pH,  $Na^+/K^+$ , SAR (Sodium adsorption ratio) and total ions in the soil were increased with enhancement of salinity. The phytoaccumulation of total ions,  $Na^+$ , and  $Cl^-$  was more in leaves in comparison to stem. While more phytoaccumulation of total ions,  $Na^+$ ,  $Cl^-$ , reduction in ECe and pH of soil in case of *Atriplex lentiflormis*, *Suaeda fruticosa*, *Salicornia brachiata*, *Portulaca oleracea*, *Atriplex amnicola*, *Aerva tomentosa* and *Trianthema portulacastrum* showed their potential salt hyperaccumulator nature that *Arundo*, *Aleurops*, *Solanum*, *Atriplex nummlaria* and *Cynodon* were observed moderate accumulators of salt ions. On the contrary, *Xanthium*, *Chenopodium*, *Sesbania*, *Heliotropium*, *Prosopis*, *Parkinsonia*, *Calotropis* and *Setaria* were the least accumulators of salt ions. The cation exchange capacity (CEC) was not affected by various salinity levels.

Salinity also affects the protein profile of plants. The *de novo* synthesis of three proteins each in *Suaeda fruticosa* (56.2, 15.8 and 14.1 kDa) and in *Portulaca oleracea* (105.2, 26.6 and 15.8 kDa); and two proteins (51.8 and 22.1 kDa) in *Atriplex nummularia* were freshly synthesized at 16 dSm<sup>-1</sup> of salinity. Similarly, one protein (10.0 kDa) in *Atriplex lentiformis* in addition to disappearance of another (22.1 kDa) might be involved in hyperaccumulation of ions under salinity. However, in *Setaria indica*-two proteins (118.9 and 8.4 kDa) and one protein (29.8 kDa) in *Chenopodium ambrosoides* disappeared under salinity thereby, showing their comparatives less accumulator nature. However, 6 proteins in *Atriplex amnicola* and 7 proteins in *Chenopodium ambrosoides* were freshly synthesized at higher salinity (16 dSm<sup>-1</sup>) which might be associated with their moderate salt accumulator nature.

The hyperaccumulator plants like members of chenopodiaceae, *Portulaca*, *Trianthema*, *Aerva*, *Arundo* and *Aleurops* have been used for the reclamation, restoration and remediation of soil salinity. Further more, these plants might be used for the production of fodder/feed for cattles, substituted vegetables and bio-salt production from saline wastelands.

**MAJOR ADVISOR**

**SIGNATURE OF STUDENT**

**HEAD OF THE DEPARTMENT**

**Table 1: List of plants collected from saline waste lands of Hisar and adjoining areas**

| Sr. No. | Name of plant                    | Family          | Place of collection  |
|---------|----------------------------------|-----------------|----------------------|
| 1.      | <i>Acacia ampliceps</i>          | Leguminocae     | Gangani (Jodhpur)    |
| 2.      | <i>Acacia colei</i>              | Leguminocae     | Gangani (Jodhpur)    |
| 3.      | <i>Aerva tomentosa</i>           | Amaranthaceae   | Fisheries Pond       |
| 4.      | <i>Aleurops lagopoides</i>       | Graminae        | Lunkarnser (Bikaner) |
| 5.      | <i>Alternanthera pungens</i>     | Amaranthaceae   | Ganganagar (Raj)     |
| 6.      | <i>Amaranthus viridis</i>        | Amaranthaceae   | Fisheries Pond       |
| 7.      | <i>Aristida adscensionis</i>     | Graminae        | DSW                  |
| 8.      | <i>Arundo donax</i>              | Graminae        | Fisheries Pond       |
| 9.      | <i>Atriplex amnicola</i>         | Chenopodiaceae  | Jodhpur (Raj.)       |
| 10.     | <i>Atriplex lentiformis</i>      | Chenopodiaceae  | Jodhpur (Raj.)       |
| 11.     | <i>Atriplex nummularia</i>       | Chenopodiaceae  | Jodhpur (Raj.)       |
| 12.     | <i>Calotropis procera</i>        | Asclepiadaceae  | Fisheries Pond       |
| 13.     | <i>Capparis aphylla</i>          | Capparidaceae   | New compos           |
| 14.     | <i>Chenopodium ambrosoides</i>   | Chenopodiaceae  | DSW                  |
| 15.     | <i>Chenopodium murale</i>        | Chenopodiaceae  | DSW                  |
| 16.     | <i>Cynodon dactylon</i>          | Graminae        | Basic Science        |
| 17.     | <i>Cyperus bulbosus</i>          | Cyperaceae      | Basic Science        |
| 18.     | <i>Dactyloctenium aegyptium</i>  | Graminae        | DSW                  |
| 19.     | <i>Eragrostis pilosa</i>         | Graminae        | DSW                  |
| 20.     | <i>Eriochloa cinerea</i>         | Graminae        | Fisheries Pond       |
| 21.     | <i>Haloxylon recurvum</i>        | Chenopodiaceae  | Shopping Complex     |
| 22.     | <i>Heliotropium procumbens</i>   | Boraginaceae    | Gandhi Bhawan        |
| 23.     | <i>Parkinsonia aculeata</i>      | Caesalpiniaceae | Dean PGS             |
| 24.     | <i>Physalis minima</i>           | Solenaceae      | Fisheries Pond       |
| 25.     | <i>Portulaca oleracea</i>        | Portulacaceae   | Shopping Complex     |
| 26.     | <i>Prosopis juliflora</i>        | Mimosaceae      | Engineering college  |
| 27.     | <i>Salsola baryosma</i>          | Chenopodiaceae  | Shopping Complex     |
| 28.     | <i>Salvadora persica</i>         | Salvadoraceae   | Shopping Complex     |
| 29.     | <i>Sesbania sesquens</i>         | Leguminocae     | Fisheries Pond       |
| 30.     | <i>Setaria indica</i>            | Graminae        | Engineering college  |
| 31.     | <i>Solanum xanthocarpum</i>      | Solanaceae      | Field                |
| 32.     | <i>Suaeda fruticosa</i>          | Chenopodiaceae  | Gandhi Bhawan        |
| 33.     | <i>Tamarix aphylla</i>           | Tamaricaceae    | Shopping Complex     |
| 34.     | <i>Trianthema portulacastrum</i> | Aizoaceae       | Shopping Complex     |
| 35.     | <i>Vernonia cinerea</i>          | Asteraceae      | Ganganagar (Raj.)    |
| 36.     | <i>Xanthium strumarium</i>       | Compositae      | Field                |

**Table 2: Some characteristics of soil samples collected from rhizospheric soil of the plant from wastelands of Hisar and adjoining areas**

| Sr. No. | Name of Plant                    | Ion content ( $\mu\text{g g}^{-1}$ soil) in the soil |                |                  |                  |                 |                               |            |       |      |       |
|---------|----------------------------------|------------------------------------------------------|----------------|------------------|------------------|-----------------|-------------------------------|------------|-------|------|-------|
|         |                                  | Na <sup>+</sup>                                      | K <sup>+</sup> | Ca <sup>2+</sup> | Mg <sup>2+</sup> | Cl <sup>-</sup> | So <sub>4</sub> <sup>2-</sup> | Total ions | ECe   | pH   | SAR   |
| 1       | <i>Acacia ampliceps</i>          | 86.80                                                | 8.15           | 13.85            | 23.70            | 182.50          | 54.34                         | 369.34     | 4.96  | 7.88 | 4.13  |
| 2       | <i>Acacia colei</i>              | 92.95                                                | 7.35           | 17.75            | 22.50            | 241.90          | 46.31                         | 428.76     | 5.02  | 8.00 | 4.19  |
| 3       | <i>Aerva tomentosa</i>           | 106.05                                               | 9.68           | 21.30            | 37.00            | 200.55          | 35.64                         | 410.22     | 7.76  | 8.91 | 4.03  |
| 4       | <i>Aleurops lagopoides</i>       | 176.50                                               | 6.93           | 61.25            | 41.70            | 430.70          | 43.21                         | 760.29     | 11.50 | 7.58 | 5.25  |
| 5       | <i>Alternanthera ungens</i>      | 229.30                                               | 21.77          | 2.35             | 40.25            | 596.65          | 40.26                         | 948.58     | 13.63 | 8.55 | 8.53  |
| 6       | <i>Amaranthus viridis</i>        | 38.44                                                | 8.43           | 16.05            | 25.55            | 145.60          | 38.96                         | 273.03     | 3.97  | 9.09 | 1.68  |
| 7       | <i>Aristida adscensionis</i>     | 50.40                                                | 4.90           | 20.60            | 38.35            | 204.90          | 35.75                         | 354.9      | 8.26  | 8.06 | 1.88  |
| 8       | <i>Arundo donax</i>              | 234.0                                                | 15.61          | 28.35            | 53.25            | 576.50          | 36.85                         | 944.56     | 18.38 | 8.66 | 7.40  |
| 9       | <i>Atriplex amnicola</i>         | 205.25                                               | 11.60          | 30.80            | 52.25            | 339.95          | 34.26                         | 674.11     | 12.57 | 8.40 | 6.49  |
| 10      | <i>Atriplex lentiformis</i>      | 131.00                                               | 8.10           | 20.85            | 30.25            | 341.35          | 33.56                         | 565.11     | 7.80  | 8.10 | 5.20  |
| 11      | <i>Atriplex nummularia</i>       | 238.95                                               | 10.50          | 27.00            | 44.35            | 314.70          | 36.46                         | 671.96     | 11.90 | 8.69 | 8.19  |
| 12      | <i>Calotropis procera</i>        | 20.46                                                | 7.91           | 10.30            | 19.10            | 106.95          | 46.59                         | 211.31     | 3.60  | 7.83 | 1.10  |
| 13      | <i>Capparis aphylla</i>          | 115.25                                               | 8.40           | 21.75            | 40.20            | 268.35          | 48.67                         | 502.62     | 10.84 | 8.15 | 4.24  |
| 14      | <i>Chenopodium ambrosoides</i>   | 55.21                                                | 6.01           | 17.85            | 32.30            | 165.46          | 34.59                         | 311.36     | 5.88  | 7.96 | 2.23  |
| 15      | <i>Chenopodium murale</i>        | 369.70                                               | 14.41          | 38.45            | 54.50            | 682.05          | 49.56                         | 1208.67    | 22.52 | 8.99 | 11.15 |
| 16      | <i>Cynodon dactylon</i>          | 85.20                                                | 10.24          | 21.60            | 40.55            | 214.95          | 46.12                         | 418.66     | 10.19 | 8.25 | 3.16  |
| 17      | <i>Cyperus bulbosus</i>          | 279.60                                               | 16.32          | 34.35            | 49.05            | 503.70          | 42.16                         | 925.18     | 37.17 | 8.94 | 8.66  |
| 18      | <i>Dactyloctenium</i>            | 121.45                                               | 10.43          | 18.90            | 26.65            | 318.20          | 47.18                         | 542.81     | 14.97 | 7.58 | 5.18  |
| 19      | <i>Eragrostis pilosa</i>         | 239.30                                               | 14.58          | 32.10            | 56.15            | 515.80          | 51.64                         | 909.57     | 22.10 | 8.42 | 7.21  |
| 20      | <i>Eriochloa cinerea</i>         | 174.10                                               | 13.41          | 25.65            | 37.95            | 425.30          | 48.52                         | 724.93     | 11.88 | 8.70 | 6.12  |
| 21      | <i>Haloxylon recurvum</i>        | 111.90                                               | 8.75           | 13.50            | 24.85            | 222.45          | 40.31                         | 421.76     | 6.70  | 7.75 | 5.21  |
| 22      | <i>Heliotropium procumbens</i>   | 172.85                                               | 9.22           | 23.25            | 43.15            | 465.30          | 37.59                         | 751.36     | 12.85 | 8.88 | 6.12  |
| 23      | <i>Parkinsonia aculeata</i>      | 437.00                                               | 16.42          | 28.42            | 55.95            | 750.35          | 42.65                         | 1330.82    | 40.35 | 8.86 | 13.78 |
| 24      | <i>Physalis minima</i>           | 177.56                                               | 9.01           | 33.00            | 51.45            | 717.95          | 41.03                         | 729.99     | 15.17 | 8.90 | 5.60  |
| 25      | <i>Portulaca oleracea</i>        | 115.25                                               | 8.40           | 21.75            | 40.20            | 268.35          | 36.45                         | 489.95     | 10.84 | 8.15 | 4.25  |
| 26      | <i>Prosopis juliflora</i>        | 271.25                                               | 9.62           | 35.90            | 48.50            | 485.90          | 50.27                         | 901.44     | 17.96 | 8.71 | 8.53  |
| 27      | <i>Salsola baryosma</i>          | 199.85                                               | 15.35          | 23.65            | 48.90            | 517.40          | 48.34                         | 853.48     | 19.35 | 8.56 | 6.82  |
| 28      | <i>Salvadora persica</i>         | 197.5                                                | 11.40          | 25.60            | 42.35            | 299.25          | 40.29                         | 616.39     | 10.67 | 8.75 | 6.96  |
| 29      | <i>Sesbania sesquens</i>         | 262.85                                               | 33.67          | 44.20            | 48.35            | 505.10          | 43.45                         | 937.62     | 19.07 | 8.85 | 7.55  |
| 30      | <i>Setaria indica</i>            | 235.3                                                | 11.40          | 23.00            | 46.75            | 523.50          | 53.23                         | 893.18     | 15.65 | 8.84 | 8.23  |
| 31      | <i>Solanum xanthocarpum</i>      | 198.4                                                | 6.19           | 26.55            | 47.85            | 456.35          | 46.35                         | 781.69     | 16.14 | 8.29 | 6.61  |
| 32      | <i>Suaeda fruticosa</i>          | 209.90                                               | 13.81          | 20.95            | 41.45            | 480.80          | 35.64                         | 802.55     | 15.78 | 9.28 | 7.69  |
| 33      | <i>Tamarix aphylla</i>           | 254.70                                               | 19.84          | 43.05            | 60.65            | 595.65          | 38.92                         | 1012.81    | 47.85 | 7.26 | 7.17  |
| 34      | <i>Trianthema portulacastrum</i> | 29.20                                                | 16.25          | 9.95             | 17.70            | 153.90          | 38.31                         | 265.31     | 3.16  | 7.54 | 1.61  |
| 35      | <i>Vernonia cinerea</i>          | 220.8                                                | 23.40          | 35.00            | 49.50            | 507.9           | 46.32                         | 882.97     | 13.55 | 8.85 | 6.87  |
| 36      | <i>Xanthium strumarium</i>       | 31.30                                                | 6.02           | 9.65             | 17.05            | 171.15          | 48.65                         | 283.82     | 2.95  | 7.83 | 1.74  |

**Table 3: Magnitude of ionic accumulation in biomass of above ground plant parts from wastelands of Hisar and adjoining areas**

| Sr No. | Name of plant                    | Ion content (mg g <sup>-1</sup> dry wt.) in the above ground parts |                |                  |                  |                 |                               |            |
|--------|----------------------------------|--------------------------------------------------------------------|----------------|------------------|------------------|-----------------|-------------------------------|------------|
|        |                                  | Na <sup>+</sup>                                                    | K <sup>+</sup> | Ca <sup>2+</sup> | Mg <sup>2+</sup> | Cl <sup>-</sup> | So <sub>4</sub> <sup>2-</sup> | Total ions |
| 1      | <i>Acacia ampliceps</i>          | 115.2                                                              | 35.7           | 40.4             | 49.2             | 128.5           | 16.32                         | 385.32     |
| 2      | <i>Acacia coleii</i>             | 115.3                                                              | 38.88          | 38.9             | 37.1             | 127.6           | 23.1                          | 380.8      |
| 3      | <i>Aerva tomentosa</i>           | 153.1                                                              | 35.5           | 12.8             | 47.1             | 131.7           | 25.31                         | 405.51     |
| 4      | <i>Aleurops lagopoides</i>       | 119.5                                                              | 35.2           | 15.0             | 50.9             | 113.1           | 20.13                         | 353.83     |
| 5      | <i>Alternanthera pungens</i>     | 127.4                                                              | 29.7           | 15.7             | 46.9             | 116.8           | 26.12                         | 362.62     |
| 6      | <i>Amaranthus viridis</i>        | 117.6                                                              | 18.8           | 12.1             | 30.4             | 101.8           | 16.32                         | 297.02     |
| 7      | <i>Aristida adscensionis</i>     | 114.4                                                              | 35.9           | 43.1             | 52.0             | 100.7           | 15.23                         | 361.33     |
| 8      | <i>Arundo donax</i>              | 124.6                                                              | 27.3           | 19.3             | 48.6             | 117.4           | 24.56                         | 361.76     |
| 9      | <i>Atriplex amnicola</i>         | 166.7                                                              | 32.1           | 44.7             | 46.6             | 177.2           | 29.85                         | 497.15     |
| 10     | <i>Atriplex lentiformis</i>      | 176.8                                                              | 32.9           | 42.5             | 50.8             | 177.2           | 30.21                         | 510.41     |
| 11     | <i>Atriplex nummularia</i>       | 171.1                                                              | 30.5           | 42.5             | 49.3             | 146.0           | 28.32                         | 467.72     |
| 12     | <i>Calotropis procera</i>        | 179.5                                                              | 25.1           | 17.2             | 41.8             | 155.0           | 19.56                         | 438.16     |
| 13     | <i>Capparis aphylla</i>          | 186.1                                                              | 24.7           | 11.8             | 50               | 185.7           | 16.48                         | 474.78     |
| 14     | <i>Chenopodium ambrosoides</i>   | 127.4                                                              | 26.5           | 18.9             | 45.5             | 115.7           | 21.67                         | 355.67     |
| 15     | <i>Chenopodium murale</i>        | 124.6                                                              | 23.1           | 16.7             | 47.1             | 117.9           | 22.38                         | 351.78     |
| 16     | <i>Cynodon dactylon</i>          | 80.4                                                               | 25.8           | 15.3             | 44.9             | 96.9            | 23.16                         | 286.46     |
| 17     | <i>Cyperus bulbosus</i>          | 108.7                                                              | 26.6           | 15.6             | 41.1             | 97.6            | 26.45                         | 316.05     |
| 18     | <i>Dactyloctenium aegyptium</i>  | 98.3                                                               | 21.4           | 13.8             | 40.1             | 87.0            | 19.46                         | 280.06     |
| 19     | <i>Eragrostis pilosa</i>         | 110.6                                                              | 25.9           | 17.9             | 46.7             | 114.6           | 23.89                         | 339.59     |
| 20     | <i>Eriochloa cinerea</i>         | 85.7                                                               | 23.5           | 18.3             | 41.6             | 107.5           | 23.12                         | 299.72     |
| 21     | <i>Haloxylon recurvum</i>        | 194.4                                                              | 24.7           | 13.1             | 40.2             | 2.9.4           | 30.65                         | 512.45     |
| 22     | <i>Heliotropium procumbens</i>   | 161.4                                                              | 28.0           | 23.0             | 44.1             | 148.5           | 28.34                         | 433.34     |
| 23     | <i>Parkinsonia aculeata</i>      | 111.5                                                              | 21.5           | 17.7             | 47.25            | 128.0           | 19.46                         | 345.36     |
| 24     | <i>Physalis minima</i>           | 244.6                                                              | 19.8           | 15.4             | 40.1             | 211.8           | 26.37                         | 558.07     |
| 25     | <i>Portulaca oleracea</i>        | 186.1                                                              | 24.7           | 11.8             | 50.0             | 185.7           | 32.16                         | 490.46     |
| 26     | <i>Prosopis juliflora</i>        | 113.2                                                              | 21.9           | 17.9             | 48.0             | 103.1           | 28.87                         | 332.97     |
| 27     | <i>Salsola baryosma</i>          | 218.0                                                              | 25.2           | 21.1             | 43.3             | 186.4           | 26.32                         | 520.32     |
| 28     | <i>Salvadora persica</i>         | 134.7                                                              | 31.0           | 21.2             | 48.7             | 112.1           | 27.36                         | 375.06     |
| 29     | <i>Sesbania sesquens</i>         | 118.4                                                              | 24.9           | 14.9             | 46.8             | 121.4           | 21.65                         | 348.05     |
| 30     | <i>Setaria indica</i>            | 150.3                                                              | 31.2           | 15.7             | 44.7             | 130.6           | 20.34                         | 392.84     |
| 31     | <i>Suaeda fruticosa</i>          | 244.0                                                              | 25.5           | 24.0             | 41.0             | 254.2           | 35.32                         | 624.02     |
| 32     | <i>Solanum xanthocarpum</i>      | 76.0                                                               | 36.1           | 23.2             | 48.5             | 71.0            | 23.52                         | 278.32     |
| 33     | <i>Tamarix aphylla</i>           | 100.0                                                              | 19.2           | 11.6             | 43.7             | 112.0           | 26.53                         | 313.03     |
| 34     | <i>Trianthema portulacastrum</i> | 104.6                                                              | 27             | 24.7             | 47.6             | 90.5            | 29.65                         | 324.05     |
| 35     | <i>Vernonia cinerea</i>          | 127.4                                                              | 29.7           | 15.7             | 46.9             | 116.8           | 190.8                         | 527.3      |
| 36     | <i>Xanthium strumarium</i>       | 102.4                                                              | 24.8           | 19.2             | 47.4             | 100.9           | 23.12                         | 317.82     |

**Table 4: Plant height (cm.) of different plants native to saline soils under various added salinity levels**

| S. No. | Name of Plant                    | S0<br>(0dSm <sup>-1</sup> ) | S1<br>(8dSm <sup>-1</sup> ) | S2<br>(16dSm <sup>-1</sup> ) | Mean         |
|--------|----------------------------------|-----------------------------|-----------------------------|------------------------------|--------------|
| 1      | <i>Portulaca oleracea</i>        | 20.47                       | 26.70<br>(30.46)            | 29.57<br>(44.46)             | <b>25.58</b> |
| 2      | <i>Trianthema portulacastrum</i> | 30.03                       | 35.23<br>(17.31)            | 41.53<br>(38.29)             | <b>35.60</b> |
| 3      | <i>Aerva tomentosa</i>           | 51.40                       | 54.93<br>(6.87)             | 56.60<br>(10.12)             | <b>54.31</b> |
| 4      | <i>Atriplex nummularia</i>       | 24.77                       | 27.37<br>(10.50)            | 24.10<br>(-2.69)             | <b>25.41</b> |
| 5      | <i>Atriplex amnicola</i>         | 42.30                       | 47.37<br>(11.98)            | 50.57<br>(19.54)             | <b>46.74</b> |
| 6      | <i>Atriplex lentiformis</i>      | 45.73                       | 48.60<br>(6.27)             | 57.60<br>(25.95)             | <b>50.64</b> |
| 7      | <i>Chenopodium ambrosoides</i>   | 51.67                       | 51.67<br>(0.00)             | 49.40<br>(-4.39)             | <b>50.91</b> |
| 8      | <i>Suaeda fruticosa</i>          | 47.37                       | 51.20<br>(8.09)             | 56.57<br>(19.42)             | <b>51.71</b> |
| 9      | <i>Salicornia brachiata</i>      | 6.37                        | 9.70<br>(52.36)             | 11.97<br>(87.96)             | <b>91.34</b> |
| 10     | <i>Solanum xanthocarpum</i>      | 5.33                        | 6.73<br>(26.25)             | 1.90<br>(-64.38)             | <b>4.65</b>  |
| 11     | <i>Xanthium strumarium</i>       | 15.17                       | 14.17<br>(-6.59)            | 17.40<br>(14.73)             | <b>15.58</b> |
| 12     | <i>Sesbania sesquens</i>         | 39.57                       | 31.27<br>(-20.98)           | 27.37<br>(-30.83)            | <b>32.73</b> |
| 13     | <i>Heliotropium procumbens</i>   | 19.33                       | 9.00<br>(-53.45)            | 12.43<br>(-35.69)            | <b>13.59</b> |
| 14     | <i>Parkinsonia aculeata</i>      | 51.07                       | 41.97<br>(-17.82)           | 36.13<br>(-29.24)            | <b>43.06</b> |
| 15     | <i>Calotropis procera</i>        | 25.53                       | 26.27<br>(2.87)             | 24.40<br>(-4.44)             | <b>25.40</b> |
| 16     | <i>Prosopis juliflora</i>        | 15.47                       | 13.67<br>(-11.64)           | 12.40<br>(-19.83)            | <b>13.84</b> |
| 17     | <i>Arundo donax</i>              | 35.43                       | 39.17<br>(10.54)            | 42.53<br>(20.04)             | <b>39.04</b> |
| 18     | <i>Aleurops lagopoides</i>       | 15.13                       | 16.73<br>(10.57)            | 17.30<br>(14.32)             | <b>16.39</b> |
| 19     | <i>Cynodon dactylon</i>          | 32.27                       | 32.27<br>(0.00)             | 22.07<br>(-31.61)            | <b>28.88</b> |
| 20     | <i>Setaria indica</i>            | 13.17                       | 13.17<br>(0.00)             | 6.67<br>(-49.37)             | <b>11.00</b> |
|        | Mean                             | <b>29.38</b>                | <b>29.86</b>                | <b>29.93</b>                 |              |

**CD (P=0.05):** Species(S) = 2.6934; Salinity levels (T) = N.S; Interaction (SxT) = 4.665

Values given in parentheses ( ) show percent increase/decrease over respective controls

**Table 5: Number of branches of different plants native to saline soils under various added salinity levels**

| S. No. | Name of Plant                    | S0<br>(0dSm <sup>-1</sup> ) | S1<br>(8dSm <sup>-1</sup> ) | S2<br>(16dSm <sup>-1</sup> ) | Mean          |
|--------|----------------------------------|-----------------------------|-----------------------------|------------------------------|---------------|
| 1      | <i>Portulaca oleracea</i>        | 6.00                        | 7.00<br>(16.67)             | 8.33<br>(38.89)              | <b>7.11</b>   |
| 2      | <i>Trianthema portulacastrum</i> | 3.00                        | 4.00<br>(33.33)             | 5.00<br>(66.67)              | <b>4.00</b>   |
| 3      | <i>Aerva tomentosa</i>           | 18.00                       | 19.67<br>(9.26)             | 20.33<br>(12.96)             | <b>19.33</b>  |
| 4      | <i>Atriplex nummularia</i>       | 9.00                        | 11.00<br>(22.22)            | 11.67<br>(29.63)             | <b>10.56</b>  |
| 5      | <i>Atriplex amnicola</i>         | 11.33                       | 13.00<br>(14.71)            | 14.00<br>(23.53)             | <b>12.778</b> |
| 6      | <i>Atriplex lentiformis</i>      | 5.00                        | 6.00<br>(20.00)             | 8.00<br>(60.00)              | <b>6.33</b>   |
| 7      | <i>Chenopodium ambrosoides</i>   | 17.33                       | 19.33<br>(11.54)            | 21.00<br>(21.15)             | <b>19.22</b>  |
| 8      | <i>Suaeda fruticosa</i>          | 16.00                       | 17.00<br>(6.25)             | 19.00<br>(18.75)             | <b>17.333</b> |
| 9      | <i>Salicornia brachiata</i>      | 4.00                        | 5.00<br>(25.00)             | 5.00<br>(25.00)              | <b>4.889</b>  |
| 10     | <i>Solanum xanthocarpum</i>      | 1.00                        | 1.00<br>(0.00)              | 1.00<br>(0.00)               | <b>1.00</b>   |
| 11     | <i>Xanthium strumarium</i>       | 1.00                        | 1.00<br>(0.00)              | 1.00<br>(0.00)               | <b>1.00</b>   |
| 12     | <i>Sesbania sesquens</i>         | 1.00                        | 1.00<br>(0.00)              | 1.00<br>(0.00)               | <b>1.00</b>   |
| 13     | <i>Heliotropium procumbens</i>   | 11.00                       | 9.00<br>(-18.18)            | 8.00<br>(-27.27)             | <b>9.33</b>   |
| 14     | <i>Parkinsonia aculeata</i>      | 1.00                        | 1.00<br>(0.00)              | 1.00<br>(0.00)               | <b>1.00</b>   |
| 15     | <i>Calotropis procera</i>        | 1.00                        | 1.00<br>(0.00)              | 1.00<br>(0.00)               | <b>1.00</b>   |
| 16     | <i>Prosopis juliflora</i>        | 1.00                        | 1.00<br>(0.00)              | 1.00<br>(0.00)               | <b>1.00</b>   |
| 17     | <i>Arundo donax</i>              | 1.00                        | 1.00<br>(0.00)              | 1.00<br>(0.00)               | <b>1.00</b>   |
| 18     | <i>Aleurops lagopoides</i>       | 5.00                        | 7.00<br>(40.00)             | 8.00<br>(60.00)              | <b>6.67</b>   |
| 19     | <i>Cynodon dactylon</i>          | 4.00                        | 4.00<br>(0.00)              | 5.00<br>(25.00)              | <b>4.33</b>   |
| 20     | <i>Setaria indica</i>            | 1.00                        | 1.00<br>(0.00)              | 1.00<br>(0.00)               | <b>1.00</b>   |
|        | Mean                             | <b>5.79</b>                 | <b>6.50</b>                 | <b>7.14</b>                  |               |

**CD (P=0.05) :** Species(S) = 1.3616; Salinity levels (T) = 0.527; Interaction (SxT) = 4.665

Values given in parentheses ( ) show percent increase/decrease over respective controls

**Table 6: Number of leaves per plant at harvesting of different plants native to saline soils under various added salinity levels**

| S. No. | Name of Plant                    | S0<br>(0dSm <sup>-1</sup> ) | S1<br>(8dSm <sup>-1</sup> ) | S2<br>(16dSm <sup>-1</sup> ) | Mean          |
|--------|----------------------------------|-----------------------------|-----------------------------|------------------------------|---------------|
| 1      | <i>Portulaca oleracea</i>        | 192.67                      | 209.67<br>(8.82)            | 216.33<br>(12.28)            | <b>206.22</b> |
| 2      | <i>Trianthema portulacastrum</i> | 20.67                       | 28.00<br>(35.43)            | 35.67<br>(72.58)             | <b>28.11</b>  |
| 3      | <i>Aerva tomentosa</i>           | 38.67                       | 43.67<br>(12.93)            | 46.33<br>(19.83)             | <b>42.89</b>  |
| 4      | <i>Atriplex nummularia</i>       | 18.00                       | 20.00<br>(11.11)            | 14.67<br>(-18.52)            | <b>17.56</b>  |
| 5      | <i>Atriplex amnicola</i>         | 23.67                       | 28.33<br>(19.72)            | 29.67<br>(25.35)             | <b>27.22</b>  |
| 6      | <i>Atriplex lentiformis</i>      | 20.67                       | 25.33<br>(22.58)            | 27.67<br>(33.87)             | <b>24.56</b>  |
| 7      | <i>Chenopodium ambrosoides</i>   | 42.00                       | 34.67<br>(-17.46)           | 30.67<br>(-26.98)            | <b>35.78</b>  |
| 8      | <i>Suaeda fruticosa</i>          | 65.00                       | 87.67<br>(34.87)            | 99.67<br>(53.33)             | <b>84.11</b>  |
| 9      | <i>Salicornia brachiata</i>      | -                           | -                           | -                            | -             |
| 10     | <i>Solanum xanthocarpum</i>      | 16.00                       | 12.00<br>(-25.00)           | 8.00<br>(-50.00)             | <b>12.00</b>  |
| 11     | <i>Xanthium strumarium</i>       | 8.00                        | 6.00<br>(-25.00)            | 5.67<br>(-29.17)             | <b>6.56</b>   |
| 12     | <i>Sesbania sesquens</i>         | 17.00                       | 18.00<br>(5.88)             | 21.00<br>(23.53)             | <b>18.67</b>  |
| 13     | <i>Heliotropium procumbens</i>   | 25.00                       | 19.00<br>(-24.00)           | 13.67<br>(-45.33)            | <b>19.22</b>  |
| 14     | <i>Parkinsonia aculeata</i>      | 27.67                       | 22.67<br>(-18.07)           | 15.00<br>(-45.78)            | <b>21.78</b>  |
| 15     | <i>Calotropis procera</i>        | 8.33                        | 6.00<br>(-28.00)            | 6.00<br>(-28.00)             | <b>6.78</b>   |
| 16     | <i>Prosopis juliflora</i>        | 43.67                       | 36.00<br>(-17.56)           | 27.00<br>(-38.17)            | <b>35.56</b>  |
| 17     | <i>Arundo donax</i>              | 9.67                        | 11.00<br>(13.79)            | 11.00<br>(13.79)             | <b>10.56</b>  |
| 18     | <i>Aelurops lagopoides</i>       | 20.67                       | 23.33<br>(12.90)            | 27.00<br>(30.65)             | <b>23.67</b>  |
| 19     | <i>Cynodon dactylon</i>          | 8.00                        | 11.67<br>(45.83)            | 7.00<br>(-12.50)             | <b>8.89</b>   |
| 20     | <i>Setaria indica</i>            | 7.67                        | 8.00<br>(4.35)              | 4.67<br>(-39.13)             | <b>6.78</b>   |
|        | Mean                             | <b>32.26</b>                | <b>34.24</b>                | <b>34.03</b>                 |               |

**CD (P=0.05):** Species(S) = 4.987; Salinity levels (T) = N.S; Interaction (S x T) = 8.638

Values given in parentheses ( ) show percent increase/decrease over respective controls

**Table 7: Fresh weight of stem (g /plant) of different plants native to saline soils under various added salinity levels**

| S. No. | Name of Plant                    | S0<br>(0dSm <sup>-1</sup> ) | S1<br>(8dSm <sup>-1</sup> ) | S2<br>(16dSm <sup>-1</sup> ) | Mean        |
|--------|----------------------------------|-----------------------------|-----------------------------|------------------------------|-------------|
| 1      | <i>Portulaca oleracea</i>        | 2.07                        | 2.92<br>(40.84)             | 3.42<br>(65.11)              | <b>2.81</b> |
| 2      | <i>Trianthema portulacastrum</i> | 2.72                        | 3.27<br>(20.22)             | 4.25<br>(56.25)              | <b>3.41</b> |
| 3      | <i>Aerva tomentosa</i>           | 2.71                        | 3.04<br>(12.16)             | 3.42<br>(26.04)              | <b>3.06</b> |
| 4      | <i>Atriplex nummularia</i>       | 1.91                        | 2.27<br>(18.85)             | 1.95<br>(2.27)               | <b>2.04</b> |
| 5      | <i>Atriplex amnicola</i>         | 3.09                        | 3.52<br>(13.81)             | 4.32<br>(39.70)              | <b>3.64</b> |
| 6      | <i>Atriplex lentiformis</i>      | 1.78                        | 2.83<br>(58.80)             | 3.87<br>(117.42)             | <b>2.83</b> |
| 7      | <i>Chenopodium ambrosoides</i>   | 1.82                        | 1.57<br>(-13.76)            | 1.11<br>(-38.72)             | <b>1.50</b> |
| 8      | <i>Suaeda fruticosa</i>          | 1.26                        | 1.86<br>(47.23)             | 2.42<br>(91.29)              | <b>1.85</b> |
| 9      | <i>Salicornia brachiata</i>      | 0.42                        | 1.11<br>(165.08)            | 1.51<br>(260.32)             | <b>1.02</b> |
| 10     | <i>Solanum xanthocarpum</i>      | 2.01                        | 3.46<br>(71.97)             | 1.46<br>(-27.36)             | <b>2.31</b> |
| 11     | <i>Xanthium strumarium</i>       | 3.50                        | 2.46<br>(-29.71)            | 2.12<br>(-39.43)             | <b>2.69</b> |
| 12     | <i>Sesbania sesquens</i>         | 3.75                        | 2.26<br>(-39.68)            | 1.32<br>(-64.68)             | <b>2.44</b> |
| 13     | <i>Heliotropium procumbens</i>   | 2.74                        | 2.34<br>(-14.60)            | 1.63<br>(-40.51)             | <b>2.24</b> |
| 14     | <i>Parkinsonia aculeata</i>      | 3.62                        | 2.43<br>(-32.84)            | 1.88<br>(-48.21)             | <b>2.64</b> |
| 15     | <i>Calotropis procera</i>        | 4.97                        | 4.50<br>(-9.58)             | 3.16<br>(-36.39)             | <b>4.21</b> |
| 16     | <i>Prosopis juliflora</i>        | 2.71                        | 2.18<br>(-19.46)            | 1.20<br>(-55.54)             | <b>2.03</b> |
| 17     | <i>Arundo donax</i>              | 0.76                        | 1.14<br>(50.66)             | 1.37<br>(81.06)              | <b>1.09</b> |
| 18     | <i>Aleurops lagopoides</i>       | 0.70                        | 1.23<br>(75.36)             | 1.60<br>(127.01)             | <b>1.18</b> |
| 19     | <i>Cynodon dactylon</i>          | 1.02                        | 1.35<br>(31.92)             | 0.56<br>(-44.95)             | <b>0.98</b> |
| 20     | <i>Setaria indica</i>            | 3.62                        | 1.52<br>(-58.01)            | 0.97<br>(-73.30)             | <b>2.04</b> |
|        | Mean                             | <b>2.36</b>                 | <b>2.36</b>                 | <b>2.13</b>                  |             |

**CD (P=0.05):** Species(S) =0.224; Salinity levels (T) =0.087; Interaction (S x T) = 0.389

Values given in parentheses ( ) show percent increase/decrease over respective controls

**Table 8: Dry weight of stem (g /plant) of different plants native to saline soils under various added salinity levels**

| S. No. | Name of Plant                    | S0<br>(0dSm <sup>-1</sup> ) | S1<br>(8dSm <sup>-1</sup> ) | S2<br>(16dSm <sup>-1</sup> ) | Mean        |
|--------|----------------------------------|-----------------------------|-----------------------------|------------------------------|-------------|
| 1      | <i>Portulaca oleracea</i>        | 0.32                        | 0.38<br>(19.12)             | 0.43<br>(35.63)              | <b>0.38</b> |
| 2      | <i>Trianthema portulacastrum</i> | 0.73                        | 0.90<br>(24.38)             | 1.34<br>(83.93)              | <b>0.99</b> |
| 3      | <i>Aerva tomentosa</i>           | 0.89                        | 1.20<br>(34.65)             | 1.76<br>(96.57)              | <b>1.28</b> |
| 4      | <i>Atriplex nummularia</i>       | 0.43                        | 0.52<br>(21.60)             | 0.65<br>(52.11)              | <b>0.53</b> |
| 5      | <i>Atriplex amnicola</i>         | 0.99                        | 1.20<br>(21.92)             | 1.50<br>(51.94)              | <b>1.23</b> |
| 6      | <i>Atriplex lentiformis</i>      | 1.13                        | 1.49<br>(31.58)             | 2.09<br>(83.87)              | <b>1.57</b> |
| 7      | <i>Chenopodium ambrosoides</i>   | 1.01                        | 0.80<br>(-21.34)            | 0.42<br>(-58.76)             | <b>0.74</b> |
| 8      | <i>Suaeda fruticosa</i>          | 0.72                        | 0.82<br>(13.91)             | 0.93<br>(29.30)              | <b>0.82</b> |
| 9      | <i>Salicornia brachiata</i>      | 0.11                        | 0.13<br>(17.75)             | 0.16<br>(48.25)              | <b>0.13</b> |
| 10     | <i>Solanum xanthocarpum</i>      | 0.41                        | 0.58<br>(41.06)             | 0.18<br>(-55.92)             | <b>0.39</b> |
| 11     | <i>Xanthium strumarium</i>       | 0.64                        | 0.48<br>(-25.00)            | 0.35<br>(-45.31)             | <b>0.49</b> |
| 12     | <i>Sesbania sesquens</i>         | 1.04                        | 0.54<br>(-48.43)            | 0.34<br>(-67.80)             | <b>0.64</b> |
| 13     | <i>Heliotropium procumbens</i>   | 0.47                        | 0.30<br>(-35.52)            | 0.18<br>(-62.85)             | <b>0.32</b> |
| 14     | <i>Parkinsonia aculeata</i>      | 1.74                        | 1.00<br>(-42.82)            | 0.77<br>(-56.03)             | <b>1.17</b> |
| 15     | <i>Calotropis procera</i>        | 1.23                        | 1.15<br>(-6.78)             | 0.64<br>(-47.97)             | <b>1.01</b> |
| 16     | <i>Prosopis juliflora</i>        | 1.01                        | 0.76<br>(-24.50)            | 0.42<br>(-58.28)             | <b>0.73</b> |
| 17     | <i>Arundo donax</i>              | 0.27                        | 0.39<br>(43.66)             | 0.48<br>(79.23)              | <b>0.38</b> |
| 18     | <i>Aleurops lagopoides</i>       | 0.28                        | 0.35<br>(23.31)             | 0.40<br>(42.69)              | <b>0.34</b> |
| 19     | <i>Cynodon dactylon</i>          | 0.41                        | 0.52<br>(28.29)             | 0.40<br>(-0.33)              | <b>0.44</b> |
| 20     | <i>Setaria indica</i>            | 0.60                        | 0.24<br>(-59.06)            | 0.14<br>(-76.51)             | <b>0.33</b> |
|        | Mean                             | <b>0.72</b>                 | <b>0.76</b>                 | <b>0.67</b>                  |             |

**CD (P=0.05):** Species(S) =0.236; Salinity levels (T) =N.S.; Interaction (S x T) =0.408

Values given in parentheses ( ) show percent increase/decrease over respective controls

**Table 9: Fresh weight of leaves (g /plant) of different plants native to saline soils under various added salinity levels**

| S. No. | Name of Plant                    | S0<br>(0dSm <sup>-1</sup> ) | S1<br>(8dSm <sup>-1</sup> ) | S2<br>(16dSm <sup>-1</sup> ) | Mean        |
|--------|----------------------------------|-----------------------------|-----------------------------|------------------------------|-------------|
| 1.     | <i>Portulaca oleracea</i>        | 5.01                        | 5.69<br>(13.58)             | 6.56<br>(30.96)              | <b>5.75</b> |
| 2      | <i>Trianthema portulacastrum</i> | 3.45                        | 5.59<br>(61.78)             | 6.55<br>(89.77)              | <b>5.20</b> |
| 3      | <i>Aerva tomentosa</i>           | 3.56                        | 4.03<br>(13.31)             | 4.53<br>(27.46)              | <b>4.04</b> |
| 4      | <i>Atriplex nummularia</i>       | 2.85                        | 3.45<br>(20.94)             | 1.84<br>(-35.56)             | <b>2.71</b> |
| 5      | <i>Atriplex amnicola</i>         | 6.49                        | 6.50<br>(0.15)              | 6.66<br>(-2.62)              | <b>6.55</b> |
| 6      | <i>Atriplex lentiformis</i>      | 1.78                        | 2.82<br>(58.43)             | 3.83<br>(115.36)             | <b>2.81</b> |
| 7      | <i>Chenopodium ambrosoides</i>   | 2.84                        | 2.49<br>(-12.44)            | 1.62<br>(-42.96)             | <b>2.32</b> |
| 8      | <i>Suaeda fruticosa</i>          | 4.19                        | 4.64<br>(10.91)             | 5.35<br>(27.79)              | <b>4.73</b> |
| 9      | <i>Salicornia brachiata</i>      | -                           | -                           | -                            | -           |
| 10     | <i>Solanum xanthocarpum</i>      | 3.29                        | 5.82<br>(76.82)             | 1.55<br>(-52.83)             | <b>3.56</b> |
| 11     | <i>Xanthium strumarium</i>       | 4.82                        | 4.23<br>(-12.17)            | 3.80<br>(-21.16)             | <b>4.28</b> |
| 12     | <i>Sesbania sesquens</i>         | 3.61                        | 3.28<br>(-9.23)             | 2.28<br>(-36.90)             | <b>3.06</b> |
| 13     | <i>Heliotropium procumbens</i>   | 6.53                        | 5.70<br>(-12.61)            | 4.44<br>(-32.02)             | <b>5.56</b> |
| 14     | <i>Parkinsonia aculeata</i>      | 3.73                        | 2.40<br>(-35.75)            | 1.25<br>(-66.58)             | <b>2.46</b> |
| 15     | <i>Calotropis procera</i>        | 6.18                        | 5.54<br>(-10.46)            | 3.61<br>(-41.67)             | <b>5.11</b> |
| 16     | <i>Prosopis juliflora</i>        | 2.65                        | 2.49<br>(-6.05)             | 1.63<br>(-38.54)             | <b>2.25</b> |
| 17     | <i>Arundo donax</i>              | 0.88                        | 1.13<br>(27.92)             | 1.43<br>(61.89)              | <b>1.15</b> |
| 18     | <i>Aleurops lagopoides</i>       | 0.85                        | 1.32<br>(55.91)             | 1.66<br>(95.67)              | <b>1.27</b> |
| 19     | <i>Cynodon dactylon</i>          | 1.07                        | 1.31<br>(23.13)             | 0.47<br>(-56.25)             | <b>0.95</b> |
| 20     | <i>Setaria indica</i>            | 3.81                        | 1.30<br>(-66.67)            | 0.96<br>(-74.80)             | <b>2.01</b> |
|        | Mean                             | <b>4.96</b>                 | <b>3.78</b>                 | <b>3.48</b>                  |             |

**CD (P=0.05):** Species(S) = N.S.; Salinity levels (T) = N.S; Interaction (S x T) = N.S.

Values given in parentheses ( ) show percent increase/decrease over respective controls

**Table 10: Dry weight of leaves per plant (g /plant) of different plants native to saline soils under various added salinity levels**

| S. No. | Name of Plant                    | S0<br>(0dSm <sup>-1</sup> ) | S1<br>(8dSm <sup>-1</sup> ) | S2<br>(16dSm <sup>-1</sup> ) | Mean        |
|--------|----------------------------------|-----------------------------|-----------------------------|------------------------------|-------------|
| 1      | <i>Portulaca oleracea</i>        | 1.32                        | 1.62<br>(22.73)             | 1.73<br>(31.21)              | <b>1.56</b> |
| 2      | <i>Trianthema portulacastrum</i> | 0.60                        | 0.80<br>(33.00)             | 1.28<br>(111.92)             | <b>0.90</b> |
| 3      | <i>Aerva tomentosa</i>           | 0.90                        | 1.28<br>(42.22)             | 1.48<br>(64.44)              | <b>1.22</b> |
| 4      | <i>Atriplex nummularia</i>       | 0.80                        | 0.97<br>(21.86)             | 0.36<br>(-54.77)             | <b>0.71</b> |
| 5      | <i>Atriplex amnicola</i>         | 1.40                        | 1.73<br>(23.25)             | 2.50<br>(78.43)              | <b>1.88</b> |
| 6      | <i>Atriplex lentiformis</i>      | 1.20                        | 1.60<br>(32.96)             | 2.14<br>(78.12)              | <b>1.65</b> |
| 7      | <i>Chenopodium ambrosoides</i>   | 0.80                        | 0.69<br>(-14.29)            | 0.54<br>(-32.24)             | <b>0.68</b> |
| 8      | <i>Suaeda fruticosa</i>          | 0.62                        | 0.68<br>(8.71)              | 0.81<br>(30.41)              | <b>0.71</b> |
| 9      | <i>Salicornia brachiata</i>      | -                           | -                           | -                            | -           |
| 10     | <i>Solanum xanthocarpum</i>      | 0.72                        | 1.24<br>(73.65)             | 0.27<br>(-62.85)             | <b>0.74</b> |
| 11     | <i>Xanthium strumarium</i>       | 1.63                        | 0.79<br>(-51.45)            | 0.62<br>(-61.94)             | <b>1.02</b> |
| 12     | <i>Sesbania sesquens</i>         | 1.19                        | 0.90<br>(-24.31)            | 0.54<br>(-54.79)             | <b>0.88</b> |
| 13     | <i>Heliotropium procumbens</i>   | 0.78                        | 0.62<br>(-20.51)            | 0.46<br>(-41.03)             | <b>0.62</b> |
| 14     | <i>Parkinsonia aculeata</i>      | 0.91                        | 0.69<br>(-24.45)            | 0.42<br>(-54.01)             | <b>0.67</b> |
| 15     | <i>Calotropis procera</i>        | 1.95                        | 1.50<br>(-22.77)            | 0.80<br>(-58.90)             | <b>1.42</b> |
| 16     | <i>Prosopis juliflora</i>        | 1.03                        | 0.90<br>(-12.62)            | 0.60<br>(-41.72)             | <b>0.84</b> |
| 17     | <i>Arundo donax</i>              | 0.37                        | 0.43<br>(16.85)             | 0.51<br>(38.77)              | <b>0.44</b> |
| 18     | <i>Aleurops lagopoides</i>       | 0.45                        | 0.54<br>(20.18)             | 0.61<br>(37.52)              | <b>0.53</b> |
| 19     | <i>Cynodon dactylon</i>          | 0.36                        | 0.23<br>(-36.13)            | 0.18<br>(-49.02)             | <b>0.26</b> |
| 20     | <i>Setaria indica</i>            | 1.02                        | 0.68<br>(-33.75)            | 0.59<br>(-42.41)             | <b>0.76</b> |
|        | Mean                             | <b>0.95</b>                 | <b>1.29</b>                 | <b>0.87</b>                  |             |

**CD (P=0.05):** Species(S) = 0.822; Salinity levels (T) = 0.327; Interaction (S x T) = 1.424

Values given in parentheses ( ) show percent increase/decrease over respective controls

**Table 11: Total shoot fresh biomass (g/plant) of different plants native to saline soils under various added salinity levels**

| S. No. | Name of Plant                    | S0<br>(0dSm <sup>-1</sup> ) | S1<br>(8dSm <sup>-1</sup> ) | S2<br>(16dSm <sup>-1</sup> ) | Mean         |
|--------|----------------------------------|-----------------------------|-----------------------------|------------------------------|--------------|
| 1      | <i>Portulaca oleracea</i>        | 7.08                        | 8.61<br>(21.56)             | 9.98<br>(40.96)              | <b>8.56</b>  |
| 2      | <i>Trianthema portulacastrum</i> | 6.17                        | 8.86<br>(43.47)             | 10.80<br>(75.00)             | <b>8.61</b>  |
| 3      | <i>Aerva tomentosa</i>           | 6.27                        | 7.07<br>(12.81)             | 7.95<br>(26.85)              | <b>7.10</b>  |
| 4      | <i>Atriplex nummularia</i>       | 4.76                        | 5.72<br>(20.10)             | 3.79<br>(-20.38)             | <b>4.76</b>  |
| 5      | <i>Atriplex amnicola</i>         | 9.58                        | 10.02<br>(4.56)             | 10.98<br>(14.61)             | <b>10.19</b> |
| 6      | <i>Atriplex lentiformis</i>      | 3.56                        | 5.65<br>(58.61)             | 7.70<br>(116.39)             | <b>5.64</b>  |
| 7      | <i>Chenopodium ambrosoides</i>   | 4.66                        | 4.05<br>(-12.96)            | 2.73<br>(-41.30)             | <b>3.81</b>  |
| 8      | <i>Suaeda fruticosa</i>          | 5.45                        | 6.50<br>(19.33)             | 7.77<br>(42.51)              | <b>6.57</b>  |
| 9      | <i>Salicornia brachiata</i>      | 0.42                        | 1.11<br>(165.08)            | 1.51<br>(260.32)             | <b>1.02</b>  |
| 10     | <i>Solanum xanthocarpum</i>      | 5.30                        | 9.28<br>(74.98)             | 3.01<br>(-43.24)             | <b>5.86</b>  |
| 11     | <i>Xanthium strumarium</i>       | 8.32                        | 6.69<br>(-19.55)            | 5.92<br>(-28.85)             | <b>6.98</b>  |
| 12     | <i>Sesbania sesquens</i>         | 7.36                        | 5.54<br>(-24.73)            | 3.60<br>(-51.04)             | <b>5.50</b>  |
| 13     | <i>Heliotropium procumbens</i>   | 9.27                        | 8.04<br>(-13.20)            | 6.07<br>(-34.53)             | <b>7.79</b>  |
| 14     | <i>Parkinsonia aculeata</i>      | 7.35                        | 4.83<br>(-34.32)            | 3.12<br>(-57.52)             | <b>5.10</b>  |
| 15     | <i>Calotropis procera</i>        | 11.16                       | 10.03<br>(-10.07)           | 6.77<br>(-39.32)             | <b>9.32</b>  |
| 16     | <i>Prosopis juliflora</i>        | 5.35                        | 4.67<br>(-12.83)            | 2.83<br>(-47.14)             | <b>4.28</b>  |
| 17     | <i>Arundo donax</i>              | 1.64                        | 2.27<br>(38.41)             | 2.80<br>(70.73)              | <b>2.24</b>  |
| 18     | <i>Aleurops lagopoides</i>       | 1.55                        | 2.55<br>(64.73)             | 3.25<br>(109.89)             | <b>2.45</b>  |
| 19     | <i>Cynodon dactylon</i>          | 2.09                        | 2.66<br>(27.43)             | 1.03<br>(-50.72)             | <b>1.93</b>  |
| 20     | <i>Setaria indica</i>            | 7.43                        | 2.82<br>(-62.00)            | 1.93<br>(-74.07)             | <b>4.06</b>  |
|        | Mean                             | <b>5.74</b>                 | <b>5.85</b>                 | <b>5.48</b>                  |              |

**CD (P=0.05)** : Species(S) =0.6546; Salinity levels (T) =0.2535; Interaction (SxT) = 1.134

Values given in parentheses ( ) show percent increase/decrease over respective controls

**Table 12: Total shoot dry biomass (g/plant) of different plants native to saline soils under various added salinity levels**

| S. No. | Name of Plant                    | S0<br>(0dSm <sup>-1</sup> ) | S1<br>(8dSm <sup>-1</sup> ) | S2<br>(16dSm <sup>-1</sup> ) | Mean        |
|--------|----------------------------------|-----------------------------|-----------------------------|------------------------------|-------------|
| 1      | <i>Portulaca oleracea</i>        | 1.64                        | 2.00<br>(22.03)             | 2.16<br>(32.07)              | <b>1.93</b> |
| 2      | <i>Trianthema portulacastrum</i> | 1.33                        | 1.71<br>(28.30)             | 2.62<br>(96.64)              | <b>1.88</b> |
| 3      | <i>Aerva tomentosa</i>           | 1.79                        | 2.48<br>(38.45))            | 3.24<br>(80.45)              | <b>2.50</b> |
| 4      | <i>Atriplex nummularia</i>       | 1.22                        | 1.49<br>(21.77)             | 1.01<br>(-17.51)             | <b>1.24</b> |
| 5      | <i>Atriplex amnicola</i>         | 2.39                        | 2.93<br>(22.70))            | 4.00<br>(67.49)              | <b>3.11</b> |
| 6      | <i>Atriplex lentiformis</i>      | 2.34                        | 3.09<br>(32.29)             | 4.23<br>(80.91)              | <b>3.22</b> |
| 7      | <i>Chenopodium ambrosoides</i>   | 1.81                        | 1.48<br>(-18.23)            | 0.96<br>(-47.06)             | <b>1.42</b> |
| 8      | <i>Suaeda fruticosa</i>          | 1.34                        | 1.49<br>(11.49)             | 1.74<br>(29.82)              | <b>1.52</b> |
| 9      | <i>Salicornia brachiata</i>      | 0.11                        | 0.13<br>(17.75)             | 0.16<br>(48.25)              | <b>0.13</b> |
| 10     | <i>Solanum xanthocarpum</i>      | 1.12                        | 1.82<br>(61.81)             | 0.44<br>(-60.48)             | <b>1.13</b> |
| 11     | <i>Xanthium strumarium</i>       | 2.27                        | 1.13<br>(-50.40)            | 0.97<br>(-57.26)             | <b>1.46</b> |
| 12     | <i>Sesbania sesquens</i>         | 2.23                        | 1.44<br>(-35.58)            | 0.87<br>(-60.87)             | <b>1.52</b> |
| 13     | <i>Heliotropium procumbens</i>   | 1.25                        | 0.92<br>(-26.17)            | 0.64<br>(-49.25)             | <b>0.94</b> |
| 14     | <i>Parkinsonia aculeata</i>      | 2.65                        | 1.69<br>(-36.49)            | 1.19<br>(-55.34)             | <b>1.84</b> |
| 15     | <i>Calotropis procera</i>        | 3.18                        | 2.65<br>(-16.58)            | 1.44<br>(-54.67)             | <b>2.42</b> |
| 16     | <i>Prosopis juliflora</i>        | 2.04                        | 1.66<br>(-18.49)            | 1.02<br>(-49.90)             | <b>1.57</b> |
| 17     | <i>Arundo donax</i>              | 0.64                        | 0.82<br>(28.14)             | 0.99<br>(55.82)              | <b>0.81</b> |
| 18     | <i>Aleurops lagopoides</i>       | 0.73                        | 0.88<br>(21.39)             | 1.01<br>(39.51)              | <b>0.87</b> |
| 19     | <i>Cynodon dactylon</i>          | 0.76                        | 0.75<br>(-1.88)             | 0.59<br>(-23.13)             | <b>0.70</b> |
| 20     | <i>Setaria indica</i>            | 1.62                        | 0.92<br>(-43.06)            | 0.93<br>(-42.67)             | <b>1.16</b> |
|        | Mean                             | <b>1.62</b>                 | <b>1.57</b>                 | <b>1.52</b>                  |             |

**CD (P=0.05):** Species(S) =0.478; Salinity levels (T) = N.S; Interaction (S x T) = 0.828

Values given in parentheses ( ) show percent increase/decrease over respective controls

**Table 13: Water content (g/plant) in stem of different plants native to saline soils under various added salinity levels**

| S. No. | Name of Plant                    | S0<br>(0dSm <sup>-1</sup> ) | S1<br>(8dSm <sup>-1</sup> ) | S2<br>(16dSm <sup>-1</sup> ) | Mean        |
|--------|----------------------------------|-----------------------------|-----------------------------|------------------------------|-------------|
| 1      | <i>Portulaca oleracea</i>        | 1.75                        | 2.54<br>(44.78)             | 2.99<br>(70.47)              | <b>2.43</b> |
| 2      | <i>Trianthema portulacastrum</i> | 1.99                        | 2.37<br>(18.71)             | 2.91<br>(46.17)              | <b>2.43</b> |
| 3      | <i>Aerva tomentosa</i>           | 1.82                        | 1.84<br>(1.12)              | 1.66<br>(-8.59)              | <b>1.77</b> |
| 4      | <i>Atriplex nummularia</i>       | 1.48                        | 1.75<br>(18.06)             | 1.31<br>(-12.04)             | <b>1.51</b> |
| 5      | <i>Atriplex amnicola</i>         | 2.10                        | 2.31<br>(10.00)             | 2.82<br>(33.95)              | <b>2.41</b> |
| 6      | <i>Atriplex lentiformis</i>      | 0.65                        | 1.33<br>(106.66)            | 1.78<br>(176.39)             | <b>1.25</b> |
| 7      | <i>Chenopodium ambrosoides</i>   | 0.80                        | 0.77<br>(-4.19)             | 0.70<br>(-13.41)             | <b>0.76</b> |
| 8      | <i>Suaeda fruticosa</i>          | 0.55                        | 1.04<br>(90.91)             | 1.49<br>(172.56)             | <b>1.03</b> |
| 9      | <i>Salicornia brachiata</i>      | 0.31                        | 1.02<br>(229.35)            | 1.35<br>(335.94)             | <b>0.89</b> |
| 10     | <i>Solanum xanthocarpum</i>      | 1.60                        | 2.88<br>(79.85)             | 1.25<br>(-22.27)             | <b>1.91</b> |
| 11     | <i>Xanthium strumarium</i>       | 2.86                        | 2.13<br>(-25.69)            | 1.77<br>(-38.11)             | <b>2.25</b> |
| 12     | <i>Sesbania sesquens</i>         | 2.70                        | 1.72<br>(-36.30)            | 0.99<br>(-63.48)             | <b>1.80</b> |
| 13     | <i>Heliotropium procumbens</i>   | 2.27                        | 2.04<br>(-10.24)            | 1.45<br>(-35.86)             | <b>1.92</b> |
| 14     | <i>Parkinsonia aculeata</i>      | 1.88                        | 1.44<br>(-23.63)            | 1.11<br>(-40.97)             | <b>1.48</b> |
| 15     | <i>Calotropis procera</i>        | 3.74                        | 3.35<br>(-10.51)            | 2.52<br>(-32.59)             | <b>3.21</b> |
| 16     | <i>Prosopis juliflora</i>        | 1.70                        | 1.42<br>(-16.47)            | 0.78<br>(-53.92)             | <b>1.30</b> |
| 17     | <i>Arundo donax</i>              | 0.49                        | 0.76<br>(54.50)             | 0.89<br>(82.06)              | <b>0.71</b> |
| 18     | <i>Aelurops lagopoides</i>       | 0.42                        | 0.89<br>(109.85)            | 1.20<br>(182.90)             | <b>0.84</b> |
| 19     | <i>Cynodon dactylon</i>          | 0.62                        | 0.83<br>(34.30)             | 0.16<br>(-74.22)             | <b>0.54</b> |
| 20     | <i>Setaria indica</i>            | 3.02                        | 1.28<br>(-57.80)            | 0.75<br>(-75.20)             | <b>1.68</b> |
|        | Mean                             | <b>1.64</b>                 | <b>1.68</b>                 | <b>1.49</b>                  |             |

**CD (P=0.05):** Species(S) =0.2277; Salinity levels (T) =0.0882; Interaction (S x T) =0.394

Values given in parentheses ( ) show percent increase/decrease over respective controls

**Table 14: Water content (g/plant) in leaves of different plants native to saline soils under various added salinity levels**

| S. No. | Name of Plant                    | S0<br>(0dSm <sup>-1</sup> ) | S1<br>(8dSm <sup>-1</sup> ) | S2<br>(16dSm <sup>-1</sup> ) | Mean        |
|--------|----------------------------------|-----------------------------|-----------------------------|------------------------------|-------------|
| 1      | <i>Portulaca oleracea</i>        | 3.69                        | 4.07<br>(10.31)             | 4.82<br>(30.87)              | <b>4.19</b> |
| 2      | <i>Trianthema portulacastrum</i> | 2.85                        | 4.78<br>(67.88)             | 5.27<br>(85.07)              | <b>4.30</b> |
| 3      | <i>Aerva tomentosa</i>           | 2.66                        | 2.75<br>(3.51)              | 3.05<br>(14.93)              | <b>2.82</b> |
| 4      | <i>Atriplex nummularia</i>       | 2.05                        | 2.48<br>(20.58)             | 1.48<br>(-28.11)             | <b>2.00</b> |
| 5      | <i>Atriplex amnicola</i>         | 5.09                        | 4.77<br>(-6.22)             | 4.16<br>(-18.23)             | <b>4.67</b> |
| 6      | <i>Atriplex lentiformis</i>      | 0.58                        | 1.22<br>(111.56)            | 1.69<br>(193.06)             | <b>1.16</b> |
| 7      | <i>Chenopodium ambrosoides</i>   | 2.04                        | 1.80<br>(-11.72)            | 1.08<br>(-47.16)             | <b>1.64</b> |
| 8      | <i>Suaeda fruticosa</i>          | 3.56                        | 3.97<br>(11.29)             | 4.54<br>(27.33)              | <b>4.02</b> |
| 9      | <i>Salicornia brachiata</i>      | -                           | -                           | -                            | -           |
| 10     | <i>Solanum xanthocarpum</i>      | 2.58                        | 4.58<br>(77.70)             | 1.29<br>(-50.05)             | <b>2.81</b> |
| 11     | <i>Xanthium strumarium</i>       | 3.19                        | 3.44<br>(7.96)              | 3.18<br>(-0.26)              | <b>3.27</b> |
| 12     | <i>Sesbania sesquens</i>         | 2.42                        | 2.38<br>(-1.82)             | 1.74<br>(-28.12)             | <b>2.18</b> |
| 13     | <i>Heliotropium procumbens</i>   | 5.75                        | 5.08<br>(-11.54)            | 3.98<br>(-30.80)             | <b>4.94</b> |
| 14     | <i>Parkinsonia aculeata</i>      | 2.82                        | 1.71<br>(-39.41)            | 0.83<br>(-70.65)             | <b>1.78</b> |
| 15     | <i>Calotropis procera</i>        | 4.24                        | 4.03<br>(-4.80)             | 2.81<br>(-33.75)             | <b>3.69</b> |
| 16     | <i>Prosopis juliflora</i>        | 1.62                        | 1.59<br>(-1.86)             | 1.03<br>(-36.52)             | <b>1.41</b> |
| 17     | <i>Arundo donax</i>              | 0.52                        | 0.70<br>(35.83)             | 0.92<br>(78.40)              | <b>0.71</b> |
| 18     | <i>Aleurops lagopoides</i>       | 0.40                        | 0.78<br>(95.67)             | 1.04<br>(160.40)             | <b>0.74</b> |
| 19     | <i>Cynodon dactylon</i>          | 0.71                        | 1.09<br>(52.94)             | 0.28<br>(-59.89)             | <b>0.69</b> |
| 20     | <i>Setaria indica</i>            | 2.79                        | 0.63<br>(-77.56)            | 0.37<br>(-86.70)             | <b>1.26</b> |
|        | Mean                             | <b>2.48</b>                 | <b>2.59</b>                 | <b>2.47</b>                  |             |

**CD (P=0.05):** Species(S) =0.4308; Salinity levels (T) = N.S; Interaction (S x T) = 0.746

Values given in parentheses ( ) show percent increase/decrease over respective controls

**Table 15: Total shoot water content (g/plant) in plant of different plants native to saline soils under various added salinity levels**

| S. No. | Name of Plant                    | S0<br>(0dSm <sup>-1</sup> ) | S1<br>(8dSm <sup>-1</sup> ) | S2<br>(16dSm <sup>-1</sup> ) | Mean        |
|--------|----------------------------------|-----------------------------|-----------------------------|------------------------------|-------------|
| 1      | <i>Portulaca oleracea</i>        | 5.44                        | 6.61<br>(21.42)             | 7.82<br>(43.64)              | <b>6.62</b> |
| 2      | <i>Trianthema portulacastrum</i> | 4.84                        | 7.15<br>(47.63)             | 8.19<br>(69.06)              | <b>6.73</b> |
| 3      | <i>Aerva tomentosa</i>           | 4.48                        | 4.59<br>(2.54)              | 4.72<br>(5.37)               | <b>4.59</b> |
| 4      | <i>Atriplex nummularia</i>       | 3.54                        | 4.23<br>(19.52)             | 2.78<br>(-21.37)             | <b>3.52</b> |
| 5      | <i>Atriplex amnicola</i>         | 7.19                        | 7.08<br>(-1.47)             | 6.98<br>(-2.97)              | <b>7.08</b> |
| 6      | <i>Atriplex lentiformis</i>      | 1.22                        | 2.55<br>(108.97)            | 3.47<br>(184.26)             | <b>2.42</b> |
| 7      | <i>Chenopodium ambrosoides</i>   | 2.84                        | 2.57<br>(-9.59)             | 1.77<br>(-37.63)             | <b>2.40</b> |
| 8      | <i>Suaeda fruticosa</i>          | 4.11                        | 5.01<br>(21.88)             | 6.03<br>(46.65)              | <b>5.05</b> |
| 9      | <i>Salicornia brachiata</i>      | 0.31                        | 1.02<br>(229.35)            | 1.35<br>(335.94)             | <b>0.89</b> |
| 10     | <i>Solanum xanthocarpum</i>      | 4.18                        | 7.46<br>(78.53)             | 2.57<br>(-38.53)             | <b>4.74</b> |
| 11     | <i>Xanthium strumarium</i>       | 6.05                        | 5.57<br>(-7.95)             | 4.95<br>(-18.16)             | <b>5.52</b> |
| 12     | <i>Sesbania sesquens</i>         | 5.13                        | 4.10<br>(-20.00)            | 2.73<br>(-46.76)             | <b>3.99</b> |
| 13     | <i>Heliotropium procumbens</i>   | 8.01                        | 7.12<br>(-11.18)            | 5.43<br>(-32.23)             | <b>6.86</b> |
| 14     | <i>Parkinsonia aculeata</i>      | 4.70                        | 3.15<br>(-33.09)            | 1.94<br>(-58.76)             | <b>3.26</b> |
| 15     | <i>Calotropis procera</i>        | 7.98                        | 7.38<br>(-7.48)             | 5.33<br>(-33.21)             | <b>6.90</b> |
| 16     | <i>Prosopis juliflora</i>        | 3.32                        | 3.01<br>(-9.35)             | 1.81<br>(-45.44)             | <b>2.71</b> |
| 17     | <i>Arundo donax</i>              | 1.00                        | 1.46<br>(44.92)             | 1.81<br>(80.18)              | <b>1.42</b> |
| 18     | <i>Aelurops lagopoides</i>       | 0.82                        | 1.67<br>(102.95)            | 2.24<br>(171.95)             | <b>1.58</b> |
| 19     | <i>Cynodon dactylon</i>          | 1.33                        | 1.92<br>(44.26)             | 0.44<br>(-66.56)             | <b>1.23</b> |
| 20     | <i>Setaria indica</i>            | 5.81                        | 1.90<br>(-67.28)            | 1.20<br>(-79.31)             | <b>2.97</b> |
|        | Mean                             | <b>4.11</b>                 | <b>4.28</b>                 | <b>3.99</b>                  |             |

**CD (P=0.05):** Species(S) =0.4608; Salinity levels (T) =0.1785; Interaction (S x T) =0.798

Values given in parentheses ( ) show percent increase/decrease over respective controls

**Table 16: Ash content of stem (g g<sup>-1</sup>dry wt.) of different plants native to saline soils under various added salinity levels**

| S. No. | Name of Plant                    | S0<br>(0dSm <sup>-1</sup> ) | S1<br>(8dSm <sup>-1</sup> ) | S2<br>(16dSm <sup>-1</sup> ) | Mean         |
|--------|----------------------------------|-----------------------------|-----------------------------|------------------------------|--------------|
| 1      | <i>Portulaca oleracea</i>        | 0.197                       | 0.215<br>(9.14)             | 0.232<br>(17.77)             | <b>0.215</b> |
| 2      | <i>Trianthema portulacastrum</i> | 0.228                       | 0.250<br>(9.65)             | 0.264<br>(15.79)             | <b>0.247</b> |
| 3      | <i>Aerva tomentosa</i>           | 0.098                       | 0.112<br>(14.29)            | 0.132<br>(34.69)             | <b>0.114</b> |
| 4      | <i>Atriplex nummularia</i>       | 0.135                       | 0.144<br>(6.67)             | 0.153<br>(13.33)             | <b>0.144</b> |
| 5      | <i>Atriplex amnicola</i>         | 0.084                       | 0.093<br>(10.71)            | 0.107<br>(27.78)             | <b>0.095</b> |
| 6      | <i>Atriplex lentiformis</i>      | 0.123                       | 0.129<br>(4.88)             | 0.138<br>(12.20)             | <b>0.130</b> |
| 7      | <i>Chenopodium ambrosoides</i>   | 0.071                       | 0.087<br>(22.54)            | 0.106<br>(49.30)             | <b>0.088</b> |
| 8      | <i>Suaeda fruticosa</i>          | 0.088                       | 0.092<br>(4.55)             | 0.108<br>(22.73)             | <b>0.096</b> |
| 9      | <i>Salicornia brachiata</i>      | 0.238                       | 0.293<br>(22.94)            | 0.312<br>(30.91)             | <b>0.281</b> |
| 10     | <i>Solanum xanthocarpum</i>      | 0.142                       | 0.142<br>(0.00)             | 0.158<br>(11.27)             | <b>0.147</b> |
| 11     | <i>Xanthium strumarium</i>       | 0.147                       | 0.154<br>(4.76)             | 0.166<br>(12.93)             | <b>0.156</b> |
| 12     | <i>Sesbania sesquens</i>         | 0.061                       | 0.084<br>(37.70)            | 0.117<br>(92.35)             | <b>0.087</b> |
| 13     | <i>Heliotropium procumbens</i>   | 0.174                       | 0.185<br>(6.32)             | 0.196<br>(12.64)             | <b>0.185</b> |
| 14     | <i>Parkinsonia aculeata</i>      | 0.075                       | 0.093<br>(24.55)            | 0.114<br>(52.68)             | <b>0.094</b> |
| 15     | <i>Calotropis procera</i>        | 0.084                       | 0.127<br>(51.19)            | 0.132<br>(57.14)             | <b>0.114</b> |
| 16     | <i>Prosopis juliflora</i>        | 0.058                       | 0.070<br>(20.19)            | 0.100<br>(72.41)             | <b>0.076</b> |
| 17     | <i>Arundo donax</i>              | 0.076                       | 0.085<br>(12.28)            | 0.101<br>(32.46)             | <b>0.087</b> |
| 18     | <i>Aleurops lagopoides</i>       | 0.105                       | 0.112<br>(6.67)             | 0.110<br>(4.76)              | <b>0.109</b> |
| 19     | <i>Cynodon dactylon</i>          | 0.068                       | 0.088<br>(29.41)            | 0.111<br>(63.24)             | <b>0.089</b> |
| 20     | <i>Setaria indica</i>            | 0.100                       | 0.141<br>(41.00)            | 0.153<br>(53.00)             | <b>0.131</b> |
|        | Mean                             | <b>0.130</b>                | <b>0.135</b>                | <b>0.163</b>                 |              |

**CD (P=0.05):** Species(S) =0.0792; Salinity levels (T) = N.S; Interaction (S xT) =0.137

Values given in parentheses ( ) show percent increase/decrease over respective controls

**Table 17: Ash content of leaves per plant (g g<sup>-1</sup> dry wt.) of different plants native to saline soils under various added salinity levels**

| S. No. | Name of Plant                    | S0<br>(0dSm <sup>-1</sup> ) | S1<br>(8dSm <sup>-1</sup> ) | S2<br>(16dSm <sup>-1</sup> ) | Mean  |
|--------|----------------------------------|-----------------------------|-----------------------------|------------------------------|-------|
| 1      | <i>Portulaca oleracea</i>        | 0.240                       | 0.256<br>(6.67)             | 0.274<br>(14.17)             | 0.257 |
| 2      | <i>Trianthema portulacastrum</i> | 0.227                       | 0.238<br>(4.85)             | 0.260<br>(14.54)             | 0.242 |
| 3      | <i>Aerva tomentosa</i>           | 0.211                       | 0.230<br>(9.00)             | 0.246<br>(16.59)             | 0.229 |
| 4      | <i>Atriplex nummularia</i>       | 0.254                       | 0.267<br>(5.12)             | 0.274<br>(7.87)              | 0.265 |
| 5      | <i>Atriplex amnicola</i>         | 0.155                       | 0.180<br>(16.13)            | 0.189<br>(21.94)             | 0.175 |
| 6      | <i>Atriplex lentiformis</i>      | 0.252                       | 0.264<br>(4.63)             | 0.276<br>(9.52)              | 0.264 |
| 7      | <i>Chenopodium ambrosoides</i>   | 0.200                       | 0.209<br>(4.67)             | 0.213<br>(6.50)              | 0.207 |
| 8      | <i>Suaeda fruticosa</i>          | 0.312                       | 0.320<br>(2.67)             | 0.360<br>(15.38)             | 0.331 |
| 9      | <i>Salicornia brachiata</i>      | -                           | -                           | -                            | -     |
| 10     | <i>Solanum xanthocarpum</i>      | 0.165                       | 0.170<br>(3.03)             | 0.180<br>(8.89)              | 0.172 |
| 11     | <i>Xanthium strumarium</i>       | 0.196                       | 0.202<br>(3.06)             | 0.205<br>(4.59)              | 0.201 |
| 12     | <i>Sesbania sesquens</i>         | 0.109                       | 0.113<br>(3.66)             | 0.118<br>(8.23)              | 0.114 |
| 13     | <i>Heliotropium procumbens</i>   | 0.318                       | 0.322<br>(1.26)             | 0.330<br>(3.77)              | 0.323 |
| 14     | <i>Parkinsonia aculeata</i>      | 0.129                       | 0.139<br>(8.03)             | 0.119<br>(-7.51)             | 0.129 |
| 15     | <i>Calotropis procera</i>        | 0.182                       | 0.202<br>(10.99)            | 0.231<br>(26.92)             | 0.205 |
| 16     | <i>Prosopis juliflora</i>        | 0.084                       | 0.094<br>(12.30)            | 0.100<br>(19.05)             | 0.093 |
| 17     | <i>Arundo donax</i>              | 0.119                       | 0.127<br>(6.44)             | 0.153<br>(28.57)             | 0.133 |
| 18     | <i>Aelurops lagopoides</i>       | 0.156                       | 0.168<br>(7.92)             | 0.117<br>(-13.70)            | 0.167 |
| 19     | <i>Cynodon dactylon</i>          | 0.103                       | 0.118<br>(14.56)            | 0.134<br>(30.10)             | 0.118 |
| 20     | <i>Setaria indica</i>            | 0.190                       | 0.206<br>(8.42)             | 0.227<br>(19.47)             | 0.208 |
|        | Mean                             | <b>0.190</b>                | <b>0.201</b>                | <b>0.214</b>                 |       |

**CD (P=0.05):** Species(S) = 0.013; Salinity levels (T) = 0.005; Interaction (S x T) = N.S.

Values given in parentheses ( ) show percent increase/decrease over respective controls

**Table 18: Organic matter in stem (g g<sup>-1</sup>dry wt.) of different plants native to saline soils under various added salinity levels**

| S. No. | Name of Plant                    | S0<br>(0dSm <sup>-1</sup> ) | S1<br>(8dSm <sup>-1</sup> ) | S2<br>(16dSm <sup>-1</sup> ) | Mean         |
|--------|----------------------------------|-----------------------------|-----------------------------|------------------------------|--------------|
| 1      | <i>Portulaca oleracea</i>        | 0.803                       | 0.785<br>(-2.24)            | 0.768<br>(-4.36)             | <b>0.785</b> |
| 2      | <i>Trianthema portulacastrum</i> | 0.772                       | 0.750<br>(-2.85)            | 0.736<br>(-4.66)             | <b>0.753</b> |
| 3      | <i>Aerva tomentosa</i>           | 0.902                       | 0.888<br>(-1.55)            | 0.868<br>(-3.77)             | <b>0.886</b> |
| 4      | <i>Atriplex nummularia</i>       | 0.865                       | 0.856<br>(-1.04)            | 0.847<br>(-2.08)             | <b>0.856</b> |
| 5      | <i>Atriplex amnicola</i>         | 0.916                       | 0.907<br>(-0.98)            | 0.893<br>(-2.55)             | <b>0.905</b> |
| 6      | <i>Atriplex lentiformis</i>      | 0.877                       | 0.871<br>(-0.68)            | 0.862<br>(-1.71)             | <b>0.870</b> |
| 7      | <i>Chenopodium ambrosoides</i>   | 0.929                       | 0.913<br>(-1.72)            | 0.894<br>(-3.77)             | <b>0.912</b> |
| 8      | <i>Suaeda fruticosa</i>          | 0.912                       | 0.908<br>(-0.44)            | 0.892<br>(-2.19)             | <b>0.904</b> |
| 9      | <i>Salicornia brachiata</i>      | 0.762                       | 0.707<br>(-7.18)            | 0.688<br>(-9.67)             | <b>0.719</b> |
| 10     | <i>Solanum xanthocarpum</i>      | 0.858                       | 0.858<br>(0.00)             | 0.842<br>(-1.86)             | <b>0.853</b> |
| 11     | <i>Xanthium strumarium</i>       | 0.852                       | 0.846<br>(-0.70)            | 0.834<br>(-2.11)             | <b>0.844</b> |
| 12     | <i>Sesbania sesquens</i>         | 0.939                       | 0.916<br>(-2.45)            | 0.883<br>(-6.00)             | <b>0.913</b> |
| 13     | <i>Heliotropium procumbens</i>   | 0.826                       | 0.815<br>(-1.33)            | 0.804<br>(-2.66)             | <b>0.815</b> |
| 14     | <i>Parkinsonia aculeata</i>      | 0.925                       | 0.907<br>(-1.98)            | 0.886<br>(-4.25)             | <b>0.906</b> |
| 15     | <i>Calotropis procera</i>        | 0.916                       | 0.873<br>(-4.69)            | 0.868<br>(-5.24)             | <b>0.886</b> |
| 16     | <i>Prosopis juliflora</i>        | 0.942                       | 0.936<br>(-0.64)            | 0.654<br>(-30.57)            | <b>0.844</b> |
| 17     | <i>Arundo donax</i>              | 0.924                       | 0.915<br>(-1.01)            | 0.899<br>(-2.67)             | <b>0.913</b> |
| 18     | <i>Aleurops lagopoides</i>       | 0.895                       | 0.888<br>(-0.78)            | 0.890<br>(-0.56)             | <b>0.891</b> |
| 19     | <i>Cynodon dactylon</i>          | 0.932                       | 0.912<br>(-2.15)            | 0.889<br>(-4.61)             | <b>0.911</b> |
| 20     | <i>Setaria indica</i>            | 0.899                       | 0.859<br>(-4.45)            | 0.847<br>(-5.78)             | <b>0.868</b> |
|        | Mean                             | 0.882                       | 0.865                       | 0.837                        |              |

**CD (P=0.05) :** Species(S) =0.0550, Salinity levels (T) =0.0213; Interaction (SxT) = N.S.

Values given in parentheses ( ) show percent increase/decrease over respective controls

**Table 19: Organic matter in leaves (g g<sup>-1</sup>dry wt.) of different plants native to saline soils under various added salinity levels**

| S. No. | Name of Plant                    | S0<br>(0dSm <sup>-1</sup> ) | S1<br>(8dSm <sup>-1</sup> ) | S2<br>(16dSm <sup>-1</sup> ) | Mean         |
|--------|----------------------------------|-----------------------------|-----------------------------|------------------------------|--------------|
| 1      | <i>Portulaca oleracea</i>        | 0.760                       | 0.744<br>(-2.11)            | 0.726<br>(-4.47)             | <b>0.743</b> |
| 2      | <i>Trianthema portulacastrum</i> | 0.773                       | 0.762<br>(-1.42)            | 0.740<br>(-4.27)             | <b>0.758</b> |
| 3      | <i>Aerva tomentosa</i>           | 0.789                       | 0.770<br>(-2.41)            | 0.754<br>(-4.44)             | <b>0.771</b> |
| 4      | <i>Atriplex nummularia</i>       | 0.746                       | 0.733<br>(-1.74)            | 0.726<br>(-2.68)             | <b>0.735</b> |
| 5      | <i>Atriplex amnicola</i>         | 0.845                       | 0.820<br>(-2.96)            | 0.811<br>(-4.02)             | <b>0.825</b> |
| 6      | <i>Atriplex lentiformis</i>      | 0.748                       | 0.736<br>(-1.56)            | 0.724<br>(-3.21)             | <b>0.736</b> |
| 7      | <i>Chenopodium ambrosoides</i>   | 0.800                       | 0.791<br>(-1.17)            | 0.787<br>(-1.63)             | <b>0.793</b> |
| 8      | <i>Suaeda fruticosa</i>          | 0.688                       | 0.680<br>(-1.21)            | 0.640<br>(-6.98)             | <b>0.669</b> |
| 9      | <i>Salicornia brachiata</i>      | -                           | -                           | -                            | -            |
| 10     | <i>Solanum xanthocarpum</i>      | 0.835                       | 0.830<br>(-0.60)            | 0.820<br>(-1.76)             | <b>0.828</b> |
| 11     | <i>Xanthium strumarium</i>       | 0.804                       | 0.798<br>(-0.75)            | 0.795<br>(-1.12)             | <b>0.799</b> |
| 12     | <i>Sesbania sesquens</i>         | 0.891                       | 0.887<br>(-0.45)            | 0.882<br>(-1.01)             | <b>0.886</b> |
| 13     | <i>Heliotropium procumbens</i>   | 0.682                       | 0.678<br>(-0.59)            | 0.670<br>(-1.76)             | <b>0.677</b> |
| 14     | <i>Parkinsonia aculeata</i>      | 0.871                       | 0.861<br>(-1.19)            | 0.881<br>(1.11)              | <b>0.871</b> |
| 15     | <i>Calotropis procera</i>        | 0.818                       | 0.798<br>(-2.44)            | 0.769<br>(-5.99)             | <b>0.795</b> |
| 16     | <i>Prosopis juliflora</i>        | 0.916                       | 0.906<br>(-1.13)            | 0.900<br>(-1.75)             | <b>0.907</b> |
| 17     | <i>Arundo donax</i>              | 0.881                       | 0.873<br>(-0.87)            | 0.847<br>(-3.86)             | <b>0.867</b> |
| 18     | <i>Aleurops lagopoides</i>       | 0.844                       | 0.832<br>(-1.46)            | 0.823<br>(-2.53)             | <b>0.833</b> |
| 19     | <i>Cynodon dactylon</i>          | 0.897                       | 0.882<br>(-1.67)            | 0.866<br>(-3.46)             | <b>0.882</b> |
| 20     | <i>Setaria indica</i>            | 0.810                       | 0.794<br>(-1.98)            | 0.773<br>(-4.57)             | <b>0.792</b> |
|        | Mean                             | <b>0.810</b>                | <b>0.799</b>                | <b>0.786</b>                 |              |

**CD (P=0.05) :** Species(S) =0.0128; Salinity levels (T) =0.0051; Interaction (SxT) = N.S

Values given in parentheses ( ) show percent increase/decrease over respective controls

**Table 20: Ionic status, Ece, pH, CEC, SAR and Na<sup>+</sup>/K<sup>+</sup> of soil before transplantation of plants under various added salinity levels**

| <b>Sr. No</b> | <b>Salinity levels (dSm<sup>-1</sup>)</b> | <b>Na<sup>+</sup> (μgg<sup>-1</sup>)</b> | <b>K<sup>+</sup> (μgg<sup>-1</sup>)</b> | <b>Ca<sup>2+</sup> (μgg<sup>-1</sup>)</b> | <b>Mg<sup>2+</sup> (μgg<sup>-1</sup>)</b> | <b>Cl<sup>-</sup> (μgg<sup>-1</sup>)</b> | <b>SO<sub>4</sub><sup>-</sup> (μgg<sup>-1</sup>)</b> | <b>C.E.C</b> | <b>pH</b>    | <b>Ece</b>   | <b>S.A.R</b> | <b>Na<sup>+</sup>/K<sup>+</sup></b> |
|---------------|-------------------------------------------|------------------------------------------|-----------------------------------------|-------------------------------------------|-------------------------------------------|------------------------------------------|------------------------------------------------------|--------------|--------------|--------------|--------------|-------------------------------------|
| <b>1</b>      | <b>0</b>                                  | 46.62                                    | 85.38                                   | 21.41                                     | 50.19                                     | 44.48                                    | 38.19                                                | 2.13         | 7.34         | 1.12         | 7.79         | 0.54                                |
| <b>2</b>      | <b>8</b>                                  | 275.74                                   | 83.57                                   | 62.45                                     | 110.40                                    | 556.68                                   | 324.62                                               | 2.13         | 7.72         | 8.22         | 29.72        | 2.68                                |
| <b>3</b>      | <b>16</b>                                 | 523.10                                   | 84.11                                   | 125.51                                    | 208.44                                    | 1110.17                                  | 648.80                                               | 2.13         | 8.29         | 16.30        | 40.49        | 6.48                                |
|               | <b>Mean</b>                               | 281.82                                   | 84.35                                   | 69.79                                     | 486.86                                    | 570.44                                   | 337.20                                               | 2.13         | 7.78         | 8.55         | 281.82       | 84.35                               |
|               | <b>CD(P=0.05)</b>                         | <b>23.406</b>                            | <b>N.S.</b>                             | <b>16.834</b>                             | <b>21.558</b>                             | <b>26.802</b>                            | <b>27.95</b>                                         | <b>N.S.</b>  | <b>0.298</b> | <b>0.524</b> | <b>1.502</b> | <b>0.90</b>                         |

**Table 21: Na<sup>+</sup> content (µg g<sup>-1</sup> soil) in soil at harvesting of different plants native to saline soils under various added salinity levels**

| S. No.                   | Name of Plant                    | S0<br>(0dSm <sup>-1</sup> ) | S1<br>(8dSm <sup>-1</sup> ) | S2<br>(16dSm <sup>-1</sup> ) | Mean          |
|--------------------------|----------------------------------|-----------------------------|-----------------------------|------------------------------|---------------|
| <b>Before plantation</b> |                                  | <b>46.62</b>                | <b>275.74</b>               | <b>523.10</b>                | <b>281.82</b> |
| 1                        | <i>Portulaca oleracea</i>        | 35.73                       | 263.30<br>(636.86)          | 510.90<br>(1329.77)          | <b>269.98</b> |
| 2                        | <i>Trianthema portulacastrum</i> | 32.32                       | 265.39<br>(721.14)          | 508.71<br>(1473.98)          | <b>268.81</b> |
| 3                        | <i>Aerva tomentosa</i>           | 36.38                       | 266.58<br>(632.77)          | 509.08<br>(1299.34)          | <b>270.68</b> |
| 4                        | <i>Atriplex nummularia</i>       | 31.88                       | 261.56<br>(720.45)          | 509.57<br>(1498.40)          | <b>267.67</b> |
| 5                        | <i>Atriplex amnicola</i>         | 30.34                       | 260.20<br>(757.52)          | 507.68<br>(1573.12)          | <b>266.07</b> |
| 6                        | <i>Atriplex lentiformis</i>      | 32.44                       | 254.39<br>(684.19)          | 508.15<br>(1466.43)          | <b>264.99</b> |
| 7                        | <i>Chenopodium ambrosoides</i>   | 37.57                       | 256.44<br>(582.50)          | 510.87<br>(1259.66)          | <b>268.29</b> |
| 8                        | <i>Suaeda fruticosa</i>          | 33.46                       | 258.21<br>(671.69)          | 507.14<br>(1415.66)          | <b>266.27</b> |
| 9                        | <i>Salicornia brachiata</i>      | 34.51                       | 246.54<br>(614.40)          | 505.22<br>(1363.98)          | <b>262.09</b> |
| 10                       | <i>Solanum xanthocarpum</i>      | 37.61                       | 264.39<br>(602.98)          | 514.31<br>(1267.48)          | <b>272.10</b> |
| 11                       | <i>Xanthium strumarium</i>       | 37.56                       | 265.41<br>(606.69)          | 515.44<br>(1272.43)          | <b>272.80</b> |
| 12                       | <i>Sesbania sesquens</i>         | 36.88                       | 267.72<br>(625.99)          | 514.26<br>(1294.55)          | <b>272.95</b> |
| 13                       | <i>Heliotropium procumbens</i>   | 36.39                       | 267.33<br>(634.56)          | 515.44<br>(1316.30)          | <b>273.05</b> |
| 14                       | <i>Parkinsonia aculeata</i>      | 37.29                       | 268.31<br>(619.46)          | 514.69<br>(1280.12)          | <b>273.43</b> |
| 15                       | <i>Calotropis procera</i>        | 36.76                       | 270.20<br>(634.98)          | 514.79<br>(1300.27)          | <b>273.92</b> |
| 16                       | <i>Prosopis juliflora</i>        | 38.61                       | 264.61<br>(585.27)          | 514.39<br>(1232.15)          | <b>272.54</b> |
| 17                       | <i>Arundo donax</i>              | 35.55                       | 265.58<br>(647.06)          | 509.28<br>(1332.57)          | <b>270.14</b> |
| 18                       | <i>Aleurops lagopoides</i>       | 34.69                       | 263.65<br>(660.02)          | 512.01<br>(1375.96)          | <b>270.12</b> |
| 19                       | <i>Cynodon dactylon</i>          | 36.21                       | 265.44<br>(633.06)          | 514.03<br>(1319.58)          | <b>271.89</b> |
| 20                       | <i>Setaria indica</i>            | 37.19                       | 266.88<br>(617.61)          | 516.53<br>(1288.89)          | <b>273.53</b> |
|                          | Mean                             | <b>35.47</b>                | <b>263.11</b>               | <b>511.63</b>                |               |

**CD (P=0.05)** : Species(S) = 7.059; Salinity levels (T) = 2.73S; Interaction (SxT) = 4.665

Values given in parentheses ( ) show percent increase/decrease over respective controls

**Table 22: Na<sup>+</sup> content (mg g<sup>-1</sup>dry wt.) in stem of different plants native to saline soils under various added salinity levels**

| S. No. | Name of Plant                    | S0<br>(0dSm <sup>-1</sup> ) | S1<br>(8dSm <sup>-1</sup> ) | S2<br>(16dSm <sup>-1</sup> ) | Mean         |
|--------|----------------------------------|-----------------------------|-----------------------------|------------------------------|--------------|
| 1      | <i>Portulaca oleracea</i>        | 15.48                       | 45.47<br>(193.76)           | 118.77<br>(667.27)           | <b>59.91</b> |
| 2      | <i>Trianthema portulacastrum</i> | 14.54                       | 42.08<br>(189.41)           | 117.34<br>(706.99)           | <b>57.99</b> |
| 3      | <i>Aerva tomentosa</i>           | 13.75                       | 41.29<br>(200.24)           | 116.56<br>(747.48)           | <b>57.20</b> |
| 4      | <i>Atriplex nummularia</i>       | 16.30                       | 53.78<br>(229.94)           | 118.52<br>(627.12)           | <b>62.87</b> |
| 5      | <i>Atriplex amnicola</i>         | 16.11                       | 52.39<br>(225.20)           | 124.59<br>(673.35)           | <b>64.36</b> |
| 6      | <i>Atriplex lentiformis</i>      | 16.66                       | 53.59<br>(221.62)           | 125.35<br>(652.23)           | <b>65.20</b> |
| 7      | <i>Chenopodium ambrosoides</i>   | 6.76                        | 18.09<br>(167.60)           | 30.16<br>(346.20)            | <b>18.34</b> |
| 8      | <i>Suaeda fruticosa</i>          | 18.79                       | 56.27<br>(199.52)           | 126.91<br>(575.53)           | <b>67.32</b> |
| 9      | <i>Salicornia brachiata</i>      | 21.29                       | 94.83<br>(345.40)           | 130.45<br>(512.73)           | <b>82.19</b> |
| 10     | <i>Solanum xanthocarpum</i>      | 8.49                        | 27.57<br>(224.65)           | 50.26<br>(491.76)            | <b>28.78</b> |
| 11     | <i>Xanthium strumarium</i>       | 5.57                        | 19.10<br>(242.70)           | 32.11<br>(476.14)            | <b>18.93</b> |
| 12     | <i>Sesbania sesquens</i>         | 5.88                        | 16.20<br>(175.67)           | 30.27<br>(415.09)            | <b>17.45</b> |
| 13     | <i>Heliotropium procumbens</i>   | 6.49                        | 15.69<br>(141.76)           | 31.46<br>(384.75)            | <b>17.88</b> |
| 14     | <i>Parkinsonia aculeata</i>      | 6.18                        | 15.77<br>(155.04)           | 29.52<br>(377.41)            | <b>17.16</b> |
| 15     | <i>Calotropis procera</i>        | 6.17                        | 14.39<br>(133.23)           | 27.15<br>(340.03)            | <b>15.90</b> |
| 16     | <i>Prosopis juliflora</i>        | 5.94                        | 16.14<br>(171.77)           | 28.91<br>(386.70)            | <b>17.00</b> |
| 17     | <i>Arundo donax</i>              | 12.27                       | 41.26<br>(236.36)           | 78.74<br>(541.90)            | <b>44.09</b> |
| 18     | <i>Aleurops lagopoides</i>       | 9.87                        | 29.26<br>(196.45)           | 62.42<br>(532.42)            | <b>33.85</b> |
| 19     | <i>Cynodon dactylon</i>          | 8.16                        | 28.11<br>(244.34)           | 44.37<br>(443.49)            | <b>26.88</b> |
| 20     | <i>Setaria indica</i>            | 5.64                        | 17.59<br>(212.06)           | 32.24<br>(471.97)            | <b>18.49</b> |
|        | Mean                             | <b>11.15</b>                | <b>34.94</b>                | <b>71.09</b>                 |              |

**CD (P=0.05)** : Species(S) =5.933; Salinity levels (T) = 2.298; Interaction (SxT) = N.S.

Values given in parentheses ( ) show percent increase/decrease over respective controls

**Table 23: Na<sup>+</sup> content (mg g<sup>-1</sup> dry wt.) in leaves of different plants native to saline soils under various added salinity levels**

| S. No. | Name of Plant                    | S0<br>(0dSm <sup>-1</sup> ) | S1<br>(8dSm <sup>-1</sup> ) | S2<br>(16dSm <sup>-1</sup> ) | Mean          |
|--------|----------------------------------|-----------------------------|-----------------------------|------------------------------|---------------|
| 1      | <i>Portulaca oleracea</i>        | 30.11                       | 120.30<br>(299.49)          | 165.30<br>(448.93)           | <b>105.24</b> |
| 2      | <i>Trianthema portulacastrum</i> | 26.81                       | 118.16<br>(340.79)          | 161.74<br>(503.34)           | <b>102.23</b> |
| 3      | <i>Aerva tomentosa</i>           | 27.53                       | 116.06<br>(321.63)          | 149.09<br>(441.62)           | <b>97.56</b>  |
| 4      | <i>Atriplex nummularia</i>       | 33.39                       | 123.89<br>(271.08)          | 149.82<br>(348.73)           | <b>102.36</b> |
| 5      | <i>Atriplex amnicola</i>         | 32.53                       | 122.23<br>(275.75)          | 170.28<br>(423.46)           | <b>108.35</b> |
| 6      | <i>Atriplex lentiformis</i>      | 35.10                       | 125.29<br>(256.95)          | 173.62<br>(394.64)           | <b>111.34</b> |
| 7      | <i>Chenopodium ambrosoides</i>   | 15.13                       | 45.06<br>(197.82)           | 68.31<br>(351.47)            | <b>42.83</b>  |
| 8      | <i>Suaeda fruticosa</i>          | 36.19                       | 128.52<br>(255.13)          | 176.57<br>(387.90)           | <b>113.76</b> |
| 9      | <i>Salicornia brachiata</i>      | -                           | -                           | -                            | -             |
| 10     | <i>Solanum xanthocarpum</i>      | 22.16                       | 69.41<br>(213.24)           | 112.25<br>(406.54)           | <b>67.94</b>  |
| 11     | <i>Xanthium strumarium</i>       | 18.47                       | 41.19<br>(122.95)           | 77.15<br>(317.63)            | <b>45.60</b>  |
| 12     | <i>Sesbania sesquens</i>         | 18.29                       | 47.01<br>(157.03)           | 80.67<br>(341.04)            | <b>48.66</b>  |
| 13     | <i>Heliotropium procumbens</i>   | 19.65                       | 49.55<br>(152.18)           | 84.44<br>(329.70)            | <b>51.21</b>  |
| 14     | <i>Parkinsonia aculeata</i>      | 15.62                       | 40.07<br>(156.53)           | 72.83<br>(366.28)            | <b>42.84</b>  |
| 15     | <i>Calotropis procera</i>        | 14.09                       | 37.16<br>(163.80)           | 84.11<br>(388.81)            | <b>49.63</b>  |
| 16     | <i>Prosopis juliflora</i>        | 18.29                       | 41.23<br>(125.46)           | 89.39<br>(664.09)            | <b>51.45</b>  |
| 17     | <i>Arundo donax</i>              | 27.31                       | 105.74<br>(287.24)          | 125.72<br>(360.40)           | <b>86.26</b>  |
| 18     | <i>Aleurops lagopoides</i>       | 25.19                       | 64.64<br>(156.61)           | 86.27<br>(242.48)            | <b>58.70</b>  |
| 19     | <i>Cynodon dactylon</i>          | 19.26                       | 62.09<br>(222.32)           | 65.06<br>(237.74)            | <b>48.80</b>  |
| 20     | <i>Setaria indica</i>            | 13.08                       | 35.30<br>(169.88)           | 37.63<br>(187.72)            | <b>28.67</b>  |
|        | Mean                             | <b>23.55</b>                | <b>78.57</b>                | <b>112.15</b>                |               |

**CD (P=0.05):** Species(S) = 6.525; Salinity levels (T) = 2.593; Interaction (S x T) = 11.301

Values given in parentheses ( ) show percent increase/decrease over respective controls

**Table 24: Phytoaccumulation of Na<sup>+</sup> (mg /total dry wt. of plants in a pot) of different plants native to saline soils under various added salinity levels**

| S. No. | Name of Plant                    | S0<br>(0dSm <sup>-1</sup> ) | S1<br>(8dSm <sup>-1</sup> ) | S2<br>(16dSm <sup>-1</sup> ) | Mean           |
|--------|----------------------------------|-----------------------------|-----------------------------|------------------------------|----------------|
| 1      | <i>Portulaca oleracea</i>        | 176.85                      | 860.24<br>(386.42)          | 1370.59<br>(675.00)          | <b>802.56</b>  |
| 2      | <i>Trianthema portulacastrum</i> | 133.30                      | 665.93<br>(399.57)          | 1844.73<br>(1283.89)         | <b>881.32</b>  |
| 3      | <i>Aerva tomentosa</i>           | 186.54                      | 999.30<br>(435.70)          | 2178.41<br>(1067.80)         | <b>1121.42</b> |
| 4      | <i>Atriplex nummularia</i>       | 168.97                      | 746.27<br>(341.65)          | 792.48<br>(368.99)           | <b>569.24</b>  |
| 5      | <i>Atriplex amnicola</i>         | 123.38                      | 552.32<br>(347.65)          | 1245.02<br>(909.08)          | <b>640.24</b>  |
| 6      | <i>Atriplex lentiformis</i>      | 185.27                      | 841.30<br>(354.10)          | 1940.41<br>(947.36)          | <b>988.99</b>  |
| 7      | <i>Chenopodium ambrosoides</i>   | 95.54                       | 228.53<br>(139.21)          | 247.12<br>(158.66)           | <b>190.40</b>  |
| 8      | <i>Suaeda fruticosa</i>          | 217.25                      | 803.09<br>(269.66)          | 1555.68<br>(616.08)          | <b>858.67</b>  |
| 9      | <i>Salicornia brachiata</i>      | 32.27                       | 132.65<br>(311.01)          | 385.84<br>(1095.50)          | <b>183.59</b>  |
| 10     | <i>Solanum xanthocarpum</i>      | 58.93                       | 308.57<br>(423.60)          | 69.11<br>(17.28)             | <b>145.54</b>  |
| 11     | <i>Xanthium strumarium</i>       | 101.78                      | 117.67<br>(15.61)           | 176.49<br>(73.40)            | <b>131.98</b>  |
| 12     | <i>Sesbania sesquens</i>         | 138.92                      | 257.86<br>(85.62)           | 269.72<br>(94.16)            | <b>222.17</b>  |
| 13     | <i>Heliotropium procumbens</i>   | 54.56                       | 105.44<br>(93.25)           | 134.10<br>(145.79)           | <b>98.03</b>   |
| 14     | <i>Parkinsonia aculeata</i>      | 49.78                       | 87.86<br>(76.50)            | 105.79<br>(112.51)           | <b>81.14</b>   |
| 15     | <i>Calotropis procera</i>        | 71.13                       | 147.35<br>(107.15)          | 168.10<br>(136.33)           | <b>128.86</b>  |
| 16     | <i>Prosopis juliflora</i>        | 50.36                       | 99.76<br>(98.10)            | 126.59<br>(151.37)           | <b>92.24</b>   |
| 17     | <i>Arundo donax</i>              | 68.77                       | 302.26<br>(339.52)          | 498.44<br>(624.79)           | <b>273.43</b>  |
| 18     | <i>Aleurops lagopoides</i>       | 85.61                       | 271.13<br>(216.70)          | 470.59<br>(449.69)           | <b>449.69</b>  |
| 19     | <i>Cynodon dactylon</i>          | 69.05                       | 205.54<br>(197.65)          | 181.26<br>(162.49)           | <b>151.95</b>  |
| 20     | <i>Setaria indica</i>            | 66.26                       | 113.48<br>(71.26)           | 132.27<br>(99.61)            | <b>104.01</b>  |
|        | Mean                             | <b>106.76</b>               | <b>392.33</b>               | <b>692.86</b>                |                |

**CD (P=0.05) :** Species(S) =0.6546; Salinity levels (T) =0.2535; Interaction (SxT) = 1.134

Values given in parentheses ( ) show percent increase/decrease over respective controls

**Table 25: K<sup>+</sup> content ( $\mu\text{g g}^{-1}$  soil) in soil at harvesting of different plants native to saline soils under various added salinity levels**

| S. No.                   | Name of Plant                    | S0<br>(0dSm <sup>-1</sup> ) | S1<br>(8dSm <sup>-1</sup> ) | S2<br>(16dSm <sup>-1</sup> ) | Mean         |
|--------------------------|----------------------------------|-----------------------------|-----------------------------|------------------------------|--------------|
| <b>Before plantation</b> |                                  | <b>85.38</b>                | <b>83.57</b>                | <b>84.11</b>                 | <b>84.35</b> |
| 1                        | <i>Portulaca oleracea</i>        | 44.45                       | 56.55<br>(27.24)            | 69.10<br>(55.47)             | <b>56.70</b> |
| 2                        | <i>Trianthema portulacastrum</i> | 45.13                       | 55.23<br>(22.39)            | 71.34<br>(58.08)             | <b>57.23</b> |
| 3                        | <i>Aerva tomentosa</i>           | 45.97                       | 57.46<br>(24.98)            | 72.09<br>(56.81)             | <b>58.51</b> |
| 4                        | <i>Atriplex nummularia</i>       | 42.34                       | 49.34<br>(16.53)            | 67.76<br>(60.02)             | <b>53.15</b> |
| 5                        | <i>Atriplex amnicola</i>         | 43.77                       | 50.17<br>(14.62)            | 66.90<br>(52.85)             | <b>53.61</b> |
| 6                        | <i>Atriplex lentiformis</i>      | 42.30                       | 49.29<br>(16.52)            | 66.17<br>(56.44)             | <b>52.59</b> |
| 7                        | <i>Chenopodium ambrosoides</i>   | 40.19                       | 58.10<br>(44.56)            | 75.61<br>(88.12)             | <b>57.97</b> |
| 8                        | <i>Suaeda fruticosa</i>          | 45.13                       | 47.70<br>(5.69)             | 59.27<br>(31.32)             | <b>50.70</b> |
| 9                        | <i>Salicornia brachiata</i>      | 41.74                       | 44.73<br>(7.15)             | 55.11<br>(32.02)             | <b>47.19</b> |
| 10                       | <i>Solanum xanthocarpum</i>      | 44.18                       | 59.90<br>(35.58)            | 71.23<br>(61.21)             | <b>58.44</b> |
| 11                       | <i>Xanthium strumarium</i>       | 44.69                       | 61.30<br>(37.17)            | 73.19<br>(63.78)             | <b>59.73</b> |
| 12                       | <i>Sesbania sesquens</i>         | 48.88                       | 60.54<br>(23.86)            | 72.66<br>(48.65)             | <b>60.69</b> |
| 13                       | <i>Heliotropium procumbens</i>   | 44.00                       | 59.12<br>(34.36)            | 73.88<br>(67.90)             | <b>59.00</b> |
| 14                       | <i>Parkinsonia aculeata</i>      | 45.44                       | 60.10<br>(32.27)            | 71.30<br>(56.91)             | <b>58.95</b> |
| 15                       | <i>Calotropis procera</i>        | 47.07                       | 59.17<br>(25.70)            | 73.27<br>(55.66)             | <b>59.84</b> |
| 16                       | <i>Prosopis juliflora</i>        | 51.02                       | 63.12<br>(23.71)            | 71.41<br>(39.96)             | <b>61.85</b> |
| 17                       | <i>Arundo donax</i>              | 39.41                       | 54.07<br>(37.21)            | 66.02<br>(67.52)             | <b>53.17</b> |
| 18                       | <i>Aleurops lagopoides</i>       | 42.03                       | 55.94<br>(33.09)            | 67.31<br>(60.13)             | <b>55.09</b> |
| 19                       | <i>Cynodon dactylon</i>          | 46.72                       | 55.92<br>(19.70)            | 67.70<br>(44.91)             | <b>56.78</b> |
| 20                       | <i>Setaria indica</i>            | 50.26                       | 59.55<br>(18.48)            | 74.79<br>(48.81)             | <b>61.53</b> |
|                          | Mean                             | <b>44.74</b>                | <b>55.87</b>                | <b>69.31</b>                 |              |

**CD (P=0.05)** : Species(S) =5.934; Salinity levels (T) = 2.297; Interaction (SxT) = N.S.

Values given in parentheses ( ) show percent increase/decrease over respective controls

**Table 26: K<sup>+</sup> content (mg g<sup>-1</sup> dry wt.) in stem of different plants native to saline soils under various added salinity levels**

| S. No. | Name of Plant                    | S0<br>(0dSm <sup>-1</sup> ) | S1<br>(8dSm <sup>-1</sup> ) | S2<br>(16dSm <sup>-1</sup> ) | Mean         |
|--------|----------------------------------|-----------------------------|-----------------------------|------------------------------|--------------|
| 1      | <i>Portulaca oleracea</i>        | 17.79                       | 7.99<br>(-55.08)            | 7.39<br>(-58.49)             | <b>11.06</b> |
| 2      | <i>Trianthema portulacastrum</i> | 16.84                       | 7.71<br>(-55.08)            | 7.00<br>(-58.42)             | <b>10.52</b> |
| 3      | <i>Aerva tomentosa</i>           | 16.62                       | 7.16<br>(-56.91)            | 6.98<br>(-58.01)             | <b>10.26</b> |
| 4      | <i>Atriplex nummularia</i>       | 18.83                       | 9.52<br>(-49.46)            | 8.24<br>(-56.22)             | <b>12.20</b> |
| 5      | <i>Atriplex amnicola</i>         | 19.45                       | 8.86<br>(-54.46)            | 7.62<br>(-60.83)             | <b>11.98</b> |
| 6      | <i>Atriplex lentiformis</i>      | 18.35                       | 10.02<br>(-45.42)           | 8.27<br>(-54.94)             | <b>12.21</b> |
| 7      | <i>Chenopodium ambrosoides</i>   | 9.07                        | 7.29<br>(-19.63)            | 5.02<br>(-44.65)             | <b>7.13</b>  |
| 8      | <i>Suaeda fruticosa</i>          | 20.08                       | 16.31<br>(-18.77)           | 9.54<br>(-52.49)             | <b>15.31</b> |
| 9      | <i>Salicornia brachiata</i>      | 26.33                       | 13.92<br>(-47.14)           | 11.62<br>(-55.86)            | <b>17.29</b> |
| 10     | <i>Solanum xanthocarpum</i>      | 7.51                        | 5.63<br>(-24.99)            | 5.31<br>(-29.25)             | <b>6.15</b>  |
| 11     | <i>Xanthium strumarium</i>       | 6.93                        | 5.0<br>(-26.88)             | 4.13<br>(-40.43)             | <b>5.38</b>  |
| 12     | <i>Sesbania sesquens</i>         | 5.07                        | 4.12<br>(-18.80)            | 3.58<br>(-29.39)             | <b>4.26</b>  |
| 13     | <i>Heliotropium procumbens</i>   | 7.02                        | 5.24<br>(-25.40)            | 3.67<br>(-47.72)             | <b>5.31</b>  |
| 14     | <i>Parkinsonia aculeata</i>      | 7.56                        | 5.02<br>(-33.60)            | 3.23<br>(-57.28)             | <b>5.27</b>  |
| 15     | <i>Calotropis procera</i>        | 6.41                        | 4.39<br>(-31.51)            | 3.92<br>(-38.85)             | <b>4.91</b>  |
| 16     | <i>Prosopis juliflora</i>        | 7.07                        | 4.76<br>(-32.67)            | 3.69<br>(-47.81)             | <b>5.17</b>  |
| 17     | <i>Arundo donax</i>              | 9.24                        | 6.71<br>(-27.35)            | 6.17<br>(-33.16)             | <b>7.37</b>  |
| 18     | <i>Aleurops lagopoides</i>       | 8.68                        | 5.99<br>(-30.98)            | 5.78<br>(-33.40)             | <b>6.82</b>  |
| 19     | <i>Cynodon dactylon</i>          | 8.50                        | 5.31<br>(-37.53)            | 5.01<br>(-41.06)             | <b>6.27</b>  |
| 20     | <i>Setaria indica</i>            | 5.01                        | 3.67<br>(-26.75)            | 3.57<br>(-28.68)             | <b>4.08</b>  |
|        | Mean                             | <b>12.12</b>                | <b>7.23</b>                 | <b>5.99</b>                  |              |

**CD (P=0.05) :** Species(S) =5.113; Salinity levels (T) = 1.980; Interaction (SxT) = N.S.

Values given in parentheses ( ) show percent increase/decrease over respective controls

**Table 27: K<sup>+</sup> content (mg g<sup>-1</sup> dry wt.) in leaves of different plants native to saline soils under various added salinity levels**

| S. No. | Name of Plant                    | S0<br>(0dSm <sup>-1</sup> ) | S1<br>(8dSm <sup>-1</sup> ) | S2<br>(16dSm <sup>-1</sup> ) | Mean         |
|--------|----------------------------------|-----------------------------|-----------------------------|------------------------------|--------------|
| 1      | <i>Portulaca oleracea</i>        | 24.51                       | 16.11<br>(-34.29)           | 9.94<br>(-59.44)             | <b>16.85</b> |
| 2      | <i>Trianthema portulacastrum</i> | 23.02                       | 15.30<br>(-33.54)           | 9.69<br>(-57.92)             | <b>16.00</b> |
| 3      | <i>Aerva tomentosa</i>           | 22.24                       | 14.14<br>(-36.42)           | 9.22<br>(-58.56)             | <b>15.20</b> |
| 4      | <i>Atriplex nummularia</i>       | 26.39                       | 18.62<br>(-29.45)           | 10.75<br>(-59.25)            | <b>18.59</b> |
| 5      | <i>Atriplex amnicola</i>         | 25.35                       | 18.11<br>(-28.56)           | 11.12<br>(-56.12)            | <b>18.19</b> |
| 6      | <i>Atriplex lentiformis</i>      | 27.29                       | 19.19<br>(-29.70)           | 11.41<br>(-58.18)            | <b>19.30</b> |
| 7      | <i>Chenopodium ambrosoides</i>   | 15.13                       | 9.47<br>(-37.40)            | 6.22<br>(-58.90)             | <b>10.27</b> |
| 8      | <i>Suaeda fruticosa</i>          | 28.10                       | 19.27<br>(-31.41)           | 13.25<br>(-52.85)            | <b>20.21</b> |
| 9      | <i>Salicornia brachiata</i>      | -                           | -                           | -                            | -            |
| 10     | <i>Solanum xanthocarpum</i>      | 13.67                       | 10.03<br>(-26.61)           | 6.03<br>(-55.85)             | <b>9.91</b>  |
| 11     | <i>Xanthium strumarium</i>       | 10.31                       | 6.57<br>(-36.29)            | 5.60<br>(-45.67)             | <b>7.49</b>  |
| 12     | <i>Sesbania sesquens</i>         | 10.13                       | 6.56<br>(-35.30)            | 5.72<br>(-43.59)             | <b>7.47</b>  |
| 13     | <i>Heliotropium procumbens</i>   | 10.24                       | 5.68<br>(-44.56)            | 4.77<br>(-53.45)             | <b>6.89</b>  |
| 14     | <i>Parkinsonia aculeata</i>      | 10.54                       | 6.24<br>(-40.78)            | 5.47<br>(-48.09)             | <b>7.42</b>  |
| 15     | <i>Calotropis procera</i>        | 9.73                        | 6.09<br>(-37.41)            | 4.89<br>(-49.74)             | <b>6.90</b>  |
| 16     | <i>Prosopis juliflora</i>        | 9.85                        | 6.43<br>(-34.72)            | 4.79<br>(-51.37)             | <b>7.02</b>  |
| 17     | <i>Arundo donax</i>              | 15.51                       | 11.56<br>(-25.47)           | 6.57<br>(-57.61)             | <b>11.21</b> |
| 18     | <i>Aleurops lagopoides</i>       | 14.95                       | 9.13<br>(-38.93)            | 6.44<br>(-56.95)             | <b>10.17</b> |
| 19     | <i>Cynodon dactylon</i>          | 12.08                       | 6.98<br>(-42.23)            | 5.02<br>(-58.43)             | <b>8.02</b>  |
| 20     | <i>Setaria indica</i>            | 9.58                        | 6.20<br>(-35.30)            | 4.52<br>(-52.83)             | <b>6.77</b>  |
|        | Mean                             | <b>16.77</b>                | <b>11.14</b>                | <b>7.44</b>                  |              |

**CD (P=0.05):** Species(S) = 1.658; Salinity levels (T) = 0.659; Interaction (S x T) = 2.872

Values given in parentheses ( ) show percent increase/decrease over respective controls

**Table 28: Phytoaccumulation of K<sup>+</sup> (mg /total dry wt. of plants in a pot) of different plants native to saline soils under various added salinity levels**

| S. No. | Name of Plant                    | S0 (0dSm <sup>-1</sup> ) | S1 (8dSm <sup>-1</sup> ) | S2 (16dSm <sup>-1</sup> ) | Mean          |
|--------|----------------------------------|--------------------------|--------------------------|---------------------------|---------------|
| 1      | <i>Portulaca oleracea</i>        | 153.43                   | 122.83 (-19.94)          | 78.79 (-48.65)            | <b>118.35</b> |
| 2      | <i>Trianthema portulacastrum</i> | 131.27                   | 98.53 (-24.94)           | 112.50 (-14.30)           | <b>114.10</b> |
| 3      | <i>Aerva tomentosa</i>           | 174.85                   | 129.77 (-25.78)          | 131.03 (-25.06)           | <b>145.22</b> |
| 4      | <i>Atriplex nummularia</i>       | 147.91                   | 117.79 (-20.36)          | 56.61 (-61.72)            | <b>107.44</b> |
| 5      | <i>Atriplex amnicola</i>         | 110.63                   | 85.73 (-22.51)           | 80.13 (-27.57)            | <b>92.16</b>  |
| 6      | <i>Atriplex lentiformis</i>      | 162.79                   | 135.70 (-16.64)          | 125.91 (-22.66)           | <b>141.47</b> |
| 7      | <i>Chenopodium ambrosoides</i>   | 106.69                   | 62.27 (-41.64)           | 27.34 (-74.37)            | <b>65.43</b>  |
| 8      | <i>Suaeda fruticosa</i>          | 193.45                   | 284.16 (46.89)           | 117.43 (-39.29)           | <b>198.35</b> |
| 9      | <i>Salicornia brachiata</i>      | 35.23                    | 19.74 (-43.98)           | 34.71 (-1.48)             | <b>29.90</b>  |
| 10     | <i>Solanum xanthocarpum</i>      | 37.93                    | 47.47 (25.16)            | 3.97 (-89.53)             | <b>29.79</b>  |
| 11     | <i>Xanthium strumarium</i>       | 63.01                    | 20.42 (-67.60)           | 15.01 (-76.18)            | <b>32.81</b>  |
| 12     | <i>Sesbania sesquens</i>         | 88.05                    | 41.51 (-52.86)           | 21.72 (-75.34)            | <b>50.43</b>  |
| 13     | <i>Heliotropium procumbens</i>   | 35.05                    | 14.88 (-57.54)           | 8.49 (-75.77)             | <b>19.48</b>  |
| 14     | <i>Parkinsonia aculeata</i>      | 45.48                    | 19.23 (-57.71)           | 9.57 (-78.95)             | <b>24.76</b>  |
| 15     | <i>Calotropis procera</i>        | 54.53                    | 29.54 (-45.83)           | 13.20 (-75.80)            | <b>32.42</b>  |
| 16     | <i>Prosopis juliflora</i>        | 34.57                    | 19.07 (-44.85)           | 8.62 (-75.07)             | <b>20.75</b>  |
| 17     | <i>Arundo donax</i>              | 42.15                    | 37.39 (-11.29)           | 30.79 (-26.95)            | <b>36.77</b>  |
| 18     | <i>Aleurops lagopoides</i>       | 54.98                    | 42.11 (-23.41)           | 37.27 (-32.22)            | <b>44.79</b>  |
| 19     | <i>Cynodon dactylon</i>          | 55.08                    | 31.45 (-42.91)           | 17.14 (-68.88)            | <b>34.55</b>  |
| 20     | <i>Setaria indica</i>            | 51.12                    | 20.45 (-60.00)           | 15.94 (-68.82)            | <b>29.17</b>  |
|        | Mean                             | <b>88.91</b>             | <b>69.00</b>             | <b>47.21</b>              |               |

**CD (P=0.05) :** Species(S) =43.2327; Salinity levels (T) =16.7440; Interaction (SxT) = N.S

Values given in parentheses ( ) show percent increase/decrease over respective controls

**Table 29: Ca<sup>2+</sup> content ( $\mu\text{g g}^{-1}$  soil) in soil at harvesting of different plants native to saline soils under various added salinity levels**

| S. No.                   | Name of Plant                    | S0<br>(0dSm <sup>-1</sup> ) | S1<br>(8dSm <sup>-1</sup> ) | S2<br>(16dSm <sup>-1</sup> ) | Mean         |
|--------------------------|----------------------------------|-----------------------------|-----------------------------|------------------------------|--------------|
| <b>Before plantation</b> |                                  | <b>21.41</b>                | <b>62.45</b>                | <b>125.51</b>                | <b>69.79</b> |
| 1                        | <i>Portulaca oleracea</i>        | 16.58                       | 52.58<br>(217.13)           | 108.23<br>(552.77)           | <b>59.13</b> |
| 2                        | <i>Trianthema portulacastrum</i> | 16.51                       | 53.50<br>(223.98)           | 110.20<br>(567.34)           | <b>60.07</b> |
| 3                        | <i>Aerva tomentosa</i>           | 17.18                       | 54.20<br>(215.48)           | 111.74<br>(550.41)           | <b>61.04</b> |
| 4                        | <i>Atriplex nummularia</i>       | 15.19                       | 51.30<br>(237.80)           | 107.04<br>(604.83)           | <b>57.84</b> |
| 5                        | <i>Atriplex amnicola</i>         | 16.13                       | 50.87<br>(215.31)           | 108.10<br>(570.04)           | <b>58.37</b> |
| 6                        | <i>Atriplex lentiformis</i>      | 16.53                       | 50.65<br>(206.35)           | 107.63<br>(551.01)           | <b>58.27</b> |
| 7                        | <i>Chenopodium ambrosoides</i>   | 17.29                       | 55.10<br>(218.60)           | 114.15<br>(560.08)           | <b>62.18</b> |
| 8                        | <i>Suaeda fruticosa</i>          | 15.41                       | 48.50<br>(214.66)           | 106.35<br>(589.99)           | <b>56.75</b> |
| 9                        | <i>Salicornia brachiata</i>      | 12.70                       | 47.26<br>(272.03)           | 102.40<br>(706.09)           | <b>54.12</b> |
| 10                       | <i>Solanum xanthocarpum</i>      | 17.29                       | 54.43<br>(214.75)           | 115.86<br>(569.97)           | <b>62.53</b> |
| 11                       | <i>Xanthium strumarium</i>       | 17.82                       | 56.50<br>(217.00)           | 117.64<br>(560.03)           | <b>63.99</b> |
| 12                       | <i>Sesbania sesquens</i>         | 17.04                       | 56.59<br>(232.02)           | 118.69<br>(596.42)           | <b>64.11</b> |
| 13                       | <i>Heliotropium procumbens</i>   | 17.47                       | 58.36<br>(234.12)           | 114.00<br>(552.67)           | <b>63.28</b> |
| 14                       | <i>Parkinsonia aculeata</i>      | 17.02                       | 56.29<br>(230.81)           | 117.05<br>(587.87)           | <b>63.45</b> |
| 15                       | <i>Calotropis procera</i>        | 17.28                       | 57.79<br>(234.35)           | 118.34<br>(584.71)           | <b>64.47</b> |
| 16                       | <i>Prosopis juliflora</i>        | 17.14                       | 54.50<br>(217.97)           | 116.58<br>(580.16)           | <b>62.74</b> |
| 17                       | <i>Arundo donax</i>              | 14.61                       | 55.08<br>(277.09)           | 112.00<br>(666.80)           | <b>60.56</b> |
| 18                       | <i>Aelurops lagopoides</i>       | 15.23                       | 55.28<br>(262.89)           | 110.60<br>(626.04)           | <b>60.37</b> |
| 19                       | <i>Cynodon dactylon</i>          | 16.51                       | 54.81<br>(232.00)           | 113.68<br>(588.53)           | <b>61.67</b> |
| 20                       | <i>Setaria indica</i>            | 18.45                       | 57.88<br>(213.71)           | 118.66<br>(543.14)           | <b>65.00</b> |
|                          | Mean                             | <b>16.47</b>                | <b>54.07</b>                | <b>112.45</b>                |              |

**CD (P=0.05)** : Species(S) =3.57; Salinity levels (T) = 1.383; Interaction (SxT) = N.S.

Values given in parentheses ( ) show percent increase/decrease over respective controls

**Table 30: Ca<sup>2+</sup> content (mg g<sup>-1</sup> dry wt.) in stem of different plants native to saline soils under various added salinity levels**

| S. No. | Name of Plant                    | S0<br>(0dSm <sup>-1</sup> ) | S1<br>(8dSm <sup>-1</sup> ) | S2<br>(16dSm <sup>-1</sup> ) | Mean         |
|--------|----------------------------------|-----------------------------|-----------------------------|------------------------------|--------------|
| 1      | <i>Portulaca oleracea</i>        | 5.83                        | 4.63<br>(-20.57)            | 3.15<br>(-46.00)             | <b>4.54</b>  |
| 2      | <i>Trianthema portulacastrum</i> | 5.32                        | 4.48<br>(-15.73)            | 3.00<br>(-43.61)             | <b>4.27</b>  |
| 3      | <i>Aerva tomentosa</i>           | 5.15                        | 4.32<br>(-16.17)            | 2.76<br>(-46.44)             | <b>4.08</b>  |
| 4      | <i>Atriplex nummularia</i>       | 6.48                        | 5.51<br>(-14.97)            | 3.43<br>(-47.07)             | <b>5.14</b>  |
| 5      | <i>Atriplex amnicola</i>         | 6.10                        | 4.83<br>(-20.82)            | 3.12<br>(-48.85)             | <b>4.68</b>  |
| 6      | <i>Atriplex lentiformis</i>      | 7.18                        | 6.05<br>(-15.78)            | 4.29<br>(-40.28)             | <b>5.84</b>  |
| 7      | <i>Chenopodium ambrosoides</i>   | 4.03                        | 3.44<br>(-14.64)            | 2.17<br>(-46.15)             | <b>3.21</b>  |
| 8      | <i>Suaeda fruticosa</i>          | 7.25                        | 6.67<br>(-8.00)             | 4.85<br>(-33.13)             | <b>6.26</b>  |
| 9      | <i>Salicornia brachiata</i>      | 13.64                       | 9.16<br>(-32.83)            | 7.40<br>(-45.73)             | <b>10.07</b> |
| 10     | <i>Solanum xanthocarpum</i>      | 4.33                        | 3.72<br>(-14.09)            | 2.71<br>(-37.41)             | <b>3.59</b>  |
| 11     | <i>Xanthium strumarium</i>       | 3.28                        | 3.14<br>(-4.27)             | 2.15<br>(-34.45)             | <b>2.86</b>  |
| 12     | <i>Sesbania sesquens</i>         | 3.48                        | 3.08<br>(-11.48)            | 2.13<br>(-38.85)             | <b>2.90</b>  |
| 13     | <i>Heliotropium procumbens</i>   | 3.95                        | 3.23<br>(-18.21)            | 2.49<br>(-37.02)             | <b>3.23</b>  |
| 14     | <i>Parkinsonia aculeata</i>      | 3.55                        | 2.26<br>(-36.30)            | 1.86<br>(-47.65)             | <b>2.56</b>  |
| 15     | <i>Calotropis procera</i>        | 3.96                        | 2.11<br>(-46.72)            | 1.72<br>(-56.57)             | <b>2.60</b>  |
| 16     | <i>Prosopis juliflora</i>        | 3.61                        | 2.47<br>(-31.58)            | 1.60<br>(-55.68)             | <b>2.56</b>  |
| 17     | <i>Arundo donax</i>              | 5.50                        | 4.29<br>(-21.94)            | 2.59<br>(-52.91)             | <b>4.13</b>  |
| 18     | <i>Aleurops lagopoides</i>       | 5.23                        | 4.00<br>(-23.52)            | 2.51<br>(-51.94)             | <b>3.91</b>  |
| 19     | <i>Cynodon dactylon</i>          | 4.72                        | 3.64<br>(-22.81)            | 2.35<br>(-50.21)             | <b>3.57</b>  |
| 20     | <i>Setaria indica</i>            | 3.15                        | 2.04<br>(-35.13)            | 1.58<br>(-49.84)             | <b>2.26</b>  |
|        | Mean                             | <b>5.29</b>                 | <b>4.16</b>                 | <b>2.89</b>                  |              |

**CD (P=0.05) :** Species(S) =0.723; Salinity levels (T) = 0.283; Interaction (SxT) = 1.264

Values given in parentheses ( ) show percent increase/decrease over respective controls

**Table 31: Ca<sup>2+</sup> content (mg g<sup>-1</sup> dry wt.) in leaves of different plants native to saline soils under various added salinity levels**

| S. No. | Name of Plant                    | S0<br>(0dSm <sup>-1</sup> ) | S1<br>(8dSm <sup>-1</sup> ) | S2<br>(16dSm <sup>-1</sup> ) | Mean         |
|--------|----------------------------------|-----------------------------|-----------------------------|------------------------------|--------------|
| 1      | <i>Portulaca oleracea</i>        | 10.56                       | 8.57<br>(-18.88)            | 6.71<br>(-36.49)             | <b>8.61</b>  |
| 2      | <i>Trianthema portulacastrum</i> | 9.66                        | 7.28<br>(-24.67)            | 6.64<br>(-31.33)             | <b>7.86</b>  |
| 3      | <i>Aerva tomentosa</i>           | 9.00                        | 7.00<br>(-22.22)            | 6.15<br>(-31.67)             | <b>7.38</b>  |
| 4      | <i>Atriplex nummularia</i>       | 12.70                       | 9.28<br>(-26.93)            | 6.88<br>(-45.83)             | <b>9.62</b>  |
| 5      | <i>Atriplex amnicola</i>         | 11.14                       | 8.73<br>(-21.58)            | 6.86<br>(-38.37)             | <b>8.91</b>  |
| 6      | <i>Atriplex lentiformis</i>      | 13.00                       | 9.49<br>(-27.00)            | 7.42<br>(-42.92)             | <b>9.97</b>  |
| 7      | <i>Chenopodium ambrosoides</i>   | 8.13                        | 6.00<br>(-26.24)            | 5.16<br>(-36.53)             | <b>6.43</b>  |
| 8      | <i>Suaeda fruticosa</i>          | 15.70                       | 10.60<br>(-32.51)           | 8.42<br>(-46.37)             | <b>11.57</b> |
| 9      | <i>Salicornia brachiata</i>      | -                           | -                           | -                            | -            |
| 10     | <i>Solanum xanthocarpum</i>      | 6.79                        | 5.95<br>(-12.37)            | 4.83<br>(-28.82)             | <b>5.86</b>  |
| 11     | <i>Xanthium strumarium</i>       | 5.44                        | 4.73<br>(-13.05)            | 3.46<br>(-36.34)             | <b>4.54</b>  |
| 12     | <i>Sesbania sesquens</i>         | 6.40                        | 5.14<br>(-19.69)            | 3.91<br>(-38.85)             | <b>5.15</b>  |
| 13     | <i>Heliotropium procumbens</i>   | 6.36                        | 5.46<br>(-14.15)            | 4.03<br>(-36.58)             | <b>5.28</b>  |
| 14     | <i>Parkinsonia aculeata</i>      | 5.82                        | 4.73<br>(-18.73)            | 3.48<br>(-40.21)             | <b>4.68</b>  |
| 15     | <i>Calotropis procera</i>        | 6.00                        | 5.30<br>(-11.67)            | 3.82<br>(-36.39)             | <b>5.04</b>  |
| 16     | <i>Prosopis juliflora</i>        | 6.32                        | 4.56<br>(-27.85)            | 4.12<br>(-34.76)             | <b>5.00</b>  |
| 17     | <i>Arundo donax</i>              | 8.06                        | 6.80<br>(-15.59)            | 4.97<br>(-38.30)             | <b>6.61</b>  |
| 18     | <i>Aleurops lagopoides</i>       | 7.70                        | 6.19<br>(-19.69)            | 4.50<br>(-41.63)             | <b>6.13</b>  |
| 19     | <i>Cynodon dactylon</i>          | 7.49                        | 4.92<br>(-34.31)            | 4.55<br>(-39.30)             | <b>5.65</b>  |
| 20     | <i>Setaria indica</i>            | 5.16                        | 3.33<br>(-35.47)            | 2.77<br>(-46.32)             | <b>3.75</b>  |
|        | Mean                             | <b>8.50</b>                 | <b>6.53</b>                 | <b>5.19</b>                  |              |

**CD (P=0.05):** Species(S) = 0.874; Salinity levels (T) = 0.347; Interaction (S x T) = 1.514

Values given in parentheses ( ) show percent increase/decrease over respective controls

**Table 32: Phytoaccumulation of Ca<sup>+</sup> (mg / total dry wt. of plants in a pot) of different plants native to saline soils under various added salinity levels**

| S. No. | Name of Plant                    | S0<br>(0dSm <sup>-1</sup> ) | S1<br>(8dSm <sup>-1</sup> ) | S2<br>(16dSm <sup>-1</sup> ) | Mean         |
|--------|----------------------------------|-----------------------------|-----------------------------|------------------------------|--------------|
| 1      | <i>Portulaca oleracea</i>        | 63.77                       | 63.31<br>(-0.72)            | 53.94<br>(-15.41)            | <b>60.34</b> |
| 2      | <i>Trianthema portulacastrum</i> | 49.08                       | 49.80<br>(1.47)             | 66.11<br>(34.69)             | <b>55.00</b> |
| 3      | <i>Aerva tomentosa</i>           | 63.94                       | 71.96<br>(12.54)            | 70.82<br>(10.77)             | <b>68.90</b> |
| 4      | <i>Atriplex nummularia</i>       | 65.60                       | 60.00<br>(-8.53)            | 29.02<br>(-55.77)            | <b>51.54</b> |
| 5      | <i>Atriplex amnicola</i>         | 44.75                       | 41.68<br>(-6.86)            | 44.58<br>(-0.39)             | <b>43.67</b> |
| 6      | <i>Atriplex lentiformis</i>      | 72.13                       | 71.14<br>(-1.38)            | 73.42<br>(1.79)              | <b>72.23</b> |
| 7      | <i>Chenopodium ambrosoides</i>   | 52.69                       | 35.08<br>(-33.42)           | 18.55<br>(-64.80)            | <b>35.44</b> |
| 8      | <i>Suaeda fruticosa</i>          | 90.28                       | 76.66<br>(-15.08)           | 70.06<br>(-22.40)            | <b>79.00</b> |
| 9      | <i>Salicornia brachiata</i>      | 18.14                       | 13.03<br>(-28.15)           | 21.90<br>(20.76)             | <b>17.69</b> |
| 10     | <i>Solanum xanthocarpum</i>      | 19.93                       | 29.73<br>(49.19)            | 3.16<br>(-84.14)             | <b>17.61</b> |
| 11     | <i>Xanthium strumarium</i>       | 33.04                       | 14.36<br>(-56.54)           | 9.16<br>(-72.27)             | <b>18.85</b> |
| 12     | <i>Sesbania sesquens</i>         | 56.08                       | 31.41<br>(-44.00)           | 14.03<br>(-74.98)            | <b>33.84</b> |
| 13     | <i>Heliotropium procumbens</i>   | 20.86                       | 13.35<br>(-35.99)           | 6.67<br>(-68.04)             | <b>13.63</b> |
| 14     | <i>Parkinsonia aculeata</i>      | 22.64                       | 10.86<br>(-52.04)           | 5.93<br>(-73.81)             | <b>13.14</b> |
| 15     | <i>Calotropis procera</i>        | 34.14                       | 21.20<br>(-37.92)           | 7.67<br>(-77.53)             | <b>21.00</b> |
| 16     | <i>Prosopis juliflora</i>        | 20.26                       | 11.99<br>(-40.84)           | 5.99<br>(-70.46)             | <b>12.74</b> |
| 17     | <i>Arundo donax</i>              | 22.63                       | 23.30<br>(2.94)             | 20.36<br>(-10.06)            | <b>22.10</b> |
| 18     | <i>Aleurops lagopoides</i>       | 29.59                       | 28.80<br>(-2.68)            | 20.89<br>(-29.42)            | <b>26.42</b> |
| 19     | <i>Cynodon dactylon</i>          | 32.72                       | 21.91<br>(-33.04)           | 10.78<br>(-67.06)            | <b>21.81</b> |
| 20     | <i>Setaria indica</i>            | 29.26                       | 10.89<br>(-62.79)           | 9.08<br>(-68.96)             | <b>16.41</b> |
|        | Mean                             | <b>42.08</b>                | <b>35.02</b>                | <b>28.04</b>                 |              |

**CD (P=0.05) :** Species(S) =14.5613; Salinity levels (T) =5.6396; Interaction (SxT) = N.S.

Values given in parentheses ( ) show percent increase/decrease over respective controls

**Table 33: Mg<sup>2+</sup> content (µg g<sup>-1</sup> soil) in soil after harvesting of different plants native to saline soils under various added salinity levels**

| S. No.                   | Name of Plant                    | S0<br>(0dSm <sup>-1</sup> ) | S1<br>(8dSm <sup>-1</sup> ) | S2<br>(16dSm <sup>-1</sup> ) | Mean          |
|--------------------------|----------------------------------|-----------------------------|-----------------------------|------------------------------|---------------|
| <b>Before plantation</b> |                                  | <b>50.19</b>                | <b>110.410</b>              | <b>208.44</b>                | <b>123.01</b> |
| 1                        | <i>Portulaca oleracea</i>        | 36.29                       | 91.47<br>(152.05)           | 190.17<br>(424.02)           | <b>105.98</b> |
| 2                        | <i>Trianthema portulacastrum</i> | 37.20                       | 93.30<br>(150.81)           | 191.07<br>(413.63)           | <b>107.19</b> |
| 3                        | <i>Aerva tomentosa</i>           | 38.33                       | 94.30<br>(146.02)           | 193.52<br>(404.88)           | <b>108.72</b> |
| 4                        | <i>Atriplex nummularia</i>       | 34.30                       | 90.09<br>(162.65)           | 195.61<br>(470.30)           | <b>106.67</b> |
| 5                        | <i>Atriplex amnicola</i>         | 35.13                       | 91.46<br>(160.35)           | 187.88<br>(434.81)           | <b>104.82</b> |
| 6                        | <i>Atriplex lentiformis</i>      | 34.27                       | 89.25<br>(160.46)           | 186.46<br>(444.14)           | <b>103.33</b> |
| 7                        | <i>Chenopodium ambrosoides</i>   | 42.33                       | 97.09<br>(129.36)           | 200.04<br>(372.57)           | <b>113.15</b> |
| 8                        | <i>Suaeda fruticosa</i>          | 33.33                       | 88.14<br>(164.45)           | 184.65<br>(454.02)           | <b>102.04</b> |
| 9                        | <i>Salicornia brachiata</i>      | 32.30                       | 87.04<br>(169.47)           | 182.03<br>(463.55)           | <b>100.46</b> |
| 10                       | <i>Solanum xanthocarpum</i>      | 39.24                       | 98.25<br>(150.38)           | 197.24<br>(402.65)           | <b>111.58</b> |
| 11                       | <i>Xanthium strumarium</i>       | 42.41                       | 96.20<br>(126.83)           | 199.15<br>(369.58)           | <b>112.59</b> |
| 12                       | <i>Sesbania sesquens</i>         | 44.40                       | 99.10<br>(123.20)           | 198.57<br>(347.24)           | <b>114.02</b> |
| 13                       | <i>Heliotropium procumbens</i>   | 42.34                       | 94.25<br>(122.60)           | 197.41<br>(366.24)           | <b>111.33</b> |
| 14                       | <i>Parkinsonia aculeata</i>      | 42.37                       | 96.30<br>(127.28)           | 200.14<br>(372.36)           | <b>112.94</b> |
| 15                       | <i>Calotropis procera</i>        | 44.22                       | 105.30<br>(138.13)          | 198.27<br>(348.37)           | <b>115.93</b> |
| 16                       | <i>Prosopis juliflora</i>        | 43.31                       | 98.27<br>(126.88)           | 197.81<br>(356.69)           | <b>113.13</b> |
| 17                       | <i>Arundo donax</i>              | 36.33                       | 94.30<br>(159.57)           | 195.04<br>(436.86)           | <b>108.56</b> |
| 18                       | <i>Aleurops lagopoides</i>       | 36.01                       | 95.24<br>(164.51)           | 195.36<br>(442.57)           | <b>108.87</b> |
| 19                       | <i>Cynodon dactylon</i>          | 37.06                       | 96.20<br>(159.58)           | 196.28<br>(429.63)           | <b>109.85</b> |
| 20                       | <i>Setaria indica</i>            | 45.34                       | 102.03<br>(125.03)          | 199.48<br>(339.96)           | <b>115.62</b> |
|                          | Mean                             | <b>38.82</b>                | <b>94.88</b>                | <b>194.31</b>                |               |

**CD (P=0.05) :** Species(S) =9.146; Salinity levels (T) =3.542; Interaction (SxT) = N.S.

Values given in parentheses ( ) show percent increase/decrease over respective controls

**Table 34: Mg<sup>2+</sup> content (mg g<sup>-1</sup> dry wt.) in stem of different plants native to saline soils under various added salinity levels**

| S. No. | Name of Plant                    | S0<br>(0dSm <sup>-1</sup> ) | S1<br>(8dSm <sup>-1</sup> ) | S2<br>(16dSm <sup>-1</sup> ) | Mean         |
|--------|----------------------------------|-----------------------------|-----------------------------|------------------------------|--------------|
| 1      | <i>Portulaca oleracea</i>        | 25.20                       | 16.30<br>(-35.32)           | 11.14<br>(-55.79)            | <b>17.55</b> |
| 2      | <i>Trianthema portulacastrum</i> | 23.11                       | 17.28<br>(-25.23)           | 10.50<br>(-54.57)            | <b>16.96</b> |
| 3      | <i>Aerva tomentosa</i>           | 21.16                       | 16.22<br>(-23.35)           | 9.83<br>(-53.54)             | <b>15.74</b> |
| 4      | <i>Atriplex nummularia</i>       | 26.28                       | 19.13<br>(-27.21)           | 13.64<br>(-48.10)            | <b>19.68</b> |
| 5      | <i>Atriplex amnicola</i>         | 25.16                       | 18.36<br>(-27.03)           | 12.26<br>(-51.27)            | <b>18.59</b> |
| 6      | <i>Atriplex lentiformis</i>      | 28.25                       | 20.37<br>(-27.89)           | 14.40<br>(-49.03)            | <b>21.01</b> |
| 7      | <i>Chenopodium ambrosoides</i>   | 16.20                       | 9.15<br>(-43.52)            | 8.32<br>(-48.66)             | <b>11.22</b> |
| 8      | <i>Suaeda fruticosa</i>          | 35.25                       | 23.25<br>(-34.04)           | 20.81<br>(-40.96)            | <b>26.44</b> |
| 9      | <i>Salicornia brachiata</i>      | 40.12                       | 28.30<br>(-29.46)           | 22.58<br>(-43.72)            | <b>30.33</b> |
| 10     | <i>Solanum xanthocarpum</i>      | 17.06                       | 13.30<br>(-22.04)           | 10.13<br>(-40.62)            | <b>13.50</b> |
| 11     | <i>Xanthium strumarium</i>       | 12.25                       | 8.14<br>(-33.55)            | 7.35<br>(-40.00)             | <b>9.25</b>  |
| 12     | <i>Sesbania sesquens</i>         | 14.31                       | 8.32<br>(-41.86)            | 7.24<br>(-49.41)             | <b>9.96</b>  |
| 13     | <i>Heliotropium procumbens</i>   | 15.09                       | 9.09<br>(-39.76)            | 7.87<br>(-47.85)             | <b>10.68</b> |
| 14     | <i>Parkinsonia aculeata</i>      | 16.33                       | 7.34<br>(-55.08)            | 6.91<br>(-57.69)             | <b>10.19</b> |
| 15     | <i>Calotropis procera</i>        | 14.25                       | 8.07<br>(-43.37)            | 7.25<br>(-49.12)             | <b>9.86</b>  |
| 16     | <i>Prosopis juliflora</i>        | 17.15                       | 8.30<br>(-51.60)            | 7.56<br>(-55.92)             | <b>11.00</b> |
| 17     | <i>Arundo donax</i>              | 21.25                       | 15.16<br>(-28.66)           | 9.65<br>(-54.59)             | <b>15.35</b> |
| 18     | <i>Aleurops lagopoides</i>       | 19.07                       | 14.23<br>(-25.38)           | 9.14<br>(-52.07)             | <b>14.15</b> |
| 19     | <i>Cynodon dactylon</i>          | 17.36                       | 13.30<br>(-23.39)           | 9.00<br>(-48.16)             | <b>13.22</b> |
| 20     | <i>Setaria indica</i>            | 11.25                       | 8.17<br>(-27.38)            | 6.24<br>(-44.53)             | <b>8.55</b>  |
|        | Mean                             | <b>20.80</b>                | <b>13.99</b>                | <b>10.59</b>                 |              |

**CD (P=0.05)** : Species(S) =4.149; Salinity levels (T) =1.607; Interaction (SxT) = 7.186

Values given in parentheses ( ) show percent increase/decrease over respective controls

**Table 35: Mg<sup>2+</sup> content (mg g<sup>-1</sup> dry wt.) in leaves of different plants native to saline soils under various added salinity levels**

| S. No. | Name of Plant                    | S0<br>(0dSm <sup>-1</sup> ) | S1<br>(8dSm <sup>-1</sup> ) | S2<br>(16dSm <sup>-1</sup> ) | Mean         |
|--------|----------------------------------|-----------------------------|-----------------------------|------------------------------|--------------|
| 1      | <i>Portulaca oleracea</i>        | 30.60                       | 23.42<br>(-23.46)           | 19.70<br>(-35.62)            | <b>24.57</b> |
| 2      | <i>Trianthema portulacastrum</i> | 28.22                       | 22.50<br>(-20.27)           | 19.11<br>(-32.29)            | <b>23.28</b> |
| 3      | <i>Aerva tomentosa</i>           | 27.14                       | 21.04<br>(-22.49)           | 18.55<br>(-31.66)            | <b>22.24</b> |
| 4      | <i>Atriplex nummularia</i>       | 32.27                       | 24.36<br>(-24.50)           | 20.50<br>(-36.47)            | <b>25.71</b> |
| 5      | <i>Atriplex amnicola</i>         | 34.06                       | 25.05<br>(-26.45)           | 20.46<br>(-39.94)            | <b>26.52</b> |
| 6      | <i>Atriplex lentiformis</i>      | 36.72                       | 26.03<br>(-29.10)           | 21.68<br>(-40.97)            | <b>28.14</b> |
| 7      | <i>Chenopodium ambrosoides</i>   | 25.80                       | 17.6<br>(-31.59)            | 16.46<br>(-36.20)            | <b>19.97</b> |
| 8      | <i>Suaeda fruticosa</i>          | 41.35                       | 30.12<br>(-27.16)           | 22.92<br>(-44.56)            | <b>31.46</b> |
| 9      | <i>Salicornia brachiata</i>      | -                           | -                           | -                            | -            |
| 10     | <i>Solanum xanthocarpum</i>      | 23.50                       | 19.75<br>(-15.96)           | 16.18<br>(-31.16)            | <b>19.81</b> |
| 11     | <i>Xanthium strumarium</i>       | 20.25                       | 16.40<br>(-19.01)           | 15.40<br>(-23.97)            | <b>17.35</b> |
| 12     | <i>Sesbania sesquens</i>         | 21.76                       | 17.25<br>(-20.73)           | 15.38<br>(-29.30)            | <b>18.13</b> |
| 13     | <i>Heliotropium procumbens</i>   | 19.85                       | 16.36<br>(-17.58)           | 16.16<br>(-18.61)            | <b>17.46</b> |
| 14     | <i>Parkinsonia aculeata</i>      | 20.59                       | 17.38<br>(-15.59)           | 15.42<br>(-25.09)            | <b>17.80</b> |
| 15     | <i>Calotropis procera</i>        | 21.41                       | 17.60<br>(-17.80)           | 14.72<br>(-31.23)            | <b>17.91</b> |
| 16     | <i>Prosopis juliflora</i>        | 20.45                       | 15.93<br>(-22.13)           | 14.46<br>(-29.29)            | <b>16.95</b> |
| 17     | <i>Arundo donax</i>              | 26.05                       | 20.79<br>(-20.20)           | 17.37<br>(-33.33)            | <b>21.40</b> |
| 18     | <i>Aleurops lagopoides</i>       | 25.63                       | 19.82<br>(-22.68)           | 16.44<br>(-35.87)            | <b>20.63</b> |
| 19     | <i>Cynodon dactylon</i>          | 23.17                       | 18.40<br>(-20.59)           | 15.01<br>(-35.20)            | <b>18.86</b> |
| 20     | <i>Setaria indica</i>            | 19.35                       | 17.97<br>(-7.11)            | 14.27<br>(-26.27)            | <b>17.20</b> |
|        | Mean                             | <b>26.22</b>                | <b>20.41</b>                | <b>17.38</b>                 |              |

**CD (P=0.05):** Species(S) = 2.902; Salinity levels (T) = 1.153; Interaction (S x T) = N.S.

Values given in parentheses ( ) show percent increase/decrease over respective controls

**Table 36: Phytoaccumulation of Mg<sup>+</sup> (mg / total dry wt. of plants in a pot) of different plants native to saline soils under various added salinity levels**

| S. No. | Name of Plant                    | S0<br>(0dSm <sup>-1</sup> ) | S1<br>(8dSm <sup>-1</sup> ) | S2<br>(16dSm <sup>-1</sup> ) | Mean          |
|--------|----------------------------------|-----------------------------|-----------------------------|------------------------------|---------------|
| 1      | <i>Portulaca oleracea</i>        | 196.46                      | 181.31<br>(-7.71)           | 160.63<br>(-18.24)           | <b>179.47</b> |
| 2      | <i>Trianthema portulacastrum</i> | 173.24                      | 170.27<br>(-1.72)           | 186.88<br>(7.87)             | <b>176.80</b> |
| 3      | <i>Aerva tomentosa</i>           | 219.20                      | 249.99<br>(14.05)           | 229.85<br>(4.86)             | <b>233.01</b> |
| 4      | <i>Atriplex nummularia</i>       | 186.94                      | 172.54<br>(-7.71)           | 99.28<br>(-46.89)            | <b>152.92</b> |
| 5      | <i>Atriplex amnicola</i>         | 149.06                      | 132.75<br>(-10.94)          | 142.18<br>(-4.61)            | <b>141.33</b> |
| 6      | <i>Atriplex lentiformis</i>      | 232.53                      | 216.11<br>(-7.06)           | 237.63<br>(2.19)             | <b>228.76</b> |
| 7      | <i>Chenopodium ambrosoides</i>   | 187.39                      | 99.30<br>(-47.01)           | 61.30<br>(-67.29)            | <b>116.00</b> |
| 8      | <i>Suaeda fruticosa</i>          | 310.02                      | 231.37<br>(-25.37)          | 233.48<br>(-24.69)           | <b>258.29</b> |
| 9      | <i>Salicornia brachiata</i>      | 53.43                       | 39.87<br>(-25.39)           | 67.15<br>(25.67)             | <b>53.48</b>  |
| 10     | <i>Solanum xanthocarpum</i>      | 72.38                       | 96.80<br>(33.74)            | 10.57<br>(-85.40)            | <b>59.91</b>  |
| 11     | <i>Xanthium strumarium</i>       | 122.36                      | 47.79<br>(-60.94)           | 37.38<br>(-69.45)            | <b>69.18</b>  |
| 12     | <i>Sesbania sesquens</i>         | 205.99                      | 101.23<br>(-50.86)          | 52.75<br>(-74.39)            | <b>119.99</b> |
| 13     | <i>Heliotropium procumbens</i>   | 69.75                       | 39.53<br>(-43.32)           | 27.12<br>(-61.12)            | <b>45.47</b>  |
| 14     | <i>Parkinsonia aculeata</i>      | 95.61                       | 38.50<br>(-59.73)           | 23.99<br>(-74.91)            | <b>52.70</b>  |
| 15     | <i>Calotropis procera</i>        | 122.64                      | 68.43<br>(-44.21)           | 33.54<br>(-72.65)            | <b>74.87</b>  |
| 16     | <i>Prosopis juliflora</i>        | 77.24                       | 40.86<br>(-47.10)           | 24.54<br>(-68.22)            | <b>47.54</b>  |
| 17     | <i>Arundo donax</i>              | 77.93                       | 74.08<br>(-4.94)            | 69.12<br>(-11.30)            | <b>73.71</b>  |
| 18     | <i>Aleurops lagopoides</i>       | 103.27                      | 90.19<br>(-12.67)           | 86.23<br>(-16.50)            | <b>93.23</b>  |
| 19     | <i>Cynodon dactylon</i>          | 107.05                      | 80.94<br>(-24.38)           | 39.22<br>(-63.36)            | <b>75.74</b>  |
| 20     | <i>Setaria indica</i>            | 108.26                      | 56.39<br>(-47.91)           | 41.99<br>(-61.21)            | <b>68.88</b>  |
|        | Mean                             | <b>143.54</b>               | <b>111.41</b>               | <b>93.13</b>                 |               |

**CD (P=0.05) :** Species(S) =47.3328; Salinity levels (T) =18.3319; Interaction (SxT) = N.S.

Values given in parentheses ( ) show percent increase/decrease over respective controls

**Table 37: Cl<sup>-</sup> content ( $\mu\text{g g}^{-1}$  soil) in soil after harvesting of different plants native to saline soils under various added salinity levels**

| S. No.                   | Name of Plant                    | S0<br>(0dSm <sup>-1</sup> ) | S1<br>(8dSm <sup>-1</sup> ) | S2<br>(16dSm <sup>-1</sup> ) | Mean          |
|--------------------------|----------------------------------|-----------------------------|-----------------------------|------------------------------|---------------|
| <b>Before plantation</b> |                                  | <b>44.48</b>                | <b>556.68</b>               | <b>1110.17</b>               | <b>570.44</b> |
| 1                        | <i>Portulaca oleracea</i>        | 34.18                       | 492.37<br>(1340.52)         | 1057.13<br>(2992.83)         | <b>527.89</b> |
| 2                        | <i>Trianthema portulacastrum</i> | 34.19                       | 495.18<br>(1348.32)         | 1060.53<br>(3001.87)         | <b>529.97</b> |
| 3                        | <i>Aerva tomentosa</i>           | 35.22                       | 498.30<br>(1314.82)         | 1062.39<br>(2916.44)         | <b>531.97</b> |
| 4                        | <i>Atriplex nummularia</i>       | 33.11                       | 488.69<br>(1375.96)         | 1052.62<br>(3079.16)         | <b>524.81</b> |
| 5                        | <i>Atriplex amnicola</i>         | 32.22                       | 491.42<br>(1425.20)         | 1050.17<br>(3159.37)         | <b>524.60</b> |
| 6                        | <i>Atriplex lentiformis</i>      | 32.36                       | 490.28<br>(1415.08)         | 1049.65<br>(3143.67)         | <b>524.10</b> |
| 7                        | <i>Chenopodium ambrosoides</i>   | 34.33                       | 528.16<br>(1438.48)         | 1066.26<br>(3005.91)         | <b>542.92</b> |
| 8                        | <i>Suaeda fruticosa</i>          | 34.32                       | 484.29<br>(1311.10)         | 1040.34<br>(2931.29)         | <b>519.65</b> |
| 9                        | <i>Salicornia brachiata</i>      | 30.31                       | 486.37<br>(1504.65)         | 1032.26<br>(3305.67)         | <b>516.31</b> |
| 10                       | <i>Solanum xanthocarpum</i>      | 37.09                       | 501.61<br>(1252.41)         | 1062.33<br>(2764.20)         | <b>533.68</b> |
| 11                       | <i>Xanthium strumarium</i>       | 40.29                       | 480.12<br>(1091.65)         | 1067.35<br>(2549.17)         | <b>529.25</b> |
| 12                       | <i>Sesbania sesquens</i>         | 38.19                       | 523.34<br>(1270.36)         | 1064.57<br>(2687.56)         | <b>542.03</b> |
| 13                       | <i>Heliotropium procumbens</i>   | 38.22                       | 519.18<br>(1258.40)         | 1069.38<br>(2697.96)         | <b>542.26</b> |
| 14                       | <i>Parkinsonia aculeata</i>      | 39.26                       | 526.24<br>(1240.40)         | 1064.51<br>(2611.44)         | <b>543.34</b> |
| 15                       | <i>Calotropis procera</i>        | 39.25                       | 525.41<br>(1238.62)         | 1065.32<br>(2614.19)         | <b>543.33</b> |
| 16                       | <i>Prosopis juliflora</i>        | 38.22                       | 520.24<br>(1261.17)         | 1068.24<br>(2694.98)         | <b>542.23</b> |
| 17                       | <i>Arundo donax</i>              | 33.15                       | 498.16<br>(1402.75)         | 1061.31<br>(3101.54)         | <b>530.87</b> |
| 18                       | <i>Aleurops lagopoides</i>       | 35.51                       | 499.31<br>(1306.24)         | 1060.42<br>(2886.54)         | <b>531.75</b> |
| 19                       | <i>Cynodon dactylon</i>          | 36.32                       | 501.37<br>(1280.30)         | 1058.34<br>(2813.66)         | <b>532.01</b> |
| 20                       | <i>Setaria indica</i>            | 40.45                       | 530.36<br>(1211.15)         | 1071.45<br>(2548.83)         | <b>547.42</b> |
|                          | Mean                             | <b>35.81</b>                | <b>504.02</b>               | <b>1059.23</b>               |               |

**CD (P=0.05) :** Species(S) =16.952; Salinity levels (T) =6.566; Interaction (SxT) = N.S.

Values given in parentheses ( ) show percent increase/decrease over respective controls

**Table 38: Cl<sup>-</sup> content (mg g<sup>-1</sup> dry wt.) in stem of different plants native to saline soils plants native to saline soils under various added salinity levels**

| S. No. | Name of Plant                    | S0<br>(0dSm <sup>-1</sup> ) | S1<br>(8dSm <sup>-1</sup> ) | S2<br>(16dSm <sup>-1</sup> ) | Mean          |
|--------|----------------------------------|-----------------------------|-----------------------------|------------------------------|---------------|
| 1      | <i>Portulaca oleracea</i>        | 21.25                       | 51.46<br>(142.16)           | 70.63<br>(232.38)            | <b>47.78</b>  |
| 2      | <i>Trianthema portulacastrum</i> | 20.50                       | 48.30<br>(135.61)           | 68.19<br>(232.63)            | <b>45.66</b>  |
| 3      | <i>Aerva tomentosa</i>           | 19.64                       | 46.19<br>(135.18)           | 62.65<br>(218.99)            | <b>42.83</b>  |
| 4      | <i>Atriplex nummularia</i>       | 23.17                       | 59.42<br>(156.47)           | 74.06<br>(219.64)            | <b>52.22</b>  |
| 5      | <i>Atriplex amnicola</i>         | 22.27                       | 55.63<br>(149.80)           | 73.76<br>(231.21)            | <b>50.55</b>  |
| 6      | <i>Atriplex lentiformis</i>      | 24.47                       | 61.41<br>(150.96)           | 75.20<br>(207.32)            | <b>53.69</b>  |
| 7      | <i>Chenopodium ambrosoides</i>   | 9.36                        | 24.27<br>(159.39)           | 38.46<br>(311.04)            | <b>24.03</b>  |
| 8      | <i>Suaeda fruticosa</i>          | 27.05                       | 60.28<br>(122.82)           | 94.84<br>(250.57)            | <b>60.72</b>  |
| 9      | <i>Salicornia brachiata</i>      | 54.73                       | 148.27<br>(170.92)          | 285.60<br>(421.85)           | <b>162.87</b> |
| 10     | <i>Solanum xanthocarpum</i>      | 13.60                       | 29.55<br>(117.28)           | 49.35<br>(262.87)            | <b>30.83</b>  |
| 11     | <i>Xanthium strumarium</i>       | 10.19                       | 20.16<br>(97.84)            | 31.28<br>(206.97)            | <b>20.54</b>  |
| 12     | <i>Sesbania sesquens</i>         | 9.40                        | 22.44<br>(138.72)           | 34.47<br>(266.70)            | <b>22.10</b>  |
| 13     | <i>Heliotropium procumbens</i>   | 10.22                       | 21.59<br>(111.25)           | 32.33<br>(216.37)            | <b>21.38</b>  |
| 14     | <i>Parkinsonia aculeata</i>      | 8.04                        | 16.54<br>(105.81)           | 33.67<br>(318.95)            | <b>19.42</b>  |
| 15     | <i>Calotropis procera</i>        | 9.16                        | 20.32<br>(121.75)           | 29.82<br>(225.43)            | <b>19.77</b>  |
| 16     | <i>Prosopis juliflora</i>        | 9.39                        | 23.47<br>(150.04)           | 31.06<br>(230.89)            | <b>21.31</b>  |
| 17     | <i>Arundo donax</i>              | 17.52                       | 33.23<br>(89.67)            | 58.24<br>(232.42)            | <b>36.33</b>  |
| 18     | <i>Aleurops lagopoides</i>       | 16.28                       | 30.55<br>(87.65)            | 52.70<br>(223.71)            | <b>33.18</b>  |
| 19     | <i>Cynodon dactylon</i>          | 16.54                       | 30.08<br>(81.86)            | 48.38<br>(192.48)            | <b>31.67</b>  |
| 20     | <i>Setaria indica</i>            | 7.04                        | 16.42<br>(133.24)           | 30.02<br>(326.42)            | <b>17.83</b>  |
|        | Mean                             | <b>17.49</b>                | <b>40.98</b>                | <b>63.74</b>                 |               |

**CD (P=0.05) :** Species(S) =4.149; Salinity levels (T) =1.607; Interaction (SxT) = 7.186

Values given in parentheses ( ) show percent increase/decrease over respective controls

**Table 39: Cl<sup>-</sup> content (mg g<sup>-1</sup> dry wt.) in leaves of different plants native to saline soils under various added salinity levels**

| S. No. | Name of Plant                    | S0<br>(0dSm <sup>-1</sup> ) | S1<br>(8dSm <sup>-1</sup> ) | S2<br>(16dSm <sup>-1</sup> ) | Mean          |
|--------|----------------------------------|-----------------------------|-----------------------------|------------------------------|---------------|
| 1      | <i>Portulaca oleracea</i>        | 28.21                       | 84.27<br>(198.72)           | 110.82<br>(292.84)           | <b>74.43</b>  |
| 2      | <i>Trianthema portulacastrum</i> | 26.26                       | 82.60<br>(214.55)           | 108.58<br>(313.48)           | <b>72.48</b>  |
| 3      | <i>Aerva tomentosa</i>           | 25.18                       | 79.57<br>(216.00)           | 106.67<br>(323.62)           | <b>70.47</b>  |
| 4      | <i>Atriplex nummularia</i>       | 35.05                       | 93.05<br>(165.50)           | 110.18<br>(214.38)           | <b>79.43</b>  |
| 5      | <i>Atriplex amnicola</i>         | 29.96                       | 95.42<br>(218.46)           | 121.48<br>(305.43)           | <b>82.29</b>  |
| 6      | <i>Atriplex lentiformis</i>      | 32.51                       | 97.84<br>(200.96)           | 125.26<br>(285.30)           | <b>85.20</b>  |
| 7      | <i>Chenopodium ambrosoides</i>   | 16.08                       | 30.33<br>(88.62)            | 57.309<br>(256.34)           | <b>34.57</b>  |
| 8      | <i>Suaeda fruticosa</i>          | 48.41                       | 109.03<br>(125.24)          | 186.75<br>(285.79)           | <b>114.73</b> |
| 9      | <i>Salicornia brachiata</i>      | -                           | -                           | -                            | -             |
| 10     | <i>Solanum xanthocarpum</i>      | 20.36                       | 34.21<br>(68.05)            | 68.75<br>(237.73)            | <b>41.11</b>  |
| 11     | <i>Xanthium strumarium</i>       | 17.06                       | 30.00<br>(75.85)            | 53.13<br>(211.43)            | <b>33.40</b>  |
| 12     | <i>Sesbania sesquens</i>         | 15.20                       | 29.59<br>(94.67)            | 51.28<br>(237.39)            | <b>32.02</b>  |
| 13     | <i>Heliotropium procumbens</i>   | 16.00                       | 30.05<br>(87.83)            | 51.46<br>(221.63)            | <b>32.50</b>  |
| 14     | <i>Parkinsonia aculeata</i>      | 14.76                       | 27.41<br>(85.75)            | 49.04<br>(232.32)            | <b>30.40</b>  |
| 15     | <i>Calotropis procera</i>        | 15.53                       | 28.33<br>(82.44)            | 52.91<br>(240.72)            | <b>32.26</b>  |
| 16     | <i>Prosopis juliflora</i>        | 14.82                       | 29.35<br>(98.04)            | 54.51<br>(267.79)            | <b>32.89</b>  |
| 17     | <i>Arundo donax</i>              | 23.47                       | 40.17<br>(71.15)            | 70.86<br>(201.92)            | <b>44.83</b>  |
| 18     | <i>Aleurops lagopoides</i>       | 22.37                       | 36.51<br>(63.23)            | 65.32<br>(192.04)            | <b>41.40</b>  |
| 19     | <i>Cynodon dactylon</i>          | 21.15                       | 35.07<br>(65.82)            | 57.23<br>(170.59)            | <b>37.82</b>  |
| 20     | <i>Setaria indica</i>            | 14.28                       | 26.25<br>(83.78)            | 45.06<br>(215.47)            | <b>28.53</b>  |
|        | Mean                             | <b>22.98</b>                | <b>53.63</b>                | <b>81.40</b>                 |               |

**CD (P=0.05):** Species(S) = 4.867; Salinity levels (T) = 1.934; Interaction (S x T) = 8.430

Values given in parentheses ( ) show percent increase/decrease over respective controls

**Table 40: Phytoaccumulation of Cl<sup>-</sup> (mg / total dry wt. of plants in a pot) of different plants native to saline soils under various added salinity levels**

| S. No. | Name of Plant                    | S0<br>(0dSm <sup>-1</sup> ) | S1<br>(8dSm <sup>-1</sup> ) | S2<br>(16dSm <sup>-1</sup> ) | Mean          |
|--------|----------------------------------|-----------------------------|-----------------------------|------------------------------|---------------|
| 1      | <i>Portulaca oleracea</i>        | 179.11                      | 630.76<br>(252.16)          | 906.48<br>(406.10)           | <b>572.12</b> |
| 2      | <i>Trianthema portulacastrum</i> | 156.19                      | 554.49<br>(255.02)          | 1173.51<br>(651.35)          | <b>628.06</b> |
| 3      | <i>Aerva tomentosa</i>           | 203.31                      | 802.55<br>(294.74)          | 1363.50<br>(570.65)          | <b>789.79</b> |
| 4      | <i>Atriplex nummularia</i>       | 197.00                      | 611.91<br>(210.61)          | 531.52<br>(169.80)           | <b>446.81</b> |
| 5      | <i>Atriplex amnicola</i>         | 133.38                      | 468.03<br>(250.91)          | 838.56<br>(528.71)           | <b>479.99</b> |
| 6      | <i>Atriplex lentiformis</i>      | 204.68                      | 741.84<br>(262.44)          | 1267.52<br>(519.26)          | <b>738.01</b> |
| 7      | <i>Chenopodium ambrosoides</i>   | 113.11                      | 203.86<br>(80.24)           | 236.33<br>(108.95)           | <b>184.43</b> |
| 8      | <i>Suaeda fruticosa</i>          | 300.37                      | 724.44<br>(141.18)          | 1461.94<br>(386.72)          | <b>828.92</b> |
| 9      | <i>Salicornia brachiata</i>      | 73.03                       | 207.07<br>(183.56)          | 846.40<br>(1059.05)          | <b>375.50</b> |
| 10     | <i>Solanum xanthocarpum</i>      | 61.92                       | 182.44<br>(194.64)          | 44.99<br>(-27.35)            | <b>96.45</b>  |
| 11     | <i>Xanthium strumarium</i>       | 103.22                      | 92.25<br>(-10.63)           | 134.03<br>(29.85)            | <b>109.83</b> |
| 12     | <i>Sesbania sesquens</i>         | 142.31                      | 196.00<br>(37.73)           | 198.88<br>(39.75)            | <b>179.07</b> |
| 13     | <i>Heliotropium procumbens</i>   | 54.32                       | 77.26<br>(42.25)            | 89.14<br>(64.12)             | <b>73.57</b>  |
| 14     | <i>Parkinsonia aculeata</i>      | 56.35                       | 71.10<br>(26.19)            | 93.34<br>(65.64)             | <b>73.60</b>  |
| 15     | <i>Calotropis procera</i>        | 80.45                       | 135.65<br>(68.61)           | 124.93<br>(55.29)            | <b>113.68</b> |
| 16     | <i>Prosopis juliflora</i>        | 50.46                       | 90.09<br>(78.54)            | 91.43<br>(81.19)             | <b>77.33</b>  |
| 17     | <i>Arundo donax</i>              | 68.48                       | 152.94<br>(123.34)          | 326.14<br>(376.28)           | <b>182.52</b> |
| 18     | <i>Aleurops lagopoides</i>       | 89.81                       | 185.66<br>(106.73)          | 375.20<br>(317.77)           | <b>216.89</b> |
| 19     | <i>Cynodon dactylon</i>          | 101.26                      | 170.63<br>(68.51)           | 182.81<br>(80.53)            | <b>151.57</b> |
| 20     | <i>Setaria indica</i>            | 76.99                       | 88.15<br>(14.49)            | 141.57<br>(83.88)            | <b>102.23</b> |
|        | Mean                             | <b>122.29</b>               | <b>319.36</b>               | <b>521.91</b>                |               |

**CD (P=0.05) :** Species(S) =163.8419; Salinity levels (T) =63.4557; Interaction (SxT) = 283.783

Values given in parentheses ( ) show percent increase/decrease over respective controls

**Table 41:  $\text{So}_4^{2-}$  content ( $\mu\text{g g}^{-1}$  soil) in soil after harvesting of different plants native to saline soils under various added salinity levels**

| S. No.                   | Name of Plant                    | S0<br>(0dSm <sup>-1</sup> ) | S1<br>(8dSm <sup>-1</sup> ) | S2<br>(16dSm <sup>-1</sup> ) | Mean          |
|--------------------------|----------------------------------|-----------------------------|-----------------------------|------------------------------|---------------|
| <b>Before plantation</b> |                                  | <b>38.19</b>                | <b>324.62</b>               | <b>648.80</b>                | <b>337.20</b> |
| 1                        | <i>Portulaca oleracea</i>        | 27.68                       | 285.75<br>(932.46)          | 625.84<br>(2161.24)          | <b>313.09</b> |
| 2                        | <i>Trianthema portulacastrum</i> | 27.95                       | 287.38<br>(928.33)          | 626.94<br>(2143.34)          | <b>314.09</b> |
| 3                        | <i>Aerva tomentosa</i>           | 28.70                       | 287.68<br>(902.24)          | 627.71<br>(2086.89)          | <b>314.70</b> |
| 4                        | <i>Atriplex nummularia</i>       | 24.52                       | 282.23<br>(1050.86)         | 622.39<br>(2437.95)          | <b>309.71</b> |
| 5                        | <i>Atriplex amnicola</i>         | 25.31                       | 284.58<br>(1024.22)         | 620.78<br>(2352.38)          | <b>310.22</b> |
| 6                        | <i>Atriplex lentiformis</i>      | 24.23                       | 280.51<br>(1057.68)         | 618.86<br>(2454.12)          | <b>307.87</b> |
| 7                        | <i>Chenopodium ambrosoides</i>   | 30.60                       | 303.98<br>(893.30)          | 629.75<br>(1957.79)          | <b>321.45</b> |
| 8                        | <i>Suaeda fruticosa</i>          | 23.36                       | 273.37<br>(1070.42)         | 605.11<br>(2490.74)          | <b>300.61</b> |
| 9                        | <i>Salicornia brachiata</i>      | 22.15                       | 270.14<br>(1119.76)         | 609.34<br>(2651.40)          | <b>300.54</b> |
| 10                       | <i>Solanum xanthocarpum</i>      | 28.29                       | 290.49<br>(926.70)          | 629.07<br>(2123.40)          | <b>315.95</b> |
| 11                       | <i>Xanthium strumarium</i>       | 32.45                       | 302.97<br>(833.57)          | 629.79<br>(1840.61)          | <b>321.74</b> |
| 12                       | <i>Sesbania sesquens</i>         | 31.24                       | 303.18<br>(870.59)          | 635.51<br>(1934.49)          | <b>323.31</b> |
| 13                       | <i>Heliotropium procumbens</i>   | 30.37                       | 302.38<br>(895.75)          | 633.51<br>(1986.19)          | <b>322.08</b> |
| 14                       | <i>Parkinsonia aculeata</i>      | 29.62                       | 299.02<br>(909.42)          | 635.01<br>(2043.61)          | <b>321.22</b> |
| 15                       | <i>Calotropis procera</i>        | 31.53                       | 302.83<br>(860.34)          | 634.72<br>(1912.84)          | <b>323.03</b> |
| 16                       | <i>Prosopis juliflora</i>        | 29.52                       | 301.64<br>(921.80)          | 631.75<br>(2040.07)          | <b>320.97</b> |
| 17                       | <i>Arundo donax</i>              | 26.97                       | 285.82<br>(959.91)          | 624.38<br>(2215.39)          | <b>312.39</b> |
| 18                       | <i>Aelurops lagopoides</i>       | 27.52                       | 286.33<br>(940.58)          | 625.85<br>(2174.45)          | <b>313.23</b> |
| 19                       | <i>Cynodon dactylon</i>          | 27.43                       | 287.57<br>(948.49)          | 627.93<br>(2189.49)          | <b>314.31</b> |
| 20                       | <i>Setaria indica</i>            | 34.31                       | 304.44<br>(787.33)          | 632.88<br>(1744.60)          | <b>323.88</b> |
|                          | Mean                             | <b>28.19</b>                | <b>291.11</b>               | <b>626.36</b>                |               |

**CD (P=0.05) :** Species(S) =9.630; Salinity levels (T) =3.730; Interaction (SxT) = N.S.

Values given in parentheses ( ) show percent increase/decrease over respective controls

**Table 42: SO<sub>4</sub><sup>2-</sup> content (mg g<sup>-1</sup> dry wt.) in stem of different plants native to saline soils under various added salinity levels**

| S. No. | Name of Plant                    | S0<br>(0dSm <sup>-1</sup> ) | S1<br>(8dSm <sup>-1</sup> ) | S2<br>(16dSm <sup>-1</sup> ) | Mean         |
|--------|----------------------------------|-----------------------------|-----------------------------|------------------------------|--------------|
| 1      | <i>Portulaca oleracea</i>        | 19.00                       | 15.20<br>(-20.00)           | 14.00<br>(-26.32)            | <b>16.07</b> |
| 2      | <i>Trianthema portulacastrum</i> | 18.27                       | 14.40<br>(-21.18)           | 13.50<br>(-26.11)            | <b>15.39</b> |
| 3      | <i>Aerva tomentosa</i>           | 17.62                       | 13.65<br>(-22.53)           | 12.44<br>(-29.40)            | <b>14.57</b> |
| 4      | <i>Atriplex nummularia</i>       | 20.55                       | 17.27<br>(-15.96)           | 17.05<br>(-17.03)            | <b>18.29</b> |
| 5      | <i>Atriplex amnicola</i>         | 20.26                       | 16.11<br>(-20.48)           | 15.77<br>(-22.16)            | <b>17.38</b> |
| 6      | <i>Atriplex lentiformis</i>      | 21.84                       | 18.42<br>(-15.67)           | 16.85<br>(-22.85)            | <b>19.04</b> |
| 7      | <i>Chenopodium ambrosoides</i>   | 11.15                       | 9.82<br>(-11.93)            | 7.94<br>(-28.79)             | <b>9.64</b>  |
| 8      | <i>Suaeda fruticosa</i>          | 35.12                       | 30.05<br>(-14.44)           | 22.06<br>(-37.19)            | <b>29.08</b> |
| 9      | <i>Salicornia brachiata</i>      | 37.48                       | 31.33<br>(-16.40)           | 24.74<br>(-33.99)            | <b>31.18</b> |
| 10     | <i>Solanum xanthocarpum</i>      | 13.32                       | 10.35<br>(-22.30)           | 7.80<br>(-41.44)             | <b>10.49</b> |
| 11     | <i>Xanthium strumarium</i>       | 10.77                       | 9.02<br>(-16.27)            | 6.52<br>(-39.48)             | <b>8.77</b>  |
| 12     | <i>Sesbania sesquens</i>         | 9.47                        | 9.43<br>(-0.46)             | 6.43<br>(-32.10)             | <b>8.44</b>  |
| 13     | <i>Heliotropium procumbens</i>   | 10.65                       | 8.58<br>(-19.44)            | 7.62<br>(-28.45)             | <b>8.95</b>  |
| 14     | <i>Parkinsonia aculeata</i>      | 10.02                       | 9.12<br>(-9.01)             | 7.33<br>(-26.84)             | <b>8.83</b>  |
| 15     | <i>Calotropis procera</i>        | 10.92                       | 8.07<br>(-26.10)            | 7.12<br>(-34.80)             | <b>8.70</b>  |
| 16     | <i>Prosopis juliflora</i>        | 12.05                       | 9.36<br>(-22.32)            | 7.87<br>(-34.69)             | <b>9.76</b>  |
| 17     | <i>Arundo donax</i>              | 17.40                       | 11.88<br>(-31.72)           | 9.72<br>(-44.14)             | <b>13.00</b> |
| 18     | <i>Aleurops lagopoides</i>       | 16.71                       | 10.66<br>(-36.21)           | 10.12<br>(-39.44)            | <b>12.50</b> |
| 19     | <i>Cynodon dactylon</i>          | 15.38                       | 10.15<br>(-34.03)           | 8.68<br>(-43.56)             | <b>11.40</b> |
| 20     | <i>Setaria indica</i>            | 9.07                        | 7.04<br>(-22.34)            | 5.46<br>(-39.80)             | <b>7.19</b>  |
|        | Mean                             | <b>16.85</b>                | <b>13.49</b>                | <b>11.45</b>                 |              |

**CD (P=0.05) :** Species(S) =1.702; Salinity levels (T) =0.659; Interaction (SxT) = 2.948

Values given in parentheses ( ) show percent increase/decrease over respective controls

**Table 43:  $\text{SO}_4^{2-}$  content ( $\text{mg g}^{-1}$  dry wt.) in leaves of different plants native to saline soils under various added salinity levels**

| S. No. | Name of Plant                    | S0<br>(0dSm <sup>-1</sup> ) | S1<br>(8dSm <sup>-1</sup> ) | S2<br>(16dSm <sup>-1</sup> ) | Mean         |
|--------|----------------------------------|-----------------------------|-----------------------------|------------------------------|--------------|
| 1      | <i>Portulaca oleracea</i>        | 34.13                       | 27.44<br>(-19.60)           | 23.00<br>(-32.61)            | <b>28.19</b> |
| 2      | <i>Trianthema portulacastrum</i> | 32.17                       | 24.28<br>(-24.52)           | 20.25<br>(-37.06)            | <b>25.57</b> |
| 3      | <i>Aerva tomentosa</i>           | 30.32                       | 23.45<br>(-22.65)           | 18.46<br>(-39.11)            | <b>24.08</b> |
| 4      | <i>Atriplex nummularia</i>       | 38.31                       | 30.05<br>(-21.57)           | 26.16<br>(-31.73)            | <b>31.51</b> |
| 5      | <i>Atriplex amnicola</i>         | 37.72                       | 29.40<br>(-22.05)           | 27.00<br>(-28.41)            | <b>31.37</b> |
| 6      | <i>Atriplex lentiformis</i>      | 39.92                       | 30.70<br>(-23.10)           | 26.89<br>(-32.64)            | <b>32.50</b> |
| 7      | <i>Chenopodium ambrosoides</i>   | 22.10                       | 19.39<br>(-12.25)           | 17.35<br>(-21.48)            | <b>19.61</b> |
| 8      | <i>Suaeda fruticosa</i>          | 41.93                       | 39.33<br>(-6.19)            | 35.73<br>(-14.79)            | <b>39.00</b> |
| 9      | <i>Salicornia brachiata</i>      | -                           | -                           | -                            | -            |
| 10     | <i>Solanum xanthocarpum</i>      | 24.04                       | 19.52<br>(-18.78)           | 17.65<br>(-26.57)            | <b>20.40</b> |
| 11     | <i>Xanthium strumarium</i>       | 19.46                       | 17.92<br>(-7.93)            | 15.08<br>(-22.52)            | <b>17.49</b> |
| 12     | <i>Sesbania sesquens</i>         | 19.25                       | 16.14<br>(-16.17)           | 14.92<br>(-22.51)            | <b>16.77</b> |
| 13     | <i>Heliotropium procumbens</i>   | 21.84                       | 16.43<br>(-24.78)           | 15.14<br>(-30.69)            | <b>17.80</b> |
| 14     | <i>Parkinsonia aculeata</i>      | 20.35                       | 17.75<br>(-12.79)           | 13.62<br>(-33.07)            | <b>17.24</b> |
| 15     | <i>Calotropis procera</i>        | 18.70                       | 16.36<br>(-12.51)           | 14.25<br>(-23.79)            | <b>16.44</b> |
| 16     | <i>Prosopis juliflora</i>        | 18.43                       | 15.48<br>(-16.01)           | 14.12<br>(-23.37)            | <b>16.01</b> |
| 17     | <i>Arundo donax</i>              | 29.44                       | 22.38<br>(-23.97)           | 18.07<br>(-38.62)            | <b>23.30</b> |
| 18     | <i>Aleurops lagopoides</i>       | 27.76                       | 20.28<br>(-26.93)           | 16.73<br>(-39.73)            | <b>21.59</b> |
| 19     | <i>Cynodon dactylon</i>          | 26.46                       | 20.17<br>(-23.77)           | 16.59<br>(-37.31)            | <b>21.07</b> |
| 20     | <i>Setaria indica</i>            | 17.71                       | 15.14<br>(-14.53)           | 13.96<br>(-21.19)            | <b>15.60</b> |
|        | Mean                             | <b>27.37</b>                | <b>22.19</b>                | <b>19.21</b>                 |              |

**CD (P=0.05):** Species(S) = 3.431; Salinity levels (T) = 1.363; Interaction (S x T) = N.S.

Values given in parentheses ( ) show percent increase/decrease over respective controls

**Table 44: Phytoaccumulation  $\text{SO}_4^{2-}$  content (mg / total dry wt. of plants in a pot) of different plants native to saline soils under various added salinity levels**

| S. No. | Name of Plant                    | S0<br>(0dSm <sup>-1</sup> ) | S1<br>(8dSm <sup>-1</sup> ) | S2<br>(16dSm <sup>-1</sup> ) | Mean          |
|--------|----------------------------------|-----------------------------|-----------------------------|------------------------------|---------------|
| 1      | <i>Portulaca oleracea</i>        | 208.90                      | 210.36<br>(0.70)            | 189.29<br>(-9.38)            | <b>202.85</b> |
| 2      | <i>Trianthema portulacastrum</i> | 167.32                      | 166.66<br>(-0.39)           | 225.25<br>(34.63)            | <b>186.41</b> |
| 3      | <i>Aerva tomentosa</i>           | 217.66                      | 222.68<br>(2.31)            | 247.97<br>(13.93)            | <b>229.44</b> |
| 4      | <i>Atriplex nummularia</i>       | 202.36                      | 194.58<br>(-3.84)           | 123.31<br>(-39.06)           | <b>173.42</b> |
| 5      | <i>Atriplex amnicola</i>         | 149.81                      | 140.75<br>(-6.04)           | 186.70<br>(24.63)            | <b>159.09</b> |
| 6      | <i>Atriplex lentiformis</i>      | 222.10                      | 231.50<br>(4.24)            | 274.31<br>(23.51)            | <b>242.64</b> |
| 7      | <i>Chenopodium ambrosoides</i>   | 147.78                      | 109.12<br>(-26.16)          | 63.77<br>(-56.85)            | <b>106.89</b> |
| 8      | <i>Suaeda fruticosa</i>          | 312.81                      | 308.80<br>(-1.28)           | 304.97<br>(-2.51)            | <b>308.86</b> |
| 9      | <i>Salicornia brachiata</i>      | 49.99                       | 44.53<br>(-10.93)           | 74.43<br>(48.87)             | <b>56.32</b>  |
| 10     | <i>Solanum xanthocarpum</i>      | 66.30                       | 93.97<br>(41.74)            | 10.87<br>(-83.60)            | <b>57.05</b>  |
| 11     | <i>Xanthium strumarium</i>       | 115.51                      | 50.51<br>(-56.27)           | 35.40<br>(-69.36)            | <b>67.14</b>  |
| 12     | <i>Sesbania sesquens</i>         | 168.78                      | 99.96<br>(-40.77)           | 51.54<br>(-69.46)            | <b>106.76</b> |
| 13     | <i>Heliotropium procumbens</i>   | 69.27                       | 39.77<br>(-42.58)           | 25.28<br>(-63.51)            | <b>44.77</b>  |
| 14     | <i>Parkinsonia aculeata</i>      | 71.95                       | 41.83<br>(-41.86)           | 22.65<br>(-68.52)            | <b>45.48</b>  |
| 15     | <i>Calotropis procera</i>        | 105.26                      | 71.71<br>(-31.88)           | 32.82<br>(-68.83)            | <b>69.93</b>  |
| 16     | <i>Prosopis juliflora</i>        | 60.38                       | 43.40<br>(-28.11)           | 23.55<br>(-61.00)            | <b>42.44</b>  |
| 17     | <i>Arundo donax</i>              | 79.52                       | 72.86<br>(-8.37)            | 70.49<br>(-11.35)            | <b>74.29</b>  |
| 18     | <i>Aleurops lagopoides</i>       | 101.24                      | 84.09<br>(-16.94)           | 86.65<br>(-14.41)            | <b>90.66</b>  |
| 19     | <i>Cynodon dactylon</i>          | 111.52                      | 68.50<br>(-38.57)           | 39.81<br>(-64.30)            | <b>73.28</b>  |
| 20     | <i>Setaria indica</i>            | 96.13                       | 48.68<br>(-49.36)           | 39.75<br>(-58.65)            | <b>61.52</b>  |
|        | Mean                             | <b>136.23</b>               | <b>117.21</b>               | <b>106.36</b>                |               |

**CD (P=0.05) :** Species(S) =50.77; Salinity levels (T) =19.6631; Interaction (SxT) = N.S.

Values given in parentheses ( ) show percent increase/decrease over respective controls

**Table 45: Na<sup>+</sup>/K<sup>+</sup> ratio in soil after harvesting of different plants native to saline soils under various added salinity levels**

| S. No.                   | Name of Plant                    | S0<br>(0dSm <sup>-1</sup> ) | S1<br>(8dSm <sup>-1</sup> ) | S2<br>(16dSm <sup>-1</sup> ) | Mean        |
|--------------------------|----------------------------------|-----------------------------|-----------------------------|------------------------------|-------------|
| <b>Before plantation</b> |                                  | <b>0.54</b>                 | <b>2.68</b>                 | <b>6.48</b>                  | <b>3.23</b> |
| 1                        | <i>Portulaca oleracea</i>        | 0.81                        | 4.67<br>(476.97)            | 7.46<br>(823.07)             | <b>4.25</b> |
| 2                        | <i>Trianthema portulacastrum</i> | 0.72                        | 4.82<br>(570.80)            | 7.21<br>(902.67)             | <b>4.19</b> |
| 3                        | <i>Aerva tomentosa</i>           | 0.80                        | 4.65<br>(481.32)            | 7.13<br>(791.40)             | <b>4.55</b> |
| 4                        | <i>Atriplex nummularia</i>       | 0.76                        | 5.33<br>(604.47)            | 7.57<br>(900.48)             | <b>4.52</b> |
| 5                        | <i>Atriplex amnicola</i>         | 0.70                        | 5.20<br>(648.03)            | 7.67<br>(1003.90)            | <b>4.58</b> |
| 6                        | <i>Atriplex lentiformis</i>      | 0.77                        | 5.18<br>(575.13)            | 7.81<br>(917.51)             | <b>4.07</b> |
| 7                        | <i>Chenopodium ambrosoides</i>   | 0.94                        | 4.44<br>(373.24)            | 6.82<br>(627.95)             | <b>4.94</b> |
| 8                        | <i>Suaeda fruticosa</i>          | 0.74                        | 5.45<br>(634.02)            | 8.62<br>(1061.82)            | <b>5.35</b> |
| 9                        | <i>Salicornia brachiata</i>      | 0.83                        | 5.65<br>(580.68)            | 9.57<br>(1052.52)            | <b>4.18</b> |
| 10                       | <i>Solanum xanthocarpum</i>      | 0.86                        | 4.42<br>(413.59)            | 7.28<br>(746.50)             | <b>4.13</b> |
| 11                       | <i>Xanthium strumarium</i>       | 0.84                        | 4.33<br>(415.13)            | 7.22<br>(758.96)             | <b>4.13</b> |
| 12                       | <i>Sesbania sesquens</i>         | 0.76                        | 4.43<br>(485.78)            | 7.19<br>(850.88)             | <b>4.14</b> |
| 13                       | <i>Heliotropium procumbens</i>   | 0.83                        | 4.53<br>(444.82)            | 7.05<br>(748.17)             | <b>4.23</b> |
| 14                       | <i>Parkinsonia aculeata</i>      | 0.83                        | 4.48<br>(442.89)            | 7.39<br>(795.80)             | <b>4.15</b> |
| 15                       | <i>Calotropis procera</i>        | 0.78                        | 4.58<br>(487.64)            | 7.10<br>(810.61)             | <b>4.06</b> |
| 16                       | <i>Prosopis juliflora</i>        | 0.76                        | 4.21<br>(454.69)            | 7.21<br>(850.37)             | <b>4.54</b> |
| 17                       | <i>Arundo donax</i>              | 0.90                        | 4.95<br>(447.57)            | 7.76<br>(759.59)             | <b>4.40</b> |
| 18                       | <i>Aleurops lagopoides</i>       | 0.83                        | 4.72<br>(470.30)            | 7.65<br>(825.25)             | <b>4.39</b> |
| 19                       | <i>Cynodon dactylon</i>          | 0.78                        | 4.76<br>(513.37)            | 7.63<br>(881.89)             | <b>4.08</b> |
| 20                       | <i>Setaria indica</i>            | 0.74                        | 4.53<br>(512.21)            | 6.97<br>(841.35)             | <b>4.31</b> |
|                          | Mean                             | <b>0.80</b>                 | <b>4.77</b>                 | <b>7.52</b>                  |             |

**CD (P=0.05) :** Species(S) =0.6125; Salinity levels (T) =0.2372; Interaction (SxT) = N.S.

Values given in parentheses ( ) show percent increase/decrease over respective controls

**Table 46: Na<sup>+</sup>/K<sup>+</sup> ratio in stem of different plants native to saline soils under various added salinity levels**

| S. No. | Name of Plant                    | S0<br>(0dSm <sup>-1</sup> ) | S1<br>(8dSm <sup>-1</sup> ) | S2<br>(16dSm <sup>-1</sup> ) | Mean        |
|--------|----------------------------------|-----------------------------|-----------------------------|------------------------------|-------------|
| 1      | <i>Portulaca oleracea</i>        | 0.90                        | 5.76<br>(540.44)            | 16.66<br>(1752.33)           | <b>7.77</b> |
| 2      | <i>Trianthema portulacastrum</i> | 0.91                        | 5.52<br>(505.84)            | 17.30<br>(1799.38)           | <b>7.91</b> |
| 3      | <i>Aerva tomentosa</i>           | 0.87                        | 5.80<br>(564.88)            | 17.32<br>(1883.67)           | <b>8.00</b> |
| 4      | <i>Atriplex nummularia</i>       | 0.87                        | 5.75<br>(557.97)            | 14.60<br>(1570.73)           | <b>7.08</b> |
| 5      | <i>Atriplex amnicola</i>         | 0.84                        | 6.03<br>(621.02)            | 16.88<br>(1919.31)           | <b>7.91</b> |
| 6      | <i>Atriplex lentiformis</i>      | 0.91                        | 5.43<br>(498.48)            | 15.40<br>(1597.95)           | <b>7.24</b> |
| 7      | <i>Chenopodium ambrosoides</i>   | 0.74                        | 2.49<br>(235.70)            | 6.05<br>(716.60)             | <b>3.09</b> |
| 8      | <i>Suaeda fruticosa</i>          | 0.94                        | 3.26<br>(247.58)            | 13.51<br>(1339.87)           | <b>5.90</b> |
| 9      | <i>Salicornia brachiata</i>      | 0.81                        | 6.91<br>(755.69)            | 11.49<br>(1322.04)           | <b>6.40</b> |
| 10     | <i>Solanum xanthocarpum</i>      | 1.28                        | 4.91<br>(282.85)            | 9.87<br>(670.63)             | <b>5.35</b> |
| 11     | <i>Xanthium strumarium</i>       | 0.81                        | 3.77<br>(364.29)            | 7.81<br>(861.39)             | <b>4.13</b> |
| 12     | <i>Sesbania sesquens</i>         | 1.19                        | 3.96<br>(233.21)            | 8.50<br>(615.45)             | <b>4.55</b> |
| 13     | <i>Heliotropium procumbens</i>   | 0.99                        | 3.02<br>(205.26)            | 8.66<br>(774.53)             | <b>4.23</b> |
| 14     | <i>Parkinsonia aculeata</i>      | 0.83                        | 3.16<br>(281.86)            | 9.39<br>(1036.74)            | <b>4.46</b> |
| 15     | <i>Calotropis procera</i>        | 0.96                        | 3.28<br>(241.09)            | 7.01<br>(628.37)             | <b>3.75</b> |
| 16     | <i>Prosopis juliflora</i>        | 0.84                        | 3.41<br>(306.10)            | 8.00<br>(853.08)             | <b>4.08</b> |
| 17     | <i>Arundo donax</i>              | 1.32                        | 6.23<br>(371.16)            | 13.09<br>(889.59)            | <b>6.88</b> |
| 18     | <i>Aleurops lagopoides</i>       | 1.13                        | 4.94<br>(335.43)            | 10.84<br>(855.60)            | <b>5.64</b> |
| 19     | <i>Cynodon dactylon</i>          | 0.95                        | 5.29<br>(454.85)            | 9.40<br>(885.41)             | <b>5.22</b> |
| 20     | <i>Setaria indica</i>            | 1.11                        | 4.84<br>(334.40)            | 9.06<br>(713.52)             | <b>5.00</b> |
|        | Mean                             | <b>0.96</b>                 | <b>4.69</b>                 | <b>11.52</b>                 |             |

**CD (P=0.05) :** Species(S) =1.2887; Salinity levels (T) =0.4991; Interaction (SxT) = 2.232

Values given in parentheses ( ) show percent increase/decrease over respective controls

**Table 47: Na<sup>+</sup>/K<sup>+</sup> ratio in leaves of different plants native to saline soils under various added salinity levels**

| <b>S. No.</b> | <b>Name of Plant</b>             | <b>S0<br/>(0dSm<sup>-1</sup>)</b> | <b>S1<br/>(8dSm<sup>-1</sup>)</b> | <b>S2<br/>(16dSm<sup>-1</sup>)</b> | <b>Mean</b>  |
|---------------|----------------------------------|-----------------------------------|-----------------------------------|------------------------------------|--------------|
| 1             | <i>Portulaca oleracea</i>        | 1.24                              | 7.59<br>(511.81)                  | 17.24<br>(1290.44)                 | <b>8.69</b>  |
| 2             | <i>Trianthema portulacastrum</i> | 1.18                              | 7.91<br>(568.33)                  | 16.86<br>(1324.01)                 | <b>8.65</b>  |
| 3             | <i>Aerva tomentosa</i>           | 1.26                              | 8.79<br>(598.88)                  | 16.55<br>(1215.47)                 | <b>8.87</b>  |
| 4             | <i>Atriplex nummularia</i>       | 1.28                              | 6.74<br>(428.72)                  | 14.03<br>(1000.40)                 | <b>7.35</b>  |
| 5             | <i>Atriplex amnicola</i>         | 1.28                              | 6.77<br>(427.14)                  | 15.35<br>(1094.70)                 | <b>7.80</b>  |
| 6             | <i>Atriplex lentiformis</i>      | 1.29                              | 6.53<br>(407.42)                  | 15.33<br>(1090.46)                 | <b>7.72</b>  |
| 7             | <i>Chenopodium ambrosoides</i>   | 1.00                              | 4.80<br>(381.18)                  | 11.00<br>(1004.10)                 | <b>5.60</b>  |
| 8             | <i>Suaeda fruticosa</i>          | 1.29                              | 6.70<br>(419.06)                  | 13.39<br>(937.62)                  | <b>7.13</b>  |
| 9             | <i>Salicornia brachiata</i>      | -                                 | -                                 | -                                  | -            |
| 10            | <i>Solanum xanthocarpum</i>      | 1.63                              | 6.93<br>(325.52)                  | 18.81<br>(1055.76)                 | <b>9.12</b>  |
| 11            | <i>Xanthium strumarium</i>       | 1.86                              | 6.43<br>(246.63)                  | 13.90<br>(648.63)                  | <b>7.40</b>  |
| 12            | <i>Sesbania sesquens</i>         | 1.81                              | 7.24<br>(299.48)                  | 14.14<br>(680.66)                  | <b>7.73</b>  |
| 13            | <i>Heliotropium procumbens</i>   | 1.99                              | 9.00<br>(353.24)                  | 17.75<br>(793.45)                  | <b>9.58</b>  |
| 14            | <i>Parkinsonia aculeata</i>      | 1.55                              | 6.58<br>(325.73)                  | 13.33<br>(762.61)                  | <b>7.15</b>  |
| 15            | <i>Calotropis procera</i>        | 1.45                              | 6.25<br>(331.54)                  | 17.50<br>(1108.54)                 | <b>8.40</b>  |
| 16            | <i>Prosopis juliflora</i>        | 1.85                              | 6.42<br>(247.44)                  | 18.52<br>(901.64)                  | <b>8.93</b>  |
| 17            | <i>Arundo donax</i>              | 1.79                              | 9.21<br>(414.36)                  | 19.13<br>(968.95)                  | <b>10.04</b> |
| 18            | <i>Aleurops lagopoides</i>       | 1.72                              | 7.17<br>(316.90)                  | 13.51<br>(685.77)                  | <b>7.46</b>  |
| 19            | <i>Cynodon dactylon</i>          | 1.68                              | 9.16<br>(445.92)                  | 13.05<br>(678.01)                  | <b>7.96</b>  |
| 20            | <i>Setaria indica</i>            | 1.39                              | 5.70<br>(310.47)                  | 8.41<br>(505.66)                   | <b>5.16</b>  |
|               | Mean                             | <b>1.50</b>                       | <b>7.15</b>                       | <b>15.15</b>                       |              |

**CD (P=0.05) :** Species(S) =1.3207; Salinity levels (T) =0.5248; Interaction (SxT) = 2.287

Values given in parentheses ( ) show percent increase/decrease over respective controls

**Table 48: Na<sup>+</sup>/K<sup>+</sup> ratio in shoot of different plants native to saline soils under various added salinity levels**

| S. No. | Name of Plant                    | S0<br>(0dSm <sup>-1</sup> ) | S1<br>(8dSm <sup>-1</sup> ) | S2<br>(16dSm <sup>-1</sup> ) | Mean         |
|--------|----------------------------------|-----------------------------|-----------------------------|------------------------------|--------------|
| 1      | <i>Portulaca oleracea</i>        | 2.14                        | 13.35<br>(523.85)           | 33.90<br>(1484.60)           | <b>16.46</b> |
| 2      | <i>Trianthema portulacastrum</i> | 2.09                        | 13.43<br>(541.16)           | 34.16<br>(1530.70)           | <b>16.56</b> |
| 3      | <i>Aerva tomentosa</i>           | 2.13                        | 14.60<br>(584.96)           | 33.87<br>(1489.21)           | <b>16.86</b> |
| 4      | <i>Atriplex nummularia</i>       | 2.15                        | 12.49<br>(481.28)           | 28.63<br>(1232.34)           | <b>14.43</b> |
| 5      | <i>Atriplex amnicola</i>         | 2.12                        | 12.80<br>(503.55)           | 32.23<br>(1419.70)           | <b>15.71</b> |
| 6      | <i>Atriplex lentiformis</i>      | 2.19                        | 11.96<br>(445.05)           | 30.72<br>(1300.17)           | <b>14.96</b> |
| 7      | <i>Chenopodium ambrosoides</i>   | 1.74                        | 7.28<br>(319.15)            | 17.05<br>(881.52)            | <b>8.69</b>  |
| 8      | <i>Suaeda fruticosa</i>          | 2.23                        | 9.96<br>(346.87)            | 26.90<br>(1106.96)           | <b>13.03</b> |
| 9      | <i>Salicornia brachiata</i>      | 0.81                        | 6.91<br>(755.69)            | 11.49<br>(1322.04)           | <b>6.40</b>  |
| 10     | <i>Solanum xanthocarpum</i>      | 2.91                        | 11.83<br>(306.73)           | 28.68<br>(886.12)            | <b>14.47</b> |
| 11     | <i>Xanthium strumarium</i>       | 2.67                        | 10.21<br>(282.45)           | 21.70<br>(713.39)            | <b>11.53</b> |
| 12     | <i>Sesbania sesquens</i>         | 3.00                        | 11.20<br>(273.22)           | 22.64<br>(654.82)            | <b>12.28</b> |
| 13     | <i>Heliotropium procumbens</i>   | 2.98                        | 12.03<br>(304.00)           | 26.41<br>(787.15)            | <b>13.81</b> |
| 14     | <i>Parkinsonia aculeata</i>      | 2.37                        | 9.74<br>(310.44)            | 22.73<br>(858.13)            | <b>11.61</b> |
| 15     | <i>Calotropis procera</i>        | 2.41                        | 9.53<br>(295.42)            | 24.51<br>(916.81)            | <b>12.15</b> |
| 16     | <i>Prosopis juliflora</i>        | 2.69                        | 9.83<br>(265.75)            | 26.52<br>(886.48)            | <b>13.01</b> |
| 17     | <i>Arundo donax</i>              | 3.11                        | 15.44<br>(396.00)           | 32.22<br>(935.23)            | <b>16.92</b> |
| 18     | <i>Aelurops lagopoides</i>       | 2.85                        | 12.11<br>(324.27)           | 24.35<br>(753.31)            | <b>13.10</b> |
| 19     | <i>Cynodon dactylon</i>          | 2.63                        | 14.45<br>(449.16)           | 22.45<br>(753.20)            | <b>13.18</b> |
| 20     | <i>Setaria indica</i>            | 2.50                        | 10.53<br>(321.12)           | 17.46<br>(598.18)            | <b>10.17</b> |
|        | Mean                             | <b>2.39</b>                 | <b>11.48</b>                | <b>25.91</b>                 |              |

**CD (P=0.05) :** Species(S) =1.6437; Salinity levels (T) =0.6366; Interaction (SxT) = 2.847

Values given in parentheses ( ) show percent increase/decrease over respective controls

**Table 49: Total ionic content ( $\mu\text{g/g}$  soil) in soil after harvesting of different plants native to saline soils under various added salinity levels**

| S. No.                   | Name of Plant                    | S0<br>(0dSm <sup>-1</sup> ) | S1<br>(8dSm <sup>-1</sup> ) | S2<br>(16dSm <sup>-1</sup> ) | Mean            |
|--------------------------|----------------------------------|-----------------------------|-----------------------------|------------------------------|-----------------|
| <b>Before plantation</b> |                                  | <b>286.28</b>               | <b>1413.46</b>              | <b>2700.14</b>               | <b>1466.593</b> |
| 1                        | <i>Portulaca oleracea</i>        | 194.91                      | 1242.03<br>(537.24)         | 2561.37<br>(1214.15)         | <b>1332.77</b>  |
| 2                        | <i>Trianthema portulacastrum</i> | 193.30                      | 1249.99<br>(546.66)         | 2568.79<br>(1228.91)         | <b>1337.36</b>  |
| 3                        | <i>Aerva tomentosa</i>           | 201.79                      | 1258.51<br>(523.69)         | 2576.53<br>(1176.86)         | <b>1345.61</b>  |
| 4                        | <i>Atriplex nummularia</i>       | 181.34                      | 1223.2<br>(574.53)          | 2554.99<br>(1308.92)         | <b>1319.85</b>  |
| 5                        | <i>Atriplex amnicola</i>         | 182.91                      | 1228.69<br>(571.76)         | 2576.51<br>(1308.65)         | <b>1329.37</b>  |
| 6                        | <i>Atriplex lentiformis</i>      | 182.13                      | 1214.36<br>(566.76)         | 2536.93<br>(1292.92)         | <b>1311.14</b>  |
| 7                        | <i>Chenopodium ambrosoides</i>   | 202.32                      | 1298.87<br>(541.99)         | 2596.68<br>(1183.45)         | <b>1365.96</b>  |
| 8                        | <i>Suaeda fruticosa</i>          | 185.01                      | 1200.21<br>(548.73)         | 2502.86<br>(1252.82)         | <b>1296.03</b>  |
| 9                        | <i>Salicornia brachiata</i>      | 173.71                      | 1182.08<br>(580.48)         | 2486.36<br>(1331.30)         | <b>1280.72</b>  |
| 10                       | <i>Solanum xanthocarpum</i>      | 203.71                      | 1269.07<br>(522.98)         | 2590.04<br>(1171.43)         | <b>1354.27</b>  |
| 11                       | <i>Xanthium strumarium</i>       | 215.22                      | 1262.50<br>(486.60)         | 2602.57<br>(1109.24)         | <b>1360.10</b>  |
| 12                       | <i>Sesbania sesquens</i>         | 216.63                      | 1310.47<br>(504.94)         | 2604.27<br>(1102.19)         | <b>1377.12</b>  |
| 13                       | <i>Heliotropium procumbens</i>   | 208.79                      | 1300.62<br>(522.93)         | 2603.61<br>(1147.00)         | <b>1371.01</b>  |
| 14                       | <i>Parkinsonia aculeata</i>      | 211.00                      | 1306.27<br>(519.08)         | 2602.71<br>(1133.49)         | <b>1373.33</b>  |
| 15                       | <i>Calotropis procera</i>        | 216.12                      | 1320.70<br>(511.08)         | 2604.71<br>(1105.19)         | <b>1380.51</b>  |
| 16                       | <i>Prosopis juliflora</i>        | 217.83                      | 1302.37<br>(497.89)         | 2600.17<br>(1093.69)         | <b>1373.46</b>  |
| 17                       | <i>Arundo donax</i>              | 186.01                      | 1253.02<br>(573.62)         | 2568.04<br>(1280.57)         | <b>1335.69</b>  |
| 18                       | <i>Aleurops lagopoides</i>       | 190.99                      | 1255.76<br>(557.51)         | 2571.55<br>(1246.46)         | <b>1339.43</b>  |
| 19                       | <i>Cynodon dactylon</i>          | 200.25                      | 1261.31<br>(529.87)         | 2577.96<br>(1187.37)         | <b>1346.51</b>  |
| 20                       | <i>Setaria indica</i>            | 226.00                      | 1321.14<br>(484.58)         | 2613.79<br>(1056.54)         | <b>1386.98</b>  |
|                          | Mean                             | <b>199.50</b>               | <b>1263.06</b>              | <b>2573.36</b>               |                 |

**CD (P=0.05)** : Species(S) =0.6125; Salinity levels (T) =0.2372; Interaction (SxT) = N.S.

Values given in parentheses ( ) show percent increase/decrease over respective controls

**Table 50: Phytoaccumulation of sum total of ions (mg/plant shoot dry wt.) in different plants native to saline soils under various added salinity levels**

| S. No. | Name of Plant                    | S0<br>(0dSm <sup>-1</sup> ) | S1<br>(8dSm <sup>-1</sup> ) | S2<br>(16dSm <sup>-1</sup> ) | Mean          |
|--------|----------------------------------|-----------------------------|-----------------------------|------------------------------|---------------|
| 1      | <i>Portulaca oleracea</i>        | 244.63                      | 517.20<br>(111.42)          | 689.93<br>(182.03)           | <b>483.92</b> |
| 2      | <i>Trianthema portulacastrum</i> | 162.08                      | 341.13<br>(110.48)          | 721.80<br>(345.34)           | <b>408.34</b> |
| 3      | <i>Aerva tomentosa</i>           | 213.10                      | 495.25<br>(132.40)          | 844.32<br>(296.21)           | <b>517.56</b> |
| 4      | <i>Atriplex nummularia</i>       | 193.76                      | 380.62<br>(96.44)           | 272.04<br>(40.40)            | <b>282.14</b> |
| 5      | <i>Atriplex amnicola</i>         | 355.50                      | 710.63<br>(99.89)           | 1268.58<br>(256.84)          | <b>778.24</b> |
| 6      | <i>Atriplex lentiformis</i>      | 359.83                      | 745.87<br>(107.28)          | 1306.40<br>(263.06)          | <b>804.03</b> |
| 7      | <i>Chenopodium ambrosoides</i>   | 140.64                      | 147.63<br>(4.97)            | 130.88<br>(-6.94)            | <b>139.72</b> |
| 8      | <i>Suaeda fruticosa</i>          | 237.36                      | 404.75<br>(70.52)           | 623.93<br>(162.86)           | <b>422.01</b> |
| 9      | <i>Salicornia brachiata</i>      | 21.51                       | 30.46<br>(41.60)            | 79.47<br>(269.44)            | <b>43.81</b>  |
| 10     | <i>Solanum xanthocarpum</i>      | 105.80                      | 252.99<br>(139.13)          | 83.75<br>(-20.83)            | <b>147.51</b> |
| 11     | <i>Xanthium strumarium</i>       | 179.64                      | 114.33<br>(-36.35)          | 135.82<br>(-24.39)           | <b>143.27</b> |
| 12     | <i>Sesbania sesquens</i>         | 160.03                      | 145.59<br>(-9.02)           | 121.73<br>(-23.93)           | <b>142.45</b> |
| 13     | <i>Heliotropium procumbens</i>   | 101.27                      | 96.75<br>(-4.46)            | 96.93<br>(-4.28)             | <b>98.32</b>  |
| 14     | <i>Parkinsonia aculeata</i>      | 170.91                      | 134.69<br>(-21.19)          | 130.63<br>(-23.56)           | <b>145.41</b> |
| 15     | <i>Calotropis procera</i>        | 234.08                      | 236.94<br>(1.22)            | 190.13<br>(-18.78)           | <b>220.38</b> |
| 16     | <i>Prosopis juliflora</i>        | 146.64                      | 152.58<br>(4.06)            | 140.36<br>(-4.28)            | <b>146.53</b> |
| 17     | <i>Arundo donax</i>              | 71.90                       | 132.57<br>(84.39)           | 203.07<br>(182.45)           | <b>135.84</b> |
| 18     | <i>Aleurops lagopoides</i>       | 77.42                       | 117.00<br>(51.12)           | 179.47<br>(131.82)           | <b>124.63</b> |
| 19     | <i>Cynodon dactylon</i>          | 68.47                       | 82.71<br>(20.79)            | 78.50<br>(14.65)             | <b>76.56</b>  |
| 20     | <i>Setaria indica</i>            | 107.52                      | 84.51<br>(-21.40)           | 80.70<br>(-24.95)            | <b>90.91</b>  |
|        | Mean                             | <b>167.60</b>               | <b>266.21</b>               | <b>368.92</b>                |               |

**CD (P=0.05) :** Species(S) =118.7967; Salinity levels (T) =46.0098; Interaction (SxT) = 205.762

Values given in parentheses ( ) show percent increase/decrease over respective controls

**Table 51: Phytoaccumulation of sum total of ions (mg/total shoot dry wt. of plants in a pot) in different plants native to saline soils under various added salinity levels**

| S. No. | Name of Plant                    | S0<br>(0dSm <sup>-1</sup> ) | S1<br>(8dSm <sup>-1</sup> ) | S2<br>(16dSm <sup>-1</sup> ) | Mean    |
|--------|----------------------------------|-----------------------------|-----------------------------|------------------------------|---------|
| 1      | <i>Portulaca oleracea</i>        | 978.51                      | 2068.81<br>(111.42)         | 2759.74<br>(182.03)          | 1935.69 |
| 2      | <i>Trianthema portulacastrum</i> | 810.39                      | 1705.67<br>(110.48)         | 3608.99<br>(345.34)          | 2041.68 |
| 3      | <i>Aerva tomentosa</i>           | 1065.50                     | 2476.24<br>(132.40)         | 4221.59<br>(296.21)          | 2587.78 |
| 4      | <i>Atriplex nummularia</i>       | 968.79                      | 1903.10<br>(96.44)          | 1632.22<br>(68.48)           | 1501.37 |
| 5      | <i>Atriplex amnicola</i>         | 711.00                      | 1421.26<br>(99.89)          | 2537.16<br>(256.84)          | 1556.47 |
| 6      | <i>Atriplex lentiformis</i>      | 1079.50                     | 2237.60<br>(107.28)         | 3919.20<br>(263.06)          | 2412.10 |
| 7      | <i>Chenopodium ambrosoides</i>   | 703.20                      | 738.16<br>(4.97)            | 654.41<br>(-6.94)            | 698.59  |
| 8      | <i>Suaeda fruticosa</i>          | 1424.17                     | 2428.52<br>(70.52)          | 3743.57<br>(162.86)          | 2532.09 |
| 9      | <i>Salicornia brachiata</i>      | 258.12                      | 456.89<br>(77.00)           | 1430.43<br>(454.17)          | 715.15  |
| 10     | <i>Solanum xanthocarpum</i>      | 317.39                      | 758.98<br>(139.13)          | 167.51<br>(-47.22)           | 414.63  |
| 11     | <i>Xanthium strumarium</i>       | 538.93                      | 343.00<br>(-36.35)          | 407.46<br>(-24.39)           | 429.80  |
| 12     | <i>Sesbania sesquens</i>         | 800.14                      | 727.96<br>(-9.02)           | 608.64<br>(-23.93)           | 712.25  |
| 13     | <i>Heliotropium procumbens</i>   | 303.80                      | 290.24<br>(-4.46)           | 290.80<br>(-4.28)            | 294.95  |
| 14     | <i>Parkinsonia aculeata</i>      | 341.81                      | 269.39<br>(-21.19)          | 261.27<br>(-23.56)           | 290.82  |
| 15     | <i>Calotropis procera</i>        | 468.17                      | 473.87<br>(1.22)            | 380.27<br>(-18.78)           | 440.77  |
| 16     | <i>Prosopis juliflora</i>        | 293.27                      | 305.17<br>(4.06)            | 280.73<br>(-4.28)            | 293.06  |
| 17     | <i>Arundo donax</i>              | 359.48                      | 662.83<br>(84.39)           | 1015.34<br>(182.45)          | 679.21  |
| 18     | <i>Aleurops lagopoides</i>       | 464.51                      | 701.98<br>(51.12)           | 1076.82<br>(131.82)          | 747.77  |
| 19     | <i>Cynodon dactylon</i>          | 479.31                      | 578.97<br>(20.79)           | 471.02<br>(-1.73)            | 509.77  |
| 20     | <i>Setaria indica</i>            | 430.09                      | 338.03<br>(-21.40)          | 322.80<br>(-24.95)           | 363.64  |
|        | Mean                             | <b>639.80</b>               | <b>1044.33</b>              | <b>1489.50</b>               |         |

**CD (P=0.05) :** Species(S) =497.6924; Salinity levels (T) =192.7554; Interaction (SxT) = 862.029

Values given in parentheses ( ) show percent increase/decrease over respective controls

**Table 52: Total Dissolved Solids ( $\mu\text{S/ppm}$ ) in stem of different plants native to saline soils under various added salinity levels**

| S. No. | Name of Plant                    | S0<br>(0dSm <sup>-1</sup> ) | S1<br>(8dSm <sup>-1</sup> ) | S2<br>(16dSm <sup>-1</sup> ) | Mean        |
|--------|----------------------------------|-----------------------------|-----------------------------|------------------------------|-------------|
| 1      | <i>Portulaca oleracea</i>        | 0.94                        | 1.22<br>(28.71)             | 1.86<br>(96.68)              | <b>1.34</b> |
| 2      | <i>Trianthema portulacastrum</i> | 0.91                        | 1.13<br>(23.90)             | 1.75<br>(92.25)              | <b>1.27</b> |
| 3      | <i>Aerva tomentosa</i>           | 0.91                        | 1.10<br>(21.37)             | 1.65<br>(82.42)              | <b>1.22</b> |
| 4      | <i>Atriplex nummularia</i>       | 1.19                        | 1.89<br>(59.27)             | 2.19<br>(84.83)              | <b>1.76</b> |
| 5      | <i>Atriplex amnicola</i>         | 1.13                        | 1.75<br>(55.42)             | 2.19<br>(94.49)              | <b>1.69</b> |
| 6      | <i>Atriplex lentiformis</i>      | 1.21                        | 1.97<br>(62.41)             | 2.36<br>(94.56)              | <b>1.85</b> |
| 7      | <i>Chenopodium ambrosoides</i>   | 0.45                        | 0.79<br>(62.41)             | 0.83<br>(83.59)              | <b>0.69</b> |
| 8      | <i>Suaeda fruticosa</i>          | 1.53                        | 2.36<br>(54.25)             | 3.08<br>(101.53)             | <b>2.32</b> |
| 9      | <i>Salicornia brachiata</i>      | 1.85                        | 2.77<br>(49.91)             | 3.78<br>(104.14)             | <b>2.80</b> |
| 10     | <i>Solanum xanthocarpum</i>      | 0.66                        | 0.85<br>(28.92)             | 0.94<br>(42.57)              | <b>0.81</b> |
| 11     | <i>Xanthium strumarium</i>       | 0.54                        | 0.71<br>(31.91)             | 0.88<br>(62.34)              | <b>0.71</b> |
| 12     | <i>Sesbania sesquens</i>         | 0.55                        | 0.71<br>(30.52)             | 0.89<br>(62.45)              | <b>0.71</b> |
| 13     | <i>Heliotropium procumbens</i>   | 0.56                        | 0.60<br>(6.58)              | 0.90<br>(60.62)              | <b>0.69</b> |
| 14     | <i>Parkinsonia aculeata</i>      | 0.54                        | 0.71<br>(31.41)             | 0.87<br>(61.51)              | <b>0.70</b> |
| 15     | <i>Calotropis procera</i>        | 0.55                        | 0.71<br>(28.78)             | 0.86<br>(57.50)              | <b>0.71</b> |
| 16     | <i>Prosopis juliflora</i>        | 0.55                        | 0.71<br>(28.74)             | 0.87<br>(57.79)              | <b>0.71</b> |
| 17     | <i>Arundo donax</i>              | 0.80                        | 0.93<br>(17.53)             | 1.42<br>(78.62)              | <b>1.05</b> |
| 18     | <i>Aleurops lagopoides</i>       | 0.72                        | 0.91<br>(27.37)             | 1.34<br>(87.62)              | <b>0.99</b> |
| 19     | <i>Cynodon dactylon</i>          | 0.69                        | 0.88<br>(27.96)             | 1.21<br>(76.10)              | <b>0.93</b> |
| 20     | <i>Setaria indica</i>            | 0.53                        | 0.69<br>(30.49)             | 0.86<br>(62.18)              | <b>0.69</b> |
|        | Mean                             | <b>0.84</b>                 | <b>1.17</b>                 | <b>1.54</b>                  |             |

**CD (P=0.05):** Species(S) =0.139; Salinity levels (T) =0.054; Interaction (S x T) = 0.241

Values given in parentheses ( ) show percent increase/decrease over respective controls

**Table 53: Total Dissolved Solids ( $\mu\text{S/ppm}$ ) in leaves of different plants native to saline soils under various added salinity levels**

| S. No. | Name of Plant                    | S0<br>(0dSm <sup>-1</sup> ) | S1<br>(8dSm <sup>-1</sup> ) | S2<br>(16dSm <sup>-1</sup> ) | Mean        |
|--------|----------------------------------|-----------------------------|-----------------------------|------------------------------|-------------|
| 1      | <i>Portulaca oleracea</i>        | 1.01                        | 1.88<br>(86.82)             | 2.11<br>(109.67)             | <b>1.67</b> |
| 2      | <i>Trianthema portulacastrum</i> | 0.98                        | 1.75<br>(79.71)             | 1.95<br>(100.20)             | <b>1.56</b> |
| 3      | <i>Aerva tomentosa</i>           | 0.95                        | 1.51<br>(59.39)             | 1.79<br>(88.95)              | <b>1.42</b> |
| 4      | <i>Atriplex nummularia</i>       | 1.21                        | 2.26<br>(87.10)             | 2.52<br>(108.60)             | <b>2.00</b> |
| 5      | <i>Atriplex amnicola</i>         | 1.24                        | 2.15<br>(73.39)             | 2.72<br>(119.62)             | <b>2.04</b> |
| 6      | <i>Atriplex lentiformis</i>      | 1.27                        | 2.31<br>(81.15)             | 2.82<br>(121.73)             | <b>2.13</b> |
| 7      | <i>Chenopodium ambrosoides</i>   | 0.71                        | 0.85<br>(19.23)             | 0.93<br>(31.12)              | <b>0.83</b> |
| 8      | <i>Suaeda fruticosa</i>          | 1.57                        | 2.47<br>(57.54)             | 3.24<br>(106.37)             | <b>2.43</b> |
| 9      | <i>Salicornia brachiata</i>      | -                           | -                           | -                            | -           |
| 10     | <i>Solanum xanthocarpum</i>      | 0.76                        | 0.89<br>(18.40)             | 0.95<br>(25.15)              | <b>0.87</b> |
| 11     | <i>Xanthium strumarium</i>       | 0.63                        | 0.73<br>(15.90)             | 0.88<br>(40.69)              | <b>0.74</b> |
| 12     | <i>Sesbania sesquens</i>         | 0.65                        | 0.73<br>(13.02)             | 0.90<br>(39.58)              | <b>0.76</b> |
| 13     | <i>Heliotropium procumbens</i>   | 0.65                        | 0.73<br>(12.26)             | 0.89<br>(37.18)              | <b>0.76</b> |
| 14     | <i>Parkinsonia aculeata</i>      | 0.63                        | 0.73<br>(16.07)             | 0.87<br>(39.02)              | <b>0.74</b> |
| 15     | <i>Calotropis procera</i>        | 0.65                        | 0.73<br>(13.18)             | 0.88<br>(36.30)              | <b>0.75</b> |
| 16     | <i>Prosopis juliflora</i>        | 0.63                        | 0.74<br>(15.97)             | 0.88<br>(38.08)              | <b>0.75</b> |
| 17     | <i>Arundo donax</i>              | 0.88                        | 1.44<br>(62.64)             | 1.54<br>(73.96)              | <b>1.29</b> |
| 18     | <i>Aleurops lagopoides</i>       | 0.86                        | 1.39<br>(61.51)             | 1.45<br>(68.47)              | <b>1.24</b> |
| 19     | <i>Cynodon dactylon</i>          | 0.86                        | 1.26<br>(47.02)             | 1.35<br>(57.92)              | <b>1.16</b> |
| 20     | <i>Setaria indica</i>            | 0.62                        | 0.73<br>(17.37)             | 0.87<br>(41.10)              | <b>0.74</b> |
|        | Mean                             | <b>0.88</b>                 | <b>1.33</b>                 | <b>1.56</b>                  |             |

**CD (P=0.05):** Species(S) = 0.145; Salinity levels (T) = 0.058; Interaction (S x T) = 0.251

Values given in parentheses ( ) show percent increase/decrease over respective controls

**Table 54: Sodium Absorption Ratio (SAR) in soil after harvesting of different plants native to saline soils under various added salinity levels**

| S. No.                   | Name of Plant                    | S0<br>(0dSm <sup>-1</sup> ) | S1<br>(8dSm <sup>-1</sup> ) | S2<br>(16dSm <sup>-1</sup> ) | Mean         |
|--------------------------|----------------------------------|-----------------------------|-----------------------------|------------------------------|--------------|
| <b>Before plantation</b> |                                  | <b>7.79</b>                 | <b>29.72</b>                | <b>40.49</b>                 | <b>26.00</b> |
| 1                        | <i>Portulaca oleracea</i>        | 6.95                        | 31.03<br>(346.36)           | 41.84<br>(501.94)            | <b>26.60</b> |
| 2                        | <i>Trianthema portulacastrum</i> | 6.24                        | 30.97<br>(396.62)           | 41.46<br>(564.80)            | <b>26.22</b> |
| 3                        | <i>Aerva tomentosa</i>           | 6.91                        | 30.95<br>(348.09)           | 41.21<br>(496.79)            | <b>26.36</b> |
| 4                        | <i>Atriplex nummularia</i>       | 6.41                        | 31.11<br>(385.60)           | 41.43<br>(546.55)            | <b>26.32</b> |
| 5                        | <i>Atriplex amnicola</i>         | 6.00                        | 30.84<br>(413.77)           | 39.93<br>(565.14)            | <b>25.59</b> |
| 6                        | <i>Atriplex lentiformis</i>      | 6.44                        | 30.41<br>(372.54)           | 41.90<br>(551.06)            | <b>26.25</b> |
| 7                        | <i>Chenopodium ambrosoides</i>   | 6.90                        | 29.40<br>(325.91)           | 40.77<br>(490.50)            | <b>25.69</b> |
| 8                        | <i>Suaeda fruticosa</i>          | 6.78                        | 31.23<br>(360.40)           | 42.07<br>(520.14)            | <b>26.70</b> |
| 9                        | <i>Salicornia brachiata</i>      | 7.28                        | 30.09<br>(313.18)           | 42.38<br>(481.98)            | <b>26.58</b> |
| 10                       | <i>Solanum xanthocarpum</i>      | 7.08                        | 30.25<br>(327.32)           | 41.12<br>(480.80)            | <b>26.15</b> |
| 11                       | <i>Xanthium strumarium</i>       | 6.84                        | 30.38<br>(344.03)           | 40.96<br>(498.79)            | <b>26.06</b> |
| 12                       | <i>Sesbania sesquens</i>         | 6.65                        | 30.35<br>(356.14)           | 40.85<br>(513.97)            | <b>25.95</b> |
| 13                       | <i>Heliotropium procumbens</i>   | 6.66                        | 30.60<br>(359.66)           | 41.31<br>(520.40)            | <b>26.19</b> |
| 14                       | <i>Parkinsonia aculeata</i>      | 6.84                        | 30.72<br>(348.99)           | 40.88<br>(497.51)            | <b>26.15</b> |
| 15                       | <i>Calotropis procera</i>        | 6.62                        | 29.93<br>(351.97)           | 40.92<br>(517.79)            | <b>25.82</b> |
| 16                       | <i>Prosopis juliflora</i>        | 7.02                        | 30.28<br>(331.11)           | 41.04<br>(484.35)            | <b>26.12</b> |
| 17                       | <i>Arundo donax</i>              | 7.06                        | 30.73<br>(335.31)           | 41.11<br>(482.33)            | <b>26.30</b> |
| 18                       | <i>Aelurops lagopoides</i>       | 6.86                        | 30.39<br>(342.76)           | 41.40<br>(503.02)            | <b>26.22</b> |
| 19                       | <i>Cynodon dactylon</i>          | 7.00                        | 30.55<br>(336.25)           | 41.30<br>(489.79)            | <b>26.29</b> |
| 20                       | <i>Setaria indica</i>            | 6.59                        | 29.84<br>(352.61)           | 40.97<br>(521.48)            | <b>25.80</b> |
|                          | Mean                             | <b>6.76</b>                 | <b>30.50</b>                | <b>41.24</b>                 |              |

**CD (P=0.05):** Species(S) = N.S.; Salinity levels (T) = 0.316; Interaction (S x T) = N.S.

Values given in parentheses ( ) show percent increase/decrease over respective controls

**Table 55: Cation Exchange Capacity (CEC) after harvesting of different plants native to saline soils under various added salinity levels**

| S. No.                   | Name of Plant                    | S0<br>(0dSm <sup>-1</sup> ) | S1<br>(8dSm <sup>-1</sup> ) | S2<br>(16dSm <sup>-1</sup> ) | Mean        |
|--------------------------|----------------------------------|-----------------------------|-----------------------------|------------------------------|-------------|
| <b>Before plantation</b> |                                  | <b>2.13</b>                 | <b>2.13</b>                 | <b>2.13</b>                  | <b>2.13</b> |
| 1                        | <i>Portulaca oleracea</i>        | 2.14                        | 2.14                        | 2.14                         | <b>2.14</b> |
| 2                        | <i>Trianthema portulacastrum</i> | 2.13                        | 2.13                        | 2.13                         | <b>2.13</b> |
| 3                        | <i>Aerva tomentosa</i>           | 2.13                        | 2.13                        | 2.13                         | <b>2.13</b> |
| 4                        | <i>Atriplex nummularia</i>       | 2.14                        | 2.14                        | 2.14                         | <b>2.14</b> |
| 5                        | <i>Atriplex amnicola</i>         | 2.13                        | 2.13                        | 2.13                         | <b>2.13</b> |
| 6                        | <i>Atriplex lentiformis</i>      | 2.14                        | 2.14                        | 2.14                         | <b>2.14</b> |
| 7                        | <i>Chenopodium ambrosoides</i>   | 2.12                        | 2.12                        | 2.12                         | <b>2.12</b> |
| 8                        | <i>Suaeda fruticosa</i>          | 2.14                        | 2.14                        | 2.14                         | <b>2.14</b> |
| 9                        | <i>Salicornia brachiata</i>      | 2.14                        | 2.14                        | 2.14                         | <b>2.14</b> |
| 10                       | <i>Solanum xanthocarpum</i>      | 2.13                        | 2.13                        | 2.13                         | <b>2.13</b> |
| 11                       | <i>Xanthium strumarium</i>       | 2.13                        | 2.13                        | 2.13                         | <b>2.13</b> |
| 12                       | <i>Sesbania sesquens</i>         | 2.13                        | 2.13                        | 2.13                         | <b>2.13</b> |
| 13                       | <i>Heliotropium procumbens</i>   | 2.13                        | 2.13                        | 2.13                         | <b>2.13</b> |
| 14                       | <i>Parkinsonia aculeata</i>      | 2.13                        | 2.13                        | 2.13                         | <b>2.13</b> |
| 15                       | <i>Calotropis procera</i>        | 2.14                        | 2.14                        | 2.14                         | <b>2.14</b> |
| 16                       | <i>Prosopis juliflora</i>        | 2.12                        | 2.12                        | 2.12                         | <b>2.12</b> |
| 17                       | <i>Arundo donax</i>              | 2.14                        | 2.14                        | 2.14                         | <b>2.14</b> |
| 18                       | <i>Aleurops lagopoides</i>       | 2.13                        | 2.13                        | 2.13                         | <b>2.13</b> |
| 19                       | <i>Cynodon dactylon</i>          | 2.14                        | 2.14                        | 2.14                         | <b>2.14</b> |
| 20                       | <i>Setaria indica</i>            | 2.13                        | 2.13                        | 2.13                         | <b>2.13</b> |
|                          | Mean                             | <b>2.13</b>                 | <b>2.13</b>                 | <b>2.13</b>                  |             |

**CD (P=0.05):** Species(S)=N.S.; Salinity levels (T) = N.S; Interaction (S x T) = N.S

Values given in parentheses ( ) show percent increase/decrease over respective controls

**Table 56: pH of soil after harvesting of different plants native to saline soils under various added salinity levels**

| S. No.                   | Name of Plant                    | S0<br>(0dSm <sup>-1</sup> ) | S1<br>(8dSm <sup>-1</sup> ) | S2<br>(16dSm <sup>-1</sup> ) | Mean        |
|--------------------------|----------------------------------|-----------------------------|-----------------------------|------------------------------|-------------|
| <b>Before plantation</b> |                                  | <b>7.34</b>                 | <b>7.72</b>                 | <b>8.29</b>                  | <b>7.78</b> |
| 1                        | <i>Portulaca oleracea</i>        | 7.04                        | 7.56<br>(7.44)              | 8.19<br>(16.39)              | <b>7.60</b> |
| 2                        | <i>Trianthema portulacastrum</i> | 7.08                        | 7.57<br>(6.92)              | 8.20<br>(15.82)              | <b>7.62</b> |
| 3                        | <i>Aerva tomentosa</i>           | 7.11                        | 7.60<br>(6.89)              | 8.21<br>(15.47)              | <b>7.64</b> |
| 4                        | <i>Atriplex nummularia</i>       | 6.90                        | 7.53<br>(9.08)              | 8.17<br>(18.35)              | <b>7.53</b> |
| 5                        | <i>Atriplex amnicola</i>         | 6.95                        | 7.55<br>(8.63)              | 8.15<br>(17.31)              | <b>7.55</b> |
| 6                        | <i>Atriplex lentiformis</i>      | 6.89                        | 7.53<br>(9.29)              | 8.15<br>(18.34)              | <b>7.52</b> |
| 7                        | <i>Chenopodium ambrosoides</i>   | 7.26                        | 7.60<br>(5.70)              | 8.20<br>(13.05)              | <b>7.71</b> |
| 8                        | <i>Suaeda fruticosa</i>          | 6.84                        | 7.48<br>(9.36)              | 8.12<br>(18.71)              | <b>7.48</b> |
| 9                        | <i>Salicornia brachiata</i>      | 6.87                        | 7.50<br>(9.12)              | 8.14<br>(18.43)              | <b>7.50</b> |
| 10                       | <i>Solanum xanthocarpum</i>      | 7.28                        | 7.60<br>(4.40)              | 8.23<br>(13.05)              | <b>7.70</b> |
| 11                       | <i>Xanthium strumarium</i>       | 7.31                        | 7.69<br>(5.20)              | 8.24<br>(12.72)              | <b>7.75</b> |
| 12                       | <i>Sesbania sesquens</i>         | 7.30                        | 7.68<br>(5.21)              | 8.25<br>(13.01)              | <b>7.74</b> |
| 13                       | <i>Heliotropium procumbens</i>   | 7.30                        | 7.66<br>(4.93)              | 8.23<br>(12.74)              | <b>7.73</b> |
| 14                       | <i>Parkinsonia aculeata</i>      | 7.22                        | 7.67<br>(6.23)              | 8.25<br>(14.27)              | <b>7.71</b> |
| 15                       | <i>Calotropis procera</i>        | 7.31                        | 7.69<br>(5.25)              | 8.24<br>(12.77)              | <b>7.75</b> |
| 16                       | <i>Prosopis juliflora</i>        | 7.32                        | 7.68<br>(4.92)              | 8.25<br>(12.70)              | <b>7.75</b> |
| 17                       | <i>Arundo donax</i>              | 7.14                        | 7.62<br>(6.72)              | 8.22<br>(15.13)              | <b>7.66</b> |
| 18                       | <i>Aleurops lagopoides</i>       | 7.20                        | 7.63<br>(5.97)              | 8.23<br>(14.35)              | <b>7.69</b> |
| 19                       | <i>Cynodon dactylon</i>          | 7.22                        | 7.64<br>(5.82)              | 8.23<br>(13.99)              | <b>7.70</b> |
| 20                       | <i>Setaria indica</i>            | 7.32                        | 7.69<br>(5.05)              | 8.25<br>(12.70)              | <b>7.75</b> |
|                          | Mean                             | <b>7.14</b>                 | <b>7.61</b>                 | <b>8.21</b>                  |             |

**CD (P=0.05) :** Species(S) =0.0849 ; Salinity levels (T) =0.0329 ; Interaction (SxT) =0.147

Values given in parentheses ( ) show percent increase/decrease over respective controls

**Table 57: ECe of soil after harvesting of different plants native to saline soils under various added salinity levels**

| S. No.                   | Name of Plant                    | S0<br>(0dSm <sup>-1</sup> ) | S1<br>(8dSm <sup>-1</sup> ) | S2<br>(16dSm <sup>-1</sup> ) | Mean        |
|--------------------------|----------------------------------|-----------------------------|-----------------------------|------------------------------|-------------|
| <b>Before plantation</b> |                                  | <b>1.12</b>                 | <b>8.22</b>                 | <b>16.30</b>                 | <b>8.55</b> |
| 1                        | <i>Portulaca oleracea</i>        | 0.60                        | 7.62<br>(1170.00)           | 15.70<br>(2516.67)           | <b>7.97</b> |
| 2                        | <i>Trianthema portulacastrum</i> | 0.62                        | 7.64<br>(1132.26)           | 15.73<br>(2437.10)           | <b>8.00</b> |
| 3                        | <i>Aerva tomentosa</i>           | 0.64                        | 7.67<br>(1098.44)           | 15.75<br>(2360.94)           | <b>8.02</b> |
| 4                        | <i>Atriplex nummularia</i>       | 0.54                        | 7.56<br>(1300.00)           | 15.68<br>(2803.70)           | <b>7.93</b> |
| 5                        | <i>Atriplex amnicola</i>         | 0.55                        | 7.58<br>(1278.18)           | 15.67<br>(2749.09)           | <b>7.93</b> |
| 6                        | <i>Atriplex lentiformis</i>      | 0.53                        | 7.55<br>(1324.53)           | 15.66<br>(2854.09)           | <b>7.91</b> |
| 7                        | <i>Chenopodium ambrosoides</i>   | 0.74                        | 7.85<br>(960.81)            | 15.89<br>(2047.30)           | <b>8.16</b> |
| 8                        | <i>Suaeda fruticosa</i>          | 0.50                        | 7.42<br>(1384.00)           | 15.56<br>(3012.00)           | <b>7.83</b> |
| 9                        | <i>Salicornia brachiata</i>      | 0.52                        | 7.50<br>(1342.31)           | 15.64<br>(2907.69)           | <b>7.89</b> |
| 10                       | <i>Solanum xanthocarpum</i>      | 0.70                        | 7.75<br>(1007.14)           | 15.80<br>(2157.14)           | <b>8.08</b> |
| 11                       | <i>Xanthium strumarium</i>       | 0.85                        | 7.84<br>(822.35)            | 15.94<br>(1774.90)           | <b>8.21</b> |
| 12                       | <i>Sesbania sesquens</i>         | 0.82                        | 7.86<br>(858.54)            | 15.96<br>(1846.34)           | <b>8.21</b> |
| 13                       | <i>Heliotropium procumbens</i>   | 0.76                        | 7.81<br>(927.63)            | 15.99<br>(2003.95)           | <b>8.19</b> |
| 14                       | <i>Parkinsonia aculeata</i>      | 0.87                        | 7.89<br>(806.90)            | 15.95<br>(1733.33)           | <b>8.24</b> |
| 15                       | <i>Calotropis procera</i>        | 0.78                        | 7.85<br>(906.41)            | 15.98<br>(1948.72)           | <b>8.20</b> |
| 16                       | <i>Prosopis juliflora</i>        | 0.83                        | 7.88<br>(849.40)            | 16.00<br>(1827.71)           | <b>8.24</b> |
| 17                       | <i>Arundo donax</i>              | 0.67                        | 7.73<br>(1054.23)           | 15.76<br>(2252.24)           | <b>8.05</b> |
| 18                       | <i>Aleurops lagopoides</i>       | 0.66                        | 7.72<br>(1063.82)           | 15.78<br>(2278.89)           | <b>8.05</b> |
| 19                       | <i>Cynodon dactylon</i>          | 0.65                        | 7.75<br>(1092.31)           | 15.82<br>(2333.85)           | <b>8.07</b> |
| 20                       | <i>Setaria indica</i>            | 0.86                        | 7.90<br>(818.60)            | 16.01<br>(1762.02)           | <b>8.26</b> |
|                          | Mean                             | <b>0.68</b>                 | <b>7.72</b>                 | <b>15.81</b>                 |             |

**CD (P=0.05) :** Species(S) =0.137; Salinity levels (T) =0.053; Interaction (SxT) = N.S.

Values given in parentheses ( ) show percent increase/decrease over respective controls

**Table 58: Percent (%) decrease in E<sub>C</sub>e of soil after harvesting of different plants native to saline soils under various added salinity levels**

| S. No. | Name of Plant                    | S0<br>(0dSm <sup>-1</sup> ) | S1<br>(8dSm <sup>-1</sup> ) | S2<br>(16dSm <sup>-1</sup> ) | Mean         |
|--------|----------------------------------|-----------------------------|-----------------------------|------------------------------|--------------|
| 1      | <i>Portulaca oleracea</i>        | 46.00                       | 7.21                        | 3.68                         | <b>18.96</b> |
| 2      | <i>Trianthema portulacastrum</i> | 43.40                       | 6.96                        | 3.50                         | <b>17.95</b> |
| 3      | <i>Aerva tomentosa</i>           | 41.69                       | 6.59                        | 3.38                         | <b>17.22</b> |
| 4      | <i>Atriplex nummularia</i>       | 50.42                       | 7.94                        | 3.80                         | <b>20.72</b> |
| 5      | <i>Atriplex amnicola</i>         | 50.19                       | 7.69                        | 3.85                         | <b>20.58</b> |
| 6      | <i>Atriplex lentiformis</i>      | 51.90                       | 8.06                        | 3.94                         | <b>21.30</b> |
| 7      | <i>Chenopodium ambrosoides</i>   | 32.42                       | 4.40                        | 2.51                         | <b>13.11</b> |
| 8      | <i>Suaeda fruticosa</i>          | 54.91                       | 9.62                        | 4.54                         | <b>23.02</b> |
| 9      | <i>Salicornia brachiata</i>      | 53.20                       | 8.66                        | 4.05                         | <b>21.97</b> |
| 10     | <i>Solanum xanthocarpum</i>      | 36.02                       | 5.62                        | 3.07                         | <b>14.90</b> |
| 11     | <i>Xanthium strumarium</i>       | 17.56                       | 4.52                        | 2.22                         | <b>8.10</b>  |
| 12     | <i>Sesbania sesquens</i>         | 20.58                       | 4.28                        | 2.08                         | <b>8.98</b>  |
| 13     | <i>Heliotropium procumbens</i>   | 31.42                       | 4.89                        | 1.89                         | <b>12.73</b> |
| 14     | <i>Parkinsonia aculeata</i>      | 21.03                       | 3.91                        | 2.14                         | <b>9.03</b>  |
| 15     | <i>Calotropis procera</i>        | 23.64                       | 4.41                        | 1.94                         | <b>10.00</b> |
| 16     | <i>Prosopis juliflora</i>        | 19.63                       | 4.11                        | 1.84                         | <b>8.53</b>  |
| 17     | <i>Arundo donax</i>              | 39.34                       | 5.81                        | 3.31                         | <b>16.15</b> |
| 18     | <i>Aleurops lagopoides</i>       | 39.56                       | 6.08                        | 3.17                         | <b>16.27</b> |
| 19     | <i>Cynodon dactylon</i>          | 40.74                       | 5.62                        | 2.94                         | <b>16.44</b> |
| 20     | <i>Setaria indica</i>            | 21.98                       | 3.88                        | 1.74                         | <b>9.20</b>  |
|        | Mean                             | <b>36.78</b>                | <b>6.01</b>                 | <b>2.98</b>                  |              |

**CD (P=0.05) :** Species(S) =9.0918; Salinity levels (T) =3.5212; Interaction (SxT) = N.S.

Values given in parentheses ( ) show percent increase/decrease over respective controls

**Table 59: Percent (%) remediation in terms of total estimated ionic accumulation after harvesting the plants in comparison to total estimated ionic accumulation under various added salinity levels before plantation**

| S. No. | Name of Plant                    | S0<br>(0dSm <sup>-1</sup> ) | S1<br>(8dSm <sup>-1</sup> ) | S2<br>(16dSm <sup>-1</sup> ) | Mean         |
|--------|----------------------------------|-----------------------------|-----------------------------|------------------------------|--------------|
| 1      | <i>Portulaca oleracea</i>        | 31.76                       | 12.15                       | 5.15                         | <b>16.35</b> |
| 2      | <i>Trianthema portulacastrum</i> | 32.30                       | 11.56                       | 4.87                         | <b>16.25</b> |
| 3      | <i>Aerva tomentosa</i>           | 29.03                       | 10.95                       | 4.56                         | <b>14.85</b> |
| 4      | <i>Atriplex nummularia</i>       | 36.49                       | 13.48                       | 5.36                         | <b>18.44</b> |
| 5      | <i>Atriplex amnicola</i>         | 35.70                       | 13.05                       | 5.81                         | <b>18.19</b> |
| 6      | <i>Atriplex lentiformis</i>      | 36.17                       | 14.10                       | 6.04                         | <b>18.77</b> |
| 7      | <i>Chenopodium ambrosoides</i>   | 28.81                       | 8.13                        | 3.84                         | <b>13.59</b> |
| 8      | <i>Suaeda fruticosa</i>          | 35.21                       | 15.09                       | 7.31                         | <b>19.20</b> |
| 9      | <i>Salicornia brachiata</i>      | 38.94                       | 16.36                       | 7.92                         | <b>21.08</b> |
| 10     | <i>Solanum xanthocarpum</i>      | 28.54                       | 10.23                       | 4.07                         | <b>14.28</b> |
| 11     | <i>Xanthium strumarium</i>       | 24.25                       | 10.71                       | 3.60                         | <b>12.85</b> |
| 12     | <i>Sesbania sesquens</i>         | 23.99                       | 7.29                        | 3.55                         | <b>11.61</b> |
| 13     | <i>Heliotropium procumbens</i>   | 26.70                       | 7.95                        | 3.57                         | <b>12.74</b> |
| 14     | <i>Parkinsonia aculeata</i>      | 25.72                       | 7.60                        | 3.60                         | <b>12.31</b> |
| 15     | <i>Calotropis procera</i>        | 24.39                       | 6.55                        | 3.54                         | <b>11.49</b> |
| 16     | <i>Prosopis juliflora</i>        | 23.38                       | 7.84                        | 3.70                         | <b>11.64</b> |
| 17     | <i>Arundo donax</i>              | 34.84                       | 11.35                       | 4.88                         | <b>17.02</b> |
| 18     | <i>Aleurops lagopoides</i>       | 32.78                       | 11.16                       | 4.76                         | <b>16.24</b> |
| 19     | <i>Cynodon dactylon</i>          | 29.81                       | 10.76                       | 4.53                         | <b>15.03</b> |
| 20     | <i>Setaria indica</i>            | 20.31                       | 6.52                        | 3.19                         | <b>10.01</b> |
|        | Mean                             | <b>29.96</b>                | <b>10.64</b>                | <b>4.69</b>                  |              |

**CD (P=0.05) :** Species(S) =3.2658; Salinity levels (T) =1.2649; Interaction (SxT) = N.S.

Values given in parentheses ( ) show percent increase/decrease over respective controls

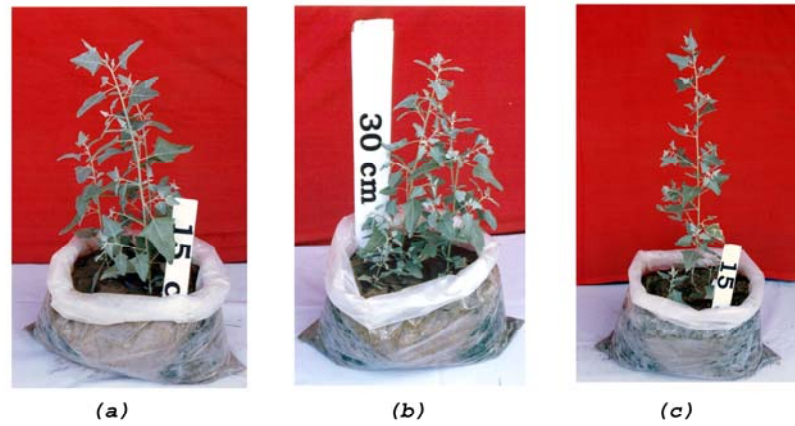


Fig. 14: *Atriplex lentiformis* growing in the screen house in polythene bags containing varying salinity levels i.e. (a) 0-, (b) 8- and (c) 16- dSm<sup>-1</sup> respectively

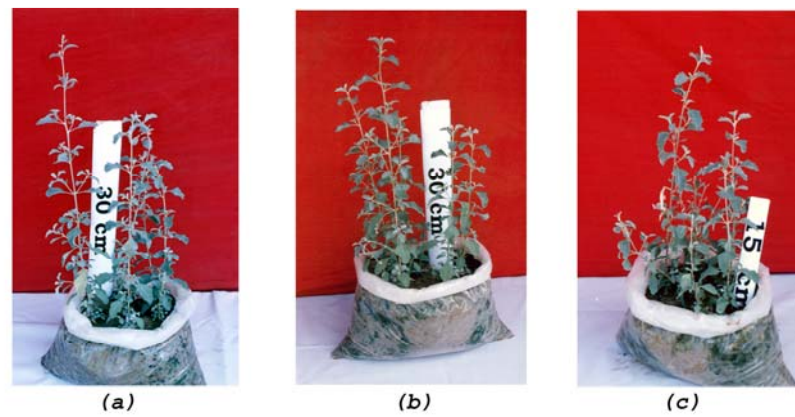


Fig. 13: *Atriplex nummularia* growing in the screen house in polythene bags containing varying salinity levels i.e. (a) 0-, (b) 8- and (c) 16- dSm<sup>-1</sup> respectively

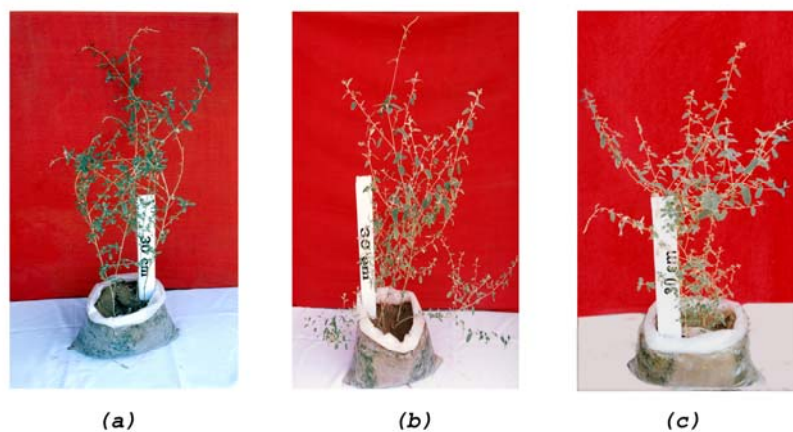


Fig. 11: *Chenopodium ambrosioides* growing in the screen house in polythene bags containing varying salinity levels i.e. (a) 0-, (b) 8- and (c) 16- dSm<sup>-1</sup> respectively

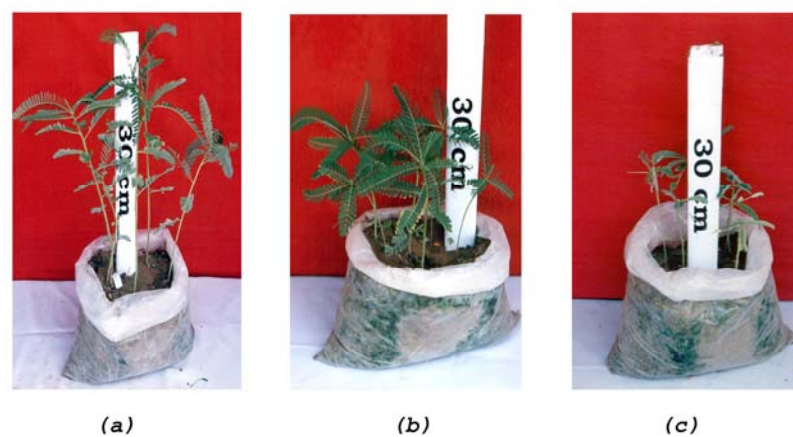


Fig. 3: *Sesbenia sesquens* growing in the screen house in polythene bags containing varying salinity levels i.e. (a) 0-, (b) 8- and (c) 16- dSm<sup>-1</sup> respectively

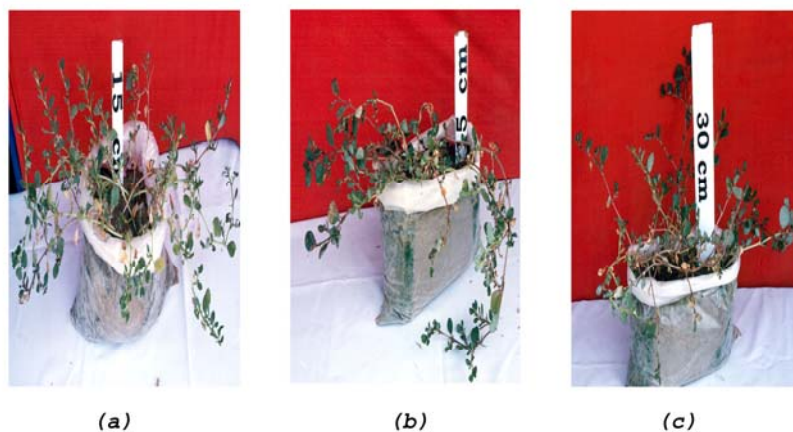


Fig. 1: *Trianthema portulacastrum* growing in the screen house in polythene bags containing varying salinity levels i.e. (a) 0, (b) 8 and (c) 16 dSm<sup>-1</sup> respectively

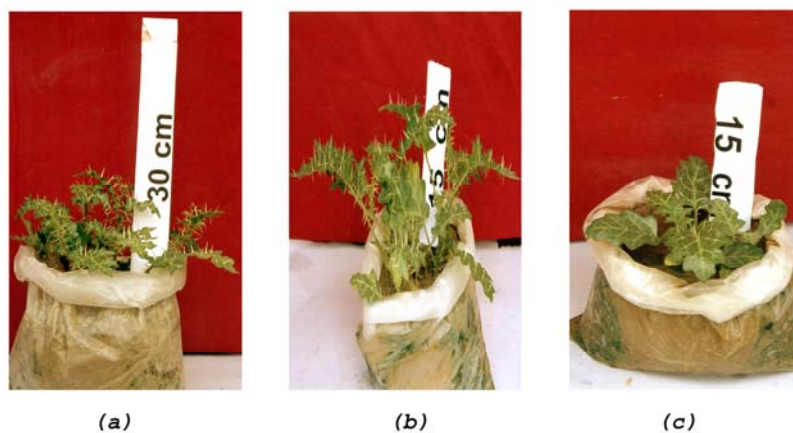


Fig. 5: *Solanum xanthocarpum* growing in the screen house in polythene bags containing varying salinity levels i.e. (a) 0-, (b) 8- and (c) 16- dSm<sup>-1</sup> respectively

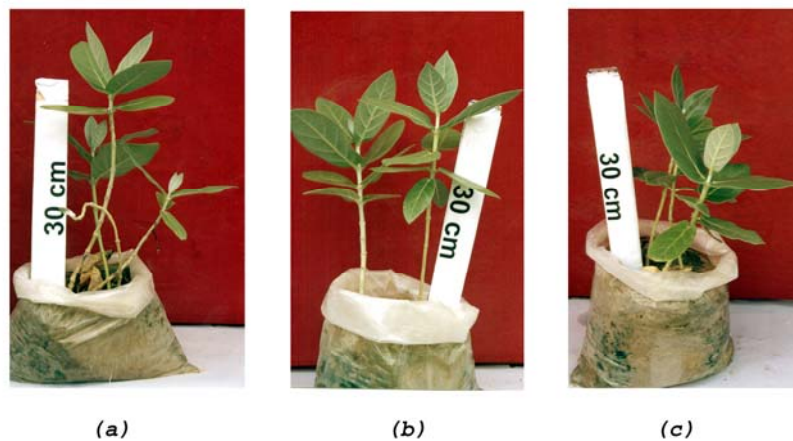


Fig. 12: *Calotropis procera* growing in the screen house in polythene bags containing varying salinity levels i.e. (a) 0-, (b) 8- and (c) 16- dSm<sup>-1</sup> respectively

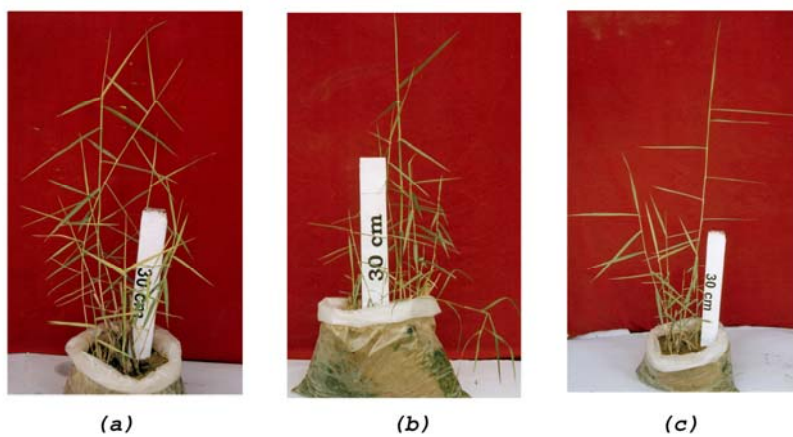


Fig. 6: *Arundo donax* growing in the screen house in polythene bags containing varying salinity levels i.e. (a) 0-, (b) 8- and (c) 16- dSm<sup>-1</sup> respectively

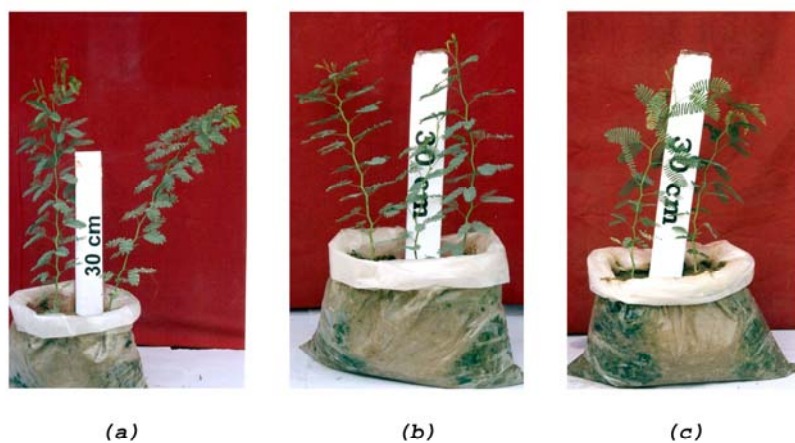


Fig. 19: *Prosopis juliflora* growing in the screen house in polythene bags containing varying salinity levels i.e. (a) 0-, (b) 8- and (c) 16- dSm<sup>-1</sup> respectively

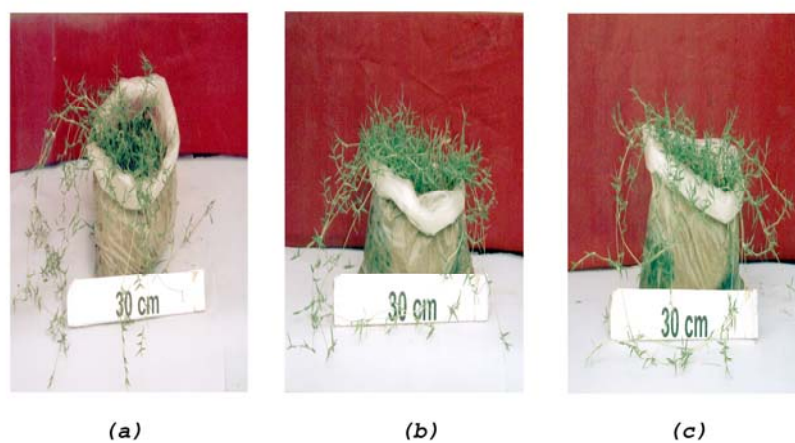


Fig. 9: *Aleurops langopoides* from near Sambhar Lake (Rajasthan) growing in the screen house in polythene bags containing varying salinity levels i.e. (a) 0-, (b) 8- and (c) 16- dSm<sup>-1</sup> respectively

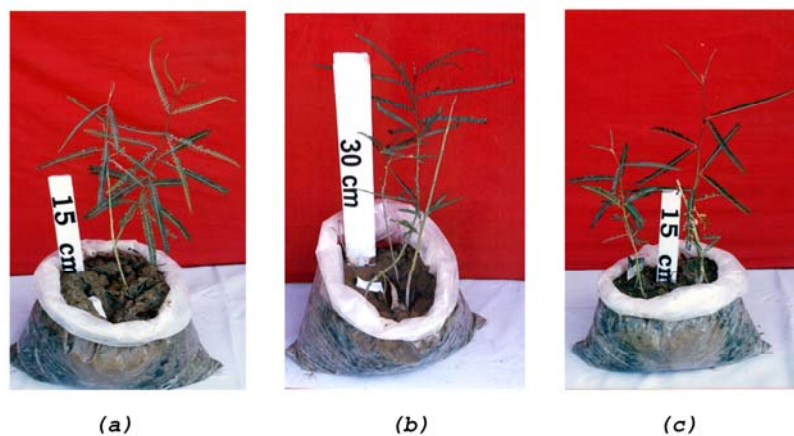


Fig. 18: *Parkinsonia aculeata* growing in the screen house in polythene bags containing varying salinity levels i.e. (a) 0-, (b) 8- and (c) 16- dSm<sup>-1</sup> respectively

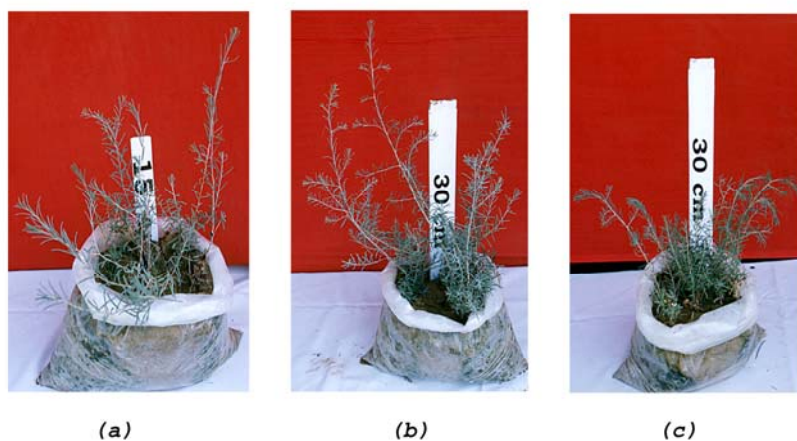


Fig. 17: *Suaeda frutescens* growing in the screen house in polythene bags containing varying salinity levels i.e. (a) 0-, (b) 8- and (c) 16- dSm<sup>-1</sup> respectively

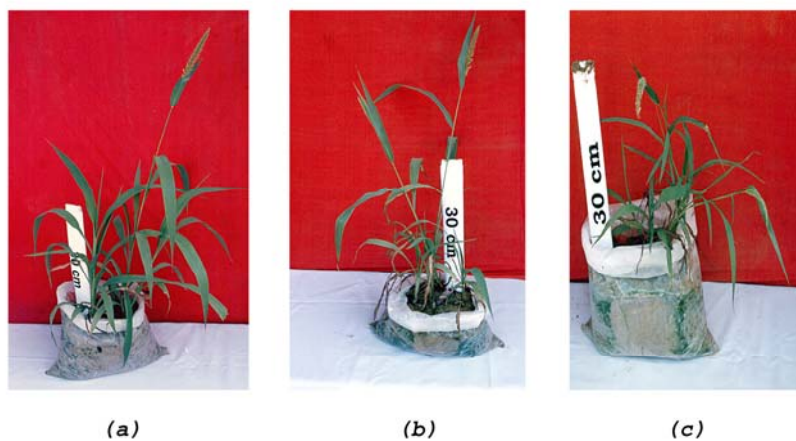


Fig. 7: *Setaria indica* growing in the screen house in polythene bags containing varying salinity levels i.e. (a) 0-, (b) 8- and (c) 16- dSm<sup>-1</sup> respectively

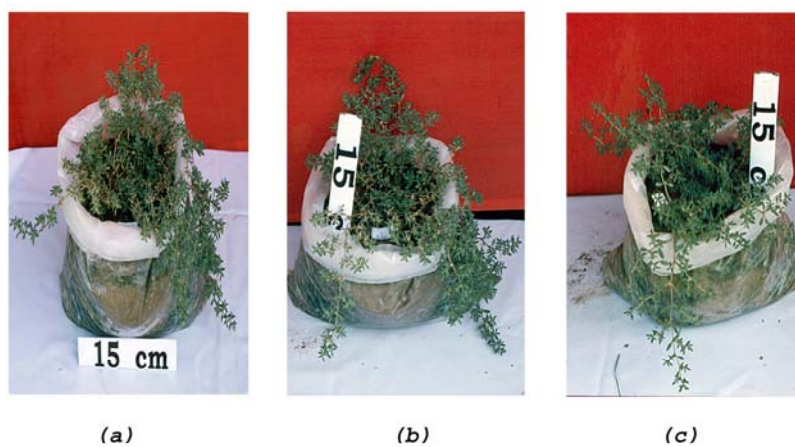


Fig. 2: *Portulaca oleracea*, growing in the screen house in polythene bags containing varying salinity levels i.e. (a) 0-, (b) 8- and (c) 16- dSm<sup>-1</sup> respectively

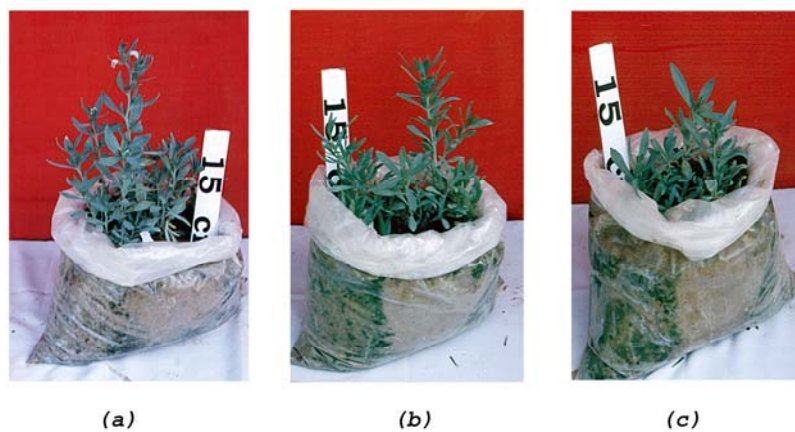


Fig. 4: *Heliotropium procumbens* growing in the screen house in polythene bags containing varying salinity levels i.e. (a) 0-, (b) 8- and (c) 16- dSm<sup>-1</sup> respectively

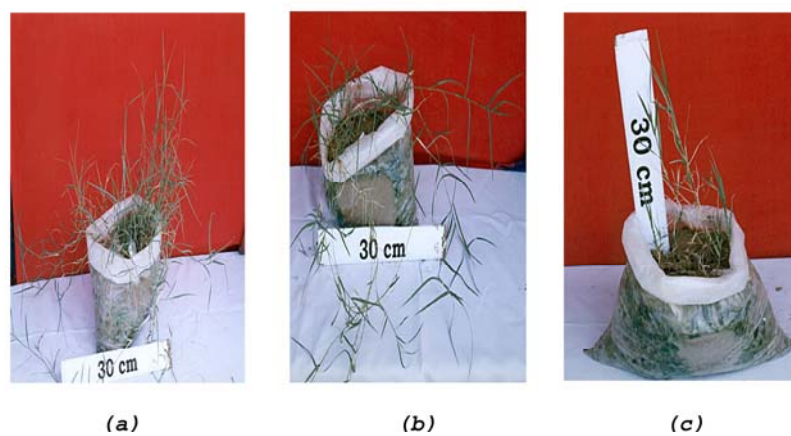


Fig. 8: *Cynodon dactylon* growing in the screen house in polythene bags containing varying salinity levels i.e. (a) 0-, (b) 8- and (c) 16- dSm<sup>-1</sup> respectively

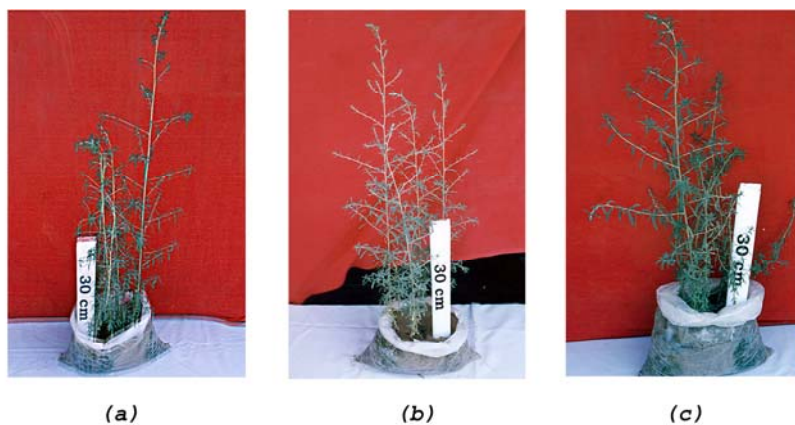


Fig. 10: *Aerva tomentosa* growing in the screen house in polythene bags containing varying salinity levels i.e. (a) 0-, (b) 8- and (c) 16- dSm<sup>-1</sup> respectively

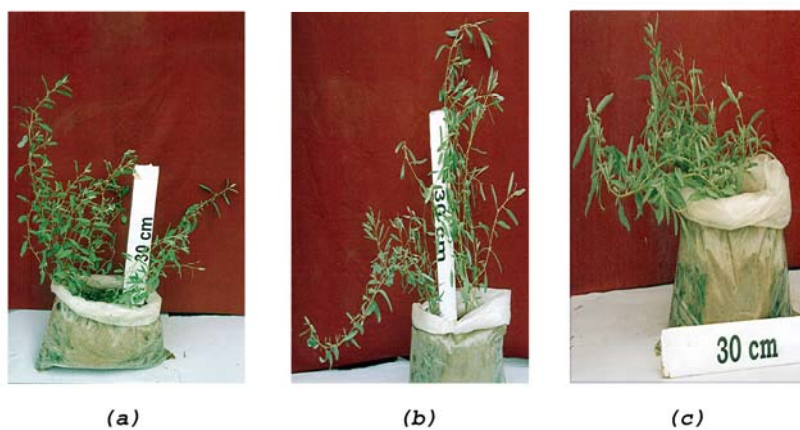


Fig. 15: *Atriplex amnicola* growing in the screen house in polythene bags containing varying salinity levels i.e. (a) 0-, (b) 8- and (c) 16- dSm<sup>-1</sup> respectively

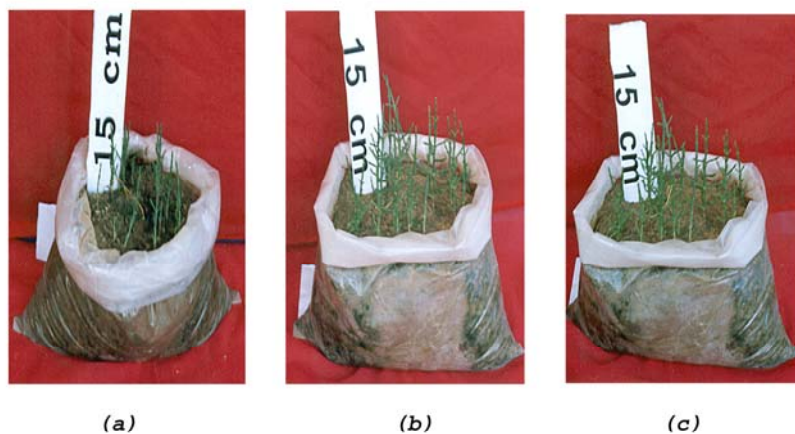
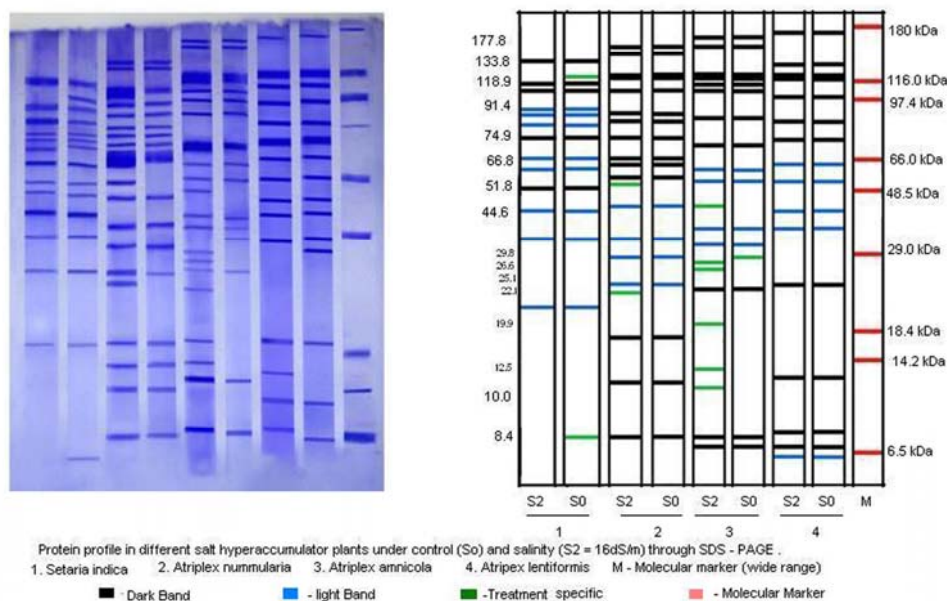
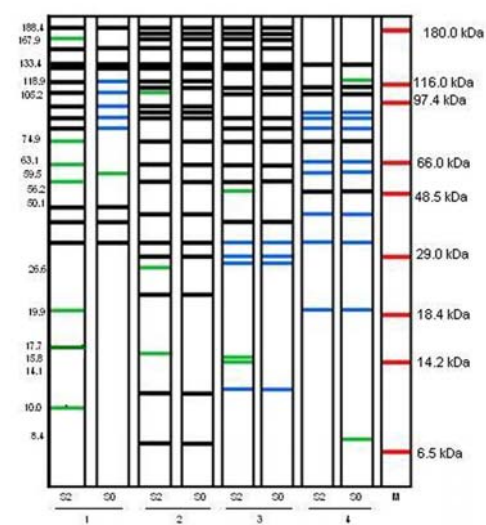


Fig. 16: *Salicornia brachiata* growing in the screen house in polythene bags containing varying salinity levels i.e. (a) 0-, (b) 8- and (c) 16- dSm<sup>-1</sup> respectively





Protein profile in different salt hyperaccumulator plants under salinity (S2 = 16dS/m) and control (S0) through SDS - PAGE .

1. Chenopodium ambrosioides

2. Portulaca oleracea

3. Suaeda fruticosa

4. Setaria indica

M - Molecular Marker

■ - Dark Band

■ - Light Band

■ - Treatment specific Band

■ - Molecular Marker



*Acacia ampliceps* Maslin



*Acacia colei* Maslin & L.A.J. Tomson



*Aerva tomentosa* Forsk.



*Aleurops lagopoides* (Linn.) Trin. ex Thw.



*Alternanthera pungens* H.B. & K.



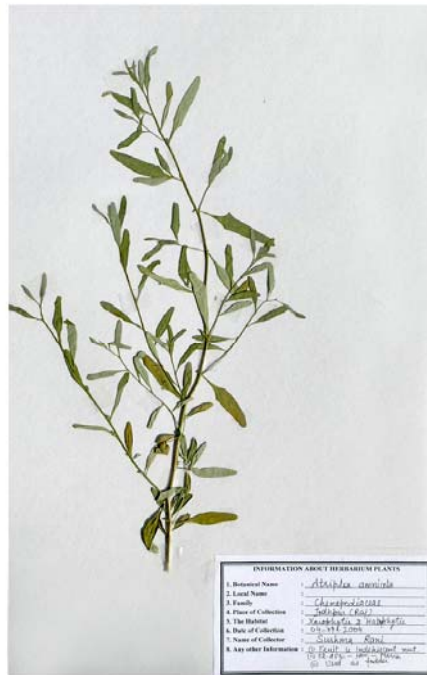
*Amaranthus viridis* Hook.f.



*Aristida adscensionis* Linn.



*Arundo donax* Linn.



*Atriplex amnicola* Linn.



*Atriplex lentiformis* (Torr.) S. Wats.



*Atriplex nummularia* Lindl.



*Calotropis procera* (Ait.) R. Br.



*Capparis aphylla* Roth.



*Chenopodium ambrosioides* Linn.



*Chenopodium murale* Linn.



*Cyanodon dactylon* (Linn.) Pers.



*Cyperus bulbosus* Vahl



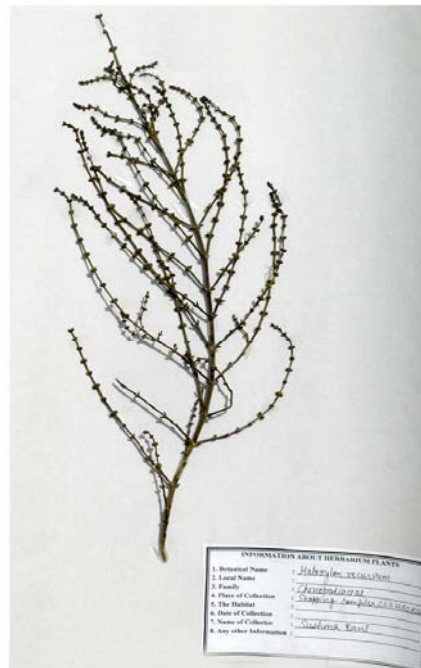
*Dactyloctenium aegyptium* (Linn.) Beauv.



*Eragrostis pilosa* (Linn.) Beauv.



*Eriochloa procera* (Retz.) C.E. Hubb.



*Haloxylon recurvum* (Moq.) Bunge ex Bion



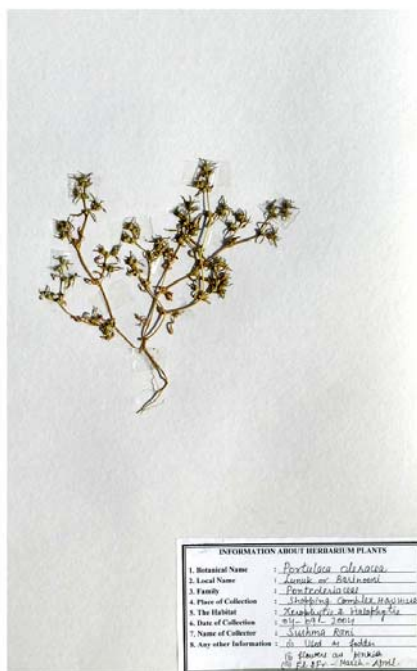
*Heliotropium procumbens* Mill.



*Parkinsonia aculeata* Linn.



*Physalis minima* Linn.



*Portulaca oleracea* Linn.



*Prosopis juliflora* (Sw.) DC.



*Salsola baryosma* (Roem&Rchult) Dandy



*Salvadora persica* Linn.



*Sesbania sesquens* Merr.



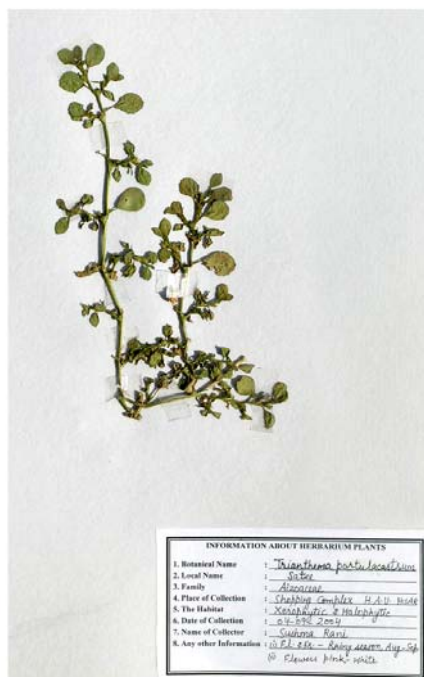
*Setaria indica* Linn. (Beauv.)



*Suaeda fruticosa* (Linn.) Forsk.



*Tamarix aphylla* Lanza



*Trianthema portulacastrum* Linn.



*Vernonia cinerea* (Linn.) Less.



*Xanthium strumarium* Linn.