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OSMOTIC POTENTIAL IN THE LEAF SAP OF HALOPHYTES IN INDIAN ARID ZONE

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In the present investigation an attempt has been made to estimate round the year pattern in osmotic potential of the halophytes collected from two different sites, *viz.* Pachpadra (saline site-I) and Jodhpur (nonsaline site-II). The results obtained reveal that osmotic potential in halophytes always remained higher during dry period and lower in moist period. In *Salsola baryosma* the highest value ranged between -61.5 to -107.5 bars at site-I and -70.0 to -110.0 bars at site-II. The fluctuations in values are directly influenced by the variations in soil moisture and salinity levels.

Key Words : Osmotic potential, halophytes, soil moisture, stress, water balance, inland salines.

Salinity, water and temperature are among the most critical factors of the environment in determining the vegetation pattern of a region. The saline areas under investigation are of the inland type and differ greatly from other saline areas in vegetation make-up; they support a relatively small number of plant species, namely those capable of tolerating the high degree of salinity levels, known as halophytes. In saline pockets, only halophytes can grow and survive. They grow under high salinity and exhibit succulence, which is helpful in physiological adaptations to overcome the high soil salinity. This extreme tolerance to salinity is related to their ability to maintain a high salt concentration within the cells. In deserts salinity is often very prominent, caused by the input of sodium chloride (NaCl) and other salts for a long period of time and lack of drainage. On such saline soils very often typical associations dominated by Chenopodiaceae develop along salt gradients (Breckle, 1986).

In saline environment, soil and its components exert multiple effects on the growth behaviour of plants. Out of many factors, high salt contents exhibit a prominent effect on plants through their increased osmotic concentrations. A critical aspect in determining the success of halophyte species in saline environment is their ability to lower water potentials, sufficiently to maintain normal water uptake relationship (Waisel, 1972). Increased osmotic stress due to drought and the high rate of evaporation during the summer months may cause rapid changes in the density and diversity of species in halophyte communities (Ungar, 1974). Seasonal precipitation is often a major factor determining soil water potentials. This factor in turn affects the establishment of seedlings, often increasing the rate of mortality during drought periods (Ungar, 1973). The main difficulty with which desert plants are confronted is to maintain a favourable balance between absorption and transpiration mechanisms under adverse conditions of environment. Thus, comparative studies on osmotic potentials of some halophytes of this region have been undertaken at saline site-I (Pachpadra) and nonsaline site-II (Jodhpur) to determine the monthly variations in plant water balance in relation to the available soil moisture.

MATERIALS AND METHODS

The present studies were conducted throughout the year depending on the availability of plants at saline site-I [Electric conductivity (EC) ranges from 3.2-13.0 mmhos/cm at 1:5 soil-water extracts] and nonsaline site-II (EC: 0.18-2.1 mmhos/cm). For the present studies, *Salsola baryosma* (Roem. et Schult.) Dandy, *Sesuvium sesuvioides* (Fenzl.) Verdc., *Suaeda fruticosa* (Linn.) Forsk., and *Trianthema triquetra* Rottler ex Willd. at both the sites, while *Cressa cretica* Linn. and *Zygophyllum simplex* Linn. only at site-I were selected. With the termination of the monsoon, *S. sesuvioides* disappeared after completing its life cycle in November and December at sites-I and II, respectively. Likewise, *T. triquetra* and *Z. simplex* at site-I, also disappeared as they completed

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their life cycle in December and February, respectively. The observations were recorded in the middle of every month. The leaf samples were taken from the same plant/plants as far as possible from a particular locality to minimize the variability in sample selection. Osmotic potential of leaves was determined according to Janardhan *et al.* (1975). For this, 1 g of fresh leaf material was ground to paste, strained through muslin cloth and made the final volume upto 25 ml by adding distilled water. The electric conductivity (EC) of cell sap was measured with the help of Systronics Conductivity Meter. The osmotic potential (-bars) of the cell sap was calculated as follows :

$$\text{Osmotic Potential (- bars)} = \frac{\text{EC} \times 0.36 \times \text{d.f.}}{0.987}$$

EC = Electric conductivity in mmhos/cm of plant extract at 25°C temperature

$$\text{d.f.} = \text{Dilution factor} = \frac{25 \text{ ml (filtrate)} \times \text{fresh weight (1 g)}}{\text{Moisture content in 1 g}}$$

0.987 = Factors for converting atmospheric pressure into bars

For soil moisture, soil samples were collected every month from soil surface and 20 cm depth at both the sites. The soil moisture has been calculated as suggested by Pandeya *et al.* (1968). The data were statistically analyzed after Gomez and Gomez (1984).

OBSERVATIONS

(A) Osmotic Potential (-bars) : The data in leaves of selected plants are presented in Fig 1. The lowest value (-20 bars) was obtained for *S. sesuvioides* at site-I in July, while at site-II it was -34.5 bars in *T. triquetra* in January. In *S. baryosma* it was highest, i.e., -107.5 and -110.0 bars at sites -I & II, respectively. In December, it was -90.0 bars in *S. fruticosa* at site-I and -77.5 at site-II in April. The high values in leaves were due to continuous uptake of soluble ions by plants.

In *C. cretica* lowest (-30.0 bars) value was found at site-I in May which increased gradually till December and decreased thereafter in January. An increasing trend was again observed, which reached to its maximum (-85.0 bars) in April (Fig. 1).

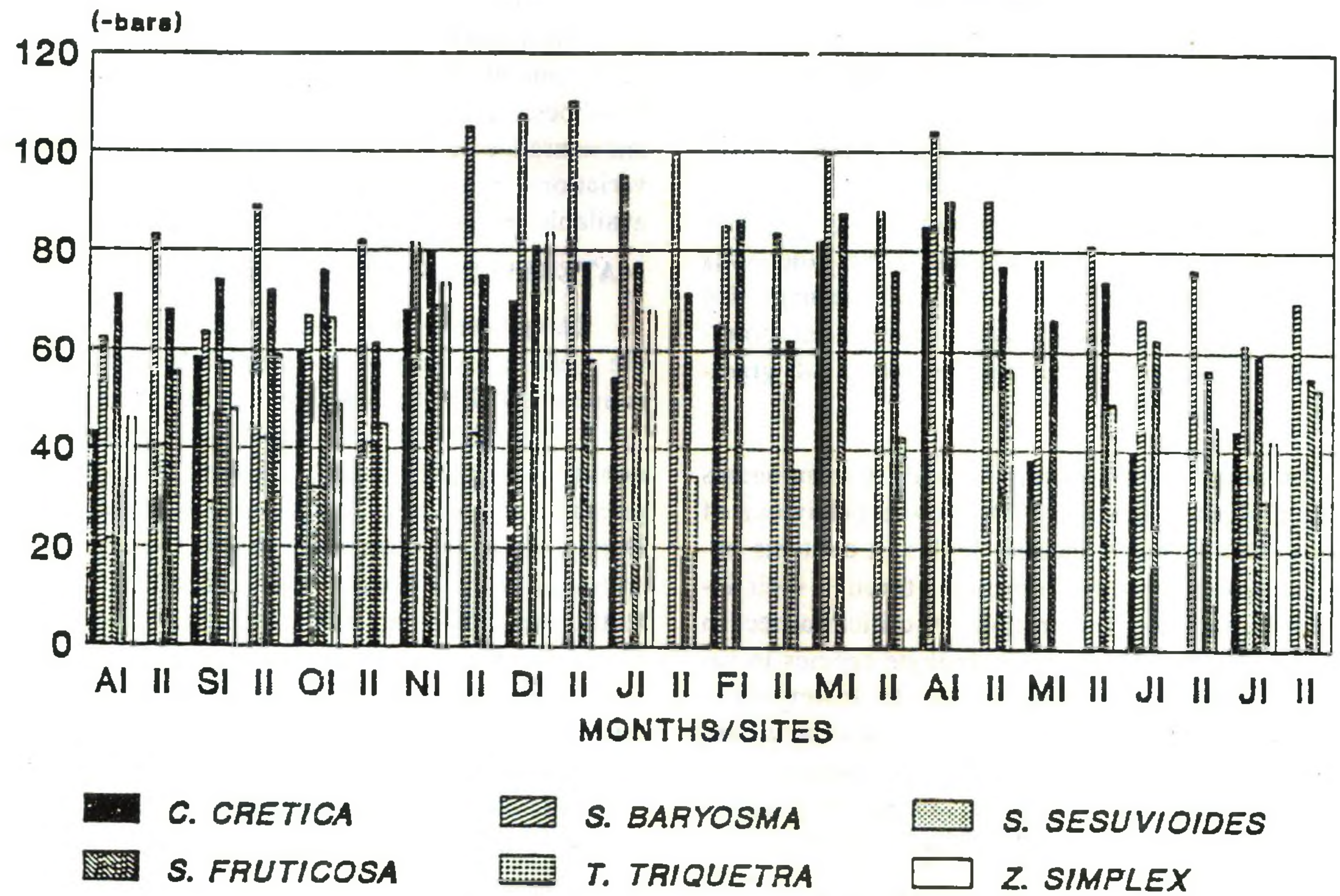


Figure 1. Showing monthly variations in OP (– bars) of halophytes at site I & II

S. baryosma at site-I exhibited minimum (-61.5 bars) value in July which increased gradually and reached to its maximum (-107.5) in December. Thereafter, it decreased in January-February and further increased till April followed by a gradual fall and reached to a minimum level in July. At site-II, the minimum (-70.0) value was seen in July, which increased in August-September. A slight fall was recorded in October, thereafter it increased gradually and a maximum (-110.0) value was recorded in December. A slight fall was seen in January-February, which increased in March-April and again declined from May onwards.

S. sesuvioides at site-I showed minimum (-20.0 bars) value in July which increased gradually and reached to a maximum (-32.0) in October. However, this plant disappeared from site-I in November onwards. At site-II, minimum (-40.5) value was recorded in August, it increased in September followed by a slight decrease in October. A maximum (-43.0) value was observed in November.

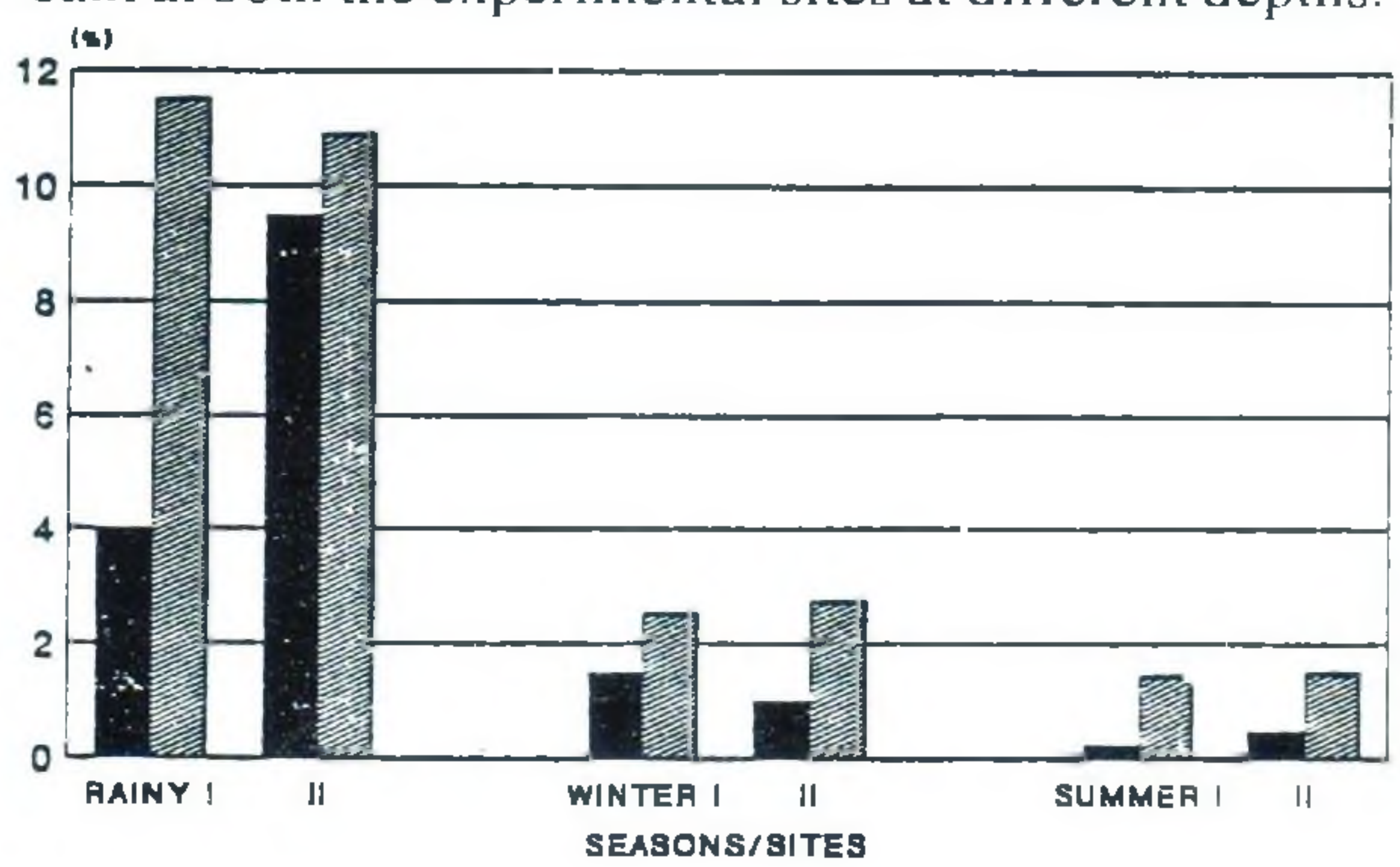
In *S. fruticosa* -87.5 bars value was recorded at site-I in March, which increased to -90.0 in April, followed by a gradual fall till July (-59.7). It increased slightly from August till December. It decreased again in January followed by an increase in February and thereafter. At site-II, the minimum (-55.0) value was observed in July. It increased til September, then it decreased in October. It again increased in November- December. A slight decrease was seen in January-February, followed by an increase in March-April. It started decreasing from May onward till July (Fig. 1).

T. triquetra showed minimum (-30.0) value in July, it increased gradually and reached to a maximum (-69.0) level in November at site-I. The plants started drying thereafter. At site-II, minimum (-34.5) value was reported in January. This value increased in the following months till April. Then this value decreased in May-June. It increased in July-September and reached to a maximum (-59.0) level in September. It decreased in October and again increased gradually till December.

Z. simplex showed low (-42.0 bars) value at site-I in July, which increased gradually and reached to its maximum (-83.5) level in December, followed by a decrease (-68.0) in January.

The data were significant at 5% probability level for all species at both the sites.

(B) Soil Moisture : Due to uncertain and erratic rainfall, soil moisture exhibited great variability throughout the experimental period. The soil moisture presented a similar pattern at both experimental sites, i.e. the moisture level was highest during monsoon period, which decreased later on (Fig. 2). The soil moisture content was low at the surface and high at 20 cm depth. The trend of moisture content showed that the soil moisture level decreased from post-monsoon period to winter season with a slight increase in January due to intermittent winter rains, thereafter it decreasd. Due to pre-monsoonal rains in May, the moisture content increased for a short period at both the sites-I & II. The data were significant at both the experimental sites at different depths.



0 CM 20 CM

Figure 2. Showing variation in soil moisture (%) at site I & II.

DISCUSSION

Monsoon rain is the only source of moisture to the vegetation in the desert of north-western Rajasthan. Although the monsoon season starts from mid-June and extends upto October, the rains are very erratic and scanty. The occurrence of a rather long intermission between successive rain showers, sometimes ranging from a few days to weeks, is not uncommon here. Whatever rainwater is retained by the soil is exploited by the roots of annual and perennial plants from June-July till October-November. After this, annual species start disappearing because of depletion of soil moisture in the upper soil layers and their inability to exploit moisture from the deeper soil layers due to shallow root system. By this time, perennial species also start showing various symptoms of water stress, which are very much reflected by a remarkable reduction in the transpiring surface. In arid zone the maximum soil moisture is recorded during monsoon season. The halophytic annuals such as *S. sesuvioides, T. triquetra* and *Z. simplex* disappear completely with the depletion of soil moisture during the post-monsoonal period. Winter showers and pre-monsoon rains, although scanty in quantity, play a significant role in improving the water status of soil and plants (Mohammed, 1988, 1995; Sen and Mohammed, 1994,1997).

The water and salt stress on halophytes is not constant but changes during the season. In order to survive under these changing conditions, halophytes must make changes in the osmotic potential in their tissues during the growing season. One of the distinguishing characteristics of halophytes from glycophytes is their capacity to accumulate selectively large quantities of ions in their cells without disrupting metabolic processes (Jefferies, 1981). A number of halophytes have been analyzed for their ionic contents (Ungar, 1991), and the most strongly accumulated ions were Na^+ and Cl^- with a few species having relatively high sulfate and K^+ concentrations. Albert and Popp (1986) concluded that the K^+ content was generally higher in monocotyledons and the Na^+ content in dicotyledons. At certain concentrations potassium is reported to inhibit the growth of halophytes such as *Suaeda* and *Atriplex,* while isomotic sodium promotes growth (Bhandal and Malik, 1988). Chellappan (1994) determined the mineral distribution in *Sesuvium portulacastrum* and found that Na^+ content increased significantly with increasing NaCl concentration.

Ion uptake by plants was largely dependent upon their availability in the soil. When these ions fluctuated in the soil by upward or downward movements, their uptake by plants was also affected (Waisel, 1972). Like soil salinity, the higher quantity of elements in plants was observed during dry periods in Indian arid zone (Mohammed, 1988). As the soil water potential increases due to the addition of salinity, the halophytes need to make more osmotic adjustments in order to maintain the movement of water into the tissues. Weber (1995) found the xylem pressure potentials in the shoots of *Atriplex triangularis* were correlated with the salinity around the roots.

In order to maintain lower water potentials within the cells, dicotyledonous halophytes normally make the necessary osmotic adjustment by adding Na^+ and Cl^- ions. In succulent halophytes, vacuolar concentrations of Na^+ and Cl^- generally exceed the external concentrations (Flowers, 1985). In the grasses, potassium and sugars are used to make the osmotic adjustment. However, in succulent halophytes, the major use of organic compounds such as vacuolar solutes seem to be precluded on the basis of energetic grounds (Weber, 1995).

In general, osmoregulation in a saline environment may utilize ions from the soil, whereas, under drought, in the absence of salinity, the necessary solutes may have to be produced within the plant. A clear distinction between the response of plants to water stress and salt stress emerges in terms of incomplete osmotic adjustment under water stress. Water stress and salt stress may have an additive effect in depressing growth. Osmotic adjustment or osmoregulation is achieved mainly by active or passive accumulation of salt(s) which may or may not be toxic, by release of K^+ from binding sites within the soil, or by means of non-toxic organic solutes synthesized by the plant such as simple sugars, polyols, proline, glycinebetaine, etc. Plants rarely show complete osmotic adjustment. In some species, only partial osmotic adjustment occurs, whereas in others over adjustment was observed. Probably the great majority of halophytes belong to the adjustable group (Krishnamoorthy, 1993), is also confirmed from our studies.

All the halophytic plant species studied here could also adjust themselves by changing their osmotic potentials rapidly with a greater range due to the change in osmotic potentials of surrounding soil. This is in accordance with Waisel (1972) who stated that it is probably true that the great majority of the halophytic plants belong to the adjustable group and that their osmotic adjustment occurs rapidly. Recovery from osmotic stress occurs faster in salt accumulating halophytes than in salt enduring ones (Greenway, 1968). Osmotic adjustment or osmoregulation enables plants to maintain growth as plant water potential decreases. Adjustment occurs through decrease in osmotic potential by solute accumulation as leaf water potential decreases, with the net results that the cell turgor potential is kept ralatively high, thus maintaining turgor dependent processes such as leaf growth and stomatal opening

(Sambo and Ashton, 1985). Further, it emerges from the present study that during the rainy season due to higher moisture in soil and leaching down of the salts, resulted in the decrease in osmotic potential of soil which led to the decreased osmotic potential of the plants. But with the increase in salt concentration and decrease in soil moisture, plants try to adjust themselves to drought by the accumulation of salts. Thus, the accumulation of salts in plants increased their osmotic potentials upto the level of highest stress, so that, plants were able to take maximum water during the hot summer, which resulted in the gradual increase in their osmotic potentials. Some plants which exhibited higher values of osmotic potentials during winter periods associated with low temperature or/and higher salinity level. Salts in the medium generally decreased the water availability to the roots, thus creating a situation of physiological drought. Osmoregulation enables plants to maintain growth as plant water potential decreases. Adjustment occurs through decrease in osmotic potential by solute accumulation in cell as leaf water potential decreases. The accumulation of high concentrations of proline in the leaves of halophytes under saline conditions suggests that it might have a role in osmotic adjustment (Sen and Mohammed, 1992). It is also observed in the present study that the fluctuations in the osmotic potential were associated with the variations in soil moisture and increase in salinity level in the soil.

REFERENCES

Albert R & M Popp 1986 Chemical composition of halophytes from the Neusiedler lake region in Australia. *Oecologia* **27** 157-170.

Bhandal T J & CP Malik 1988 Potassium estimation uptake and its role in the physiology and mechanism of flowering plant. *Int Rev Cytology* **110** 205-254.

Breckle S W 1986 Studies on halophytes from Iran and Afghanistan. III. Ecology of halophytes along salt gradients. *Proc Royal Bot Soc* Edinburgh **89 B** 203-215.

Chellappan K P 1994 Growth and mineral distribution of *Sesuvium portulacastrum* L., a salt marsh halophyte under sodium chloride stress. *Compendium of Soil Science Plant Analysis* **25** 2797-2805.

Flowers I J 1985 Physiology of halophytes. *Plant & Soil* **89** 41-56.

Gomez K A & A A Gomes 1984 *Statistical Procedures for Agricultural Research.* John Wiley & Sons, New York.

Greenway H 1968 Growth stimulation by high chloride concentration in halophytes. *Israel J Bot* **17** 169-177.

Janardhan K V, S P Murthy K Giriraj & S Panchaksharaih 1975 A rapid method for determination of osmotic potential of plant cell sap. *Curr Sci* **44** 390-391.

Jefferies R L 1981 Osmotic adjustment and the response of halophytic plants to salinity. *Bioscience* **31** 42-46.

Krishnamoorthy H N 1993 *Physiology of Plant Growth and Development,* Atma Ram & Sons, Delhi.

Mohammed S 1988 *Comparative Studies on Saline and Nonsaline Vegetation of Indian Arid Zone.* Ph D Thesis University of Jodhpur, Jodhpur, India.

Mohammed S 1995 Stomatal behaviour and water loss in halophytes of Indian arid zone. In: *Environment and Adaptive Biology of Plants,* Prof D N Sen Commemoration Volume (ed DD Chawan), Scientific Publishers, Jodhpur p 151-165.

Pandeya S C, G S Puri & J S Singh 1968 *Research Methods in Plant Ecology.* Asia Publication House Bombay.

Sambo E Y & M J Ashton 1985 Evidence for osmotic adjustment in *Phalaris tuberosa* L. cv. *Australian and Sirosa. Aust J Plant Physiol* **12** 481-486.

Sen D N & S Mohammed 1992 Proline accumulation in some halophytes in the Indian desert. In: *Role of Biotechnology in Agriculture* (eds B N Prasad G P S Ghimire and V P Agrawal) Oxford & IBH Publishing Co Pvt Ltd., New Delhi p 129-137.

Sen D N & S Mohammed 1994 General aspects of salinity and the biology of saline plants. In: *Handbook of Plant and Crop Stress* (ed M Pessarakali) Marcel Dekker Inc., New York, USA p 125-145.

Sen D N & S Mohammed 1997 Water relations of halophytes in Indian arid zone. In: *The Changing Landscape of Plant Sciences,* Prof S D Sabnis Felicitation Volume (ed M Daniel) Intern. Book Distributors, Dehra Dun p 283-298.

Ungar I A 1973 Salinity tolerance of inland halophytic vegetation of North America *Bull Soc Bot* **120** 217-222.

Ungar I A 1974 The effect of salinity and temperature on seed germination and growth of *Hordeum jubatum* L. *Can J Bot* **52** 1357-1362.

Ungar I A 1991 *Ecophysiology of Vascular Halophytes* CRC Press Ann Arbor. Michigan USA.

Waisel Y 1972 *Biology of Halophytes.* Academic Press New York

Weber D J 1995 Mechanisms and reactions to halophytes to water and salt stress. In: *Biology of Salt Tolerant Plants* (eds M A Khan and IA Ungar) Book Crafters, Michigan USA p 170-180.