Environment Conservation Journal 17(1&2), 119-135, 2016
ISSN 0972-3099 (Print) 2278-5124 (Online)
Abstracted and Indexed

Role of Calcium and Vegetation in salinity and desertification (Western India)

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Received: 15.02.2016 **Revised:21.04.2016** **Accepted: 15.05.2016**

Abstract

Excess salinity is one of the main factors for low productivity of land and desertification. To know the effect of salinity and sodicity on vegetation study was taken at Little Rann of Kutch (saline desert). Ca have positive since EC and Na have negative consequence on vegetation. Calcium enhances tolerance capacity for salinity/sodicity and diminishes their adverse effects on vegetation. Species found dominating were capable to tolerate high salinity/sodicity, temperature and low rainfall. 82 species representing 64 genera belonging to 25 families were recorded. Poaceae, Papilionaceae and Cyperaceae were dominant in herbs and Mimosaceae and Salvadoraceae in shrubs and trees. *Cyperus rotundus* Linn. (4.438 plants/m^2) and *Aeluropus lagopoides* (Linn.) (4.104 plants/m^2) were dominating in herbs and *Prosopis juliflora* (Sw.) (7.109 plants/10m^2) in shrubs and trees. Concentration of dominance and diversity indexes were very low. Sustainable management and novel indigenous plantation of species with high tolerance capacity should be made to enhance vegetation which will improve soil structure and help to combat salinity/sodicity and desertification.

Keywords: Calcium; Desert; Salinity; Sodicity; Soil; Vegetation

Introduction

Surplus quantity of salt in the soil/water badly affects soil and vegetation. Salinity in soil / water is one of the major stresses particularly in arid and semi-arid regions and harshly limit land productivity (de Oliveira *et. al.*, 2013). Almost 20% of the world's cultivated area and nearly half of the world's irrigated lands are affected by salinity (Zhu, 2001). The majority of this salt affected land has arisen from natural causes, from the addition of salts over long periods in arid and semi-arid zones (Rengasamy, 2002; Munns and Tester, 2008). Salinization is the augment of the soluble salt in the root zone of the soil while sodification is the increase of exchangeable sodium in the root zone of the soil. The two processes may operate concurrently and form saline-sodic soils. Salinity is a soil condition characterized by a high concentration of soluble salts such as NaCl. Soils are classified as saline when the EC is 4 dSm^{-1} or more (USDA-ARS, 2008), which is equivalent to approximately 40mM NaCl and generates an osmotic pressure of its detrimental effects are credited to a reduced osmotic potential of soil, specific ion toxicity, nutrient deficiency (Luo *et al.*, 2005; Bhattacharjee, 2008) and the consequence of these can be plant demise (Niu *et al.*, 1995; Yeo, 1998; Glenn *et al.*, 1999; Hasegawa *et al.*, 2000). Processes such as seed germination, seedling growth and vitality, vegetative growth, flowering and fruits are negatively affected by high salt concentration (Sairam and Tyagi, 2004). Plants cope by either avoiding or tolerating salt stress. Plants are either dormant during the saline condition or they prepare cellular adjustment to tolerate the saline environment (Yokoi *et. al.*, 2002). The interactions of salts with mineral may result in nutrient imbalances and deficiencies. The consequence of all these can ultimately lead to plant death as a result of reduced or detained growth and molecular damage (McCue and Hanson, 1990). The foremost task to achieve salt-tolerance is either to prevent or alleviate the damage, or to re-establish homeostatic conditions in stressful environment (Zhu, 2001). Saline soil is reclaimed by leaching *i.e.* by keeping the water table below the critical depth by drainage and to diminish the salt content in the root zone (Mahanta *et al.*, 2015). High salinity results in increased cytosolic Ca^{2+} that is transported from the apoplast and intracellular compartments (Lynch *et al.*, 1989; Knight *et al.*, 1997). Ca^{2+} function in salt adaptation, the resultant transient Ca^{2+} increase potentiates stress signal transduction and leads to salt adaptation (Perez-Prat *et al.*, 1992; Wimmers

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et al., 1992; Mendoza *et al.*, 1994; Knight *et al.*, 1997; Sanders *et al.*, 1999). Sodic soil can be reclaimed by Ca. The adsorbed Na^+ ions are exchanged against the Ca^{2+} ions, which is effectuated by applying Ca salts and leaching with water of a low SAR value (Kamphorst and Bolt, 1978; Wang *et al.*, 1998). Externally supplied Ca^{2+} reduces the toxic effects of NaCl, presumably by facilitating higher K^+/Na^+ selectivity (Cramer *et al.*, 1987; L¨auchli and Schubert, 1989; Liu and Zhu, 1997). To augment the reclamation process in the sodic soil, Ca^{2+} ions are directly or indirectly added to the soil system. Chemical amendments like gypsum is helpful to reduce swelling and dispersion of the soils and Ca^+ ions from the gypsum replace the Na^+ ions that are held on the clay surface (Mahanta *et al*., 2015). Calcium increases salinity tolerance and diminish the undesirable effects of saline conditions on vegetation (Jaleel *et al.*, 2007). High concentrations of salts have detrimental effects on plant growth (Garg and Gupta, 1997; Mer *et al.*, 2000; Vaghasiya *et al.*, 2015) and very high concentrations kill growing plants. Vegetation was affected negatively by Na^+ and positively by organic carbon, nitrogen, phosphorous and Ca^{2+} (Pilania and Panchal, 2014) and vegetation loss is also occurred due to unavailability of water and high concentration of salts (Pilania and Panchal, 2013; Vaghasiya *et al.*, 2015). The chief effect of salts on vegetation is, during increased osmotic pressure plants find it gradually more difficult to haul out water from the soil. This is the main cause of vegetative demur on saline areas, leading to many of the adverse environmental consequences of salinization of desert. Change in vegetation, either to dominance of additional salt tolerant species or through reduced growth of existing species, is frequently the first understandable signs of desert salinization trouble. These effects depend, mainly on seasonal conditions, plant growth and root zone salt levels varying according to rainfall pattern and the occurrence of periods of drying weather (Charman and Junor, 1989). Soil and vegetation are mutually supporting each other. Diverse aspects of soil influence vegetation of any vicinity (Pilania and Panchal, 2014). With this alarm, the study was conducted to know the effect of salinity and sodicity on vegetation at Little Rann of Kutch (saline desert).

Material and Methods

Study Area

Study area and collection of data

The main causes for land degradation and desertification are salinity, high temperature and low rainfall. To know the consequences of salinity/sodicity on vegetation, study was carried out at Little Rann of Kutch (Figure 1) also known as saline desert (22° 55" to 24° 35" North latitudes and 70° 30" to 71° 45" East longitudes).

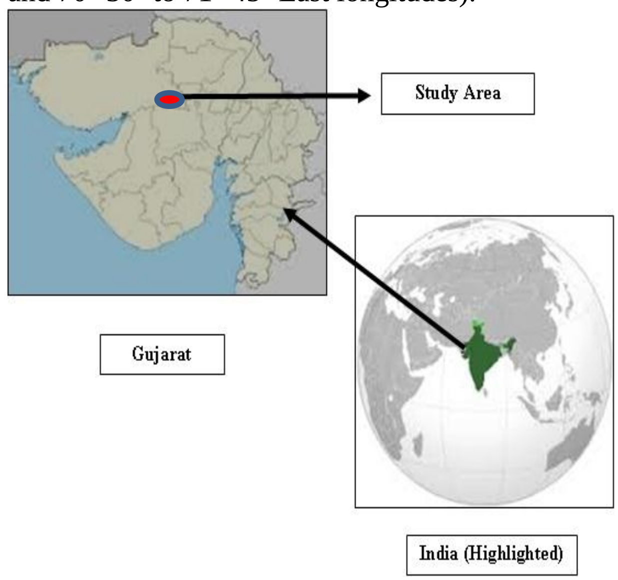

Figure 1: Little Rann of Kutch- Study Area

Field analysis and collection of data were done in the months of winter *i.e.* November to February covering an area of 8820 ha. Total 784 quadrates laid down, for herbs 1*1 m and for shrubs and trees 10*10 m. The size and the number of quadrates were determined by the species area curve (Misra, 1968) and the running mean method (Kershaw, 1973) respectively.

Vegetation analysis

The vegetation data were quantitatively analyzed for density, abundance and frequency Curtis and McIntosh, 1950. The relative values of frequency, density and dominance were obtained as per Phillips, 1959. Importance value index (IVI) of individual species was obtained as per (Curtis 1959; Misra 1968). Distribution patterns for different species were as per (Curtis and Cottam, 1956). The species diversity index (DI) for different sites was determined by using Shannon-Wiener information function ($\overline{H}$) (Shannon and Wiener, 1963). Concentration of dominance (CD) was computed by Simpson's index (Simpson, 1949). Soreason's similarity (similarity index) for herb, shrub and tree layer were obtained as per Magurran, 1988. Species richness (SR) was calculated following Margalef, 1958.

Herbaceous biomass

Monoliths of the 25 x 25 x 30 cm with intact plans were excavated randomly at each site. Plants were separated species wise and plant fractions were oven dried at 60^0 C to a constant weight.

Properties of Soil

Electrical Conductivity (**EC**) was measured by an E. C. meter (1:2 ratio). Sodium (**Na**) and Calcium (**Ca**) were measured (Lindsay and Norvell, 1978) by AAS (Atomic Absorbance Spectrophotometer).

Results and Discussion

Arid regions inhabit the interface between the generally well vegetated semiarid zones and the biologically unproductive hyper-arid deserts and are thought to be most vulnerable to global climate change (Ezcurra, 2006). In spite of the global consequence of these arid zones, slight is known about the soil and plant relationship of these areas and floral diversity.The main causes for low productivity of soil are salinity and sodicity at Little Rann of Kutch (LRK). Salinity (6.660 to 14.581dSm^{-1}) and sodium (60.435 to 137.310ppm) was found very high. The study was carried out to determine the effect of salinity and sodicity on vegetation. 64 genera consisting of 82 species were found; grasses (29 species), herbs (38 species), climbers (3 species), shrub (6 species) and trees (6 species). 25 families were found. Poaceae (29 species) followed by Papilionaceae, Cyperaceae, Convolvulaceae and Chenopodiaceae were dominant in herbs and Mimosaceae (3 species) and Salvadoraceae in shrubs and trees (Table 1). When land contains high concentration of solutes and there is no chance to flush out accumulated salts to drainage system, salts can quickly reach levels that are injurious to salt sensitive species. High concentrations of salts have detrimental effects on plant growth (Mer *et al*,. 2000; Vaghasiya *et al.*, 2015) and excessive concentrations kill growing plants (Donahue *et al.*, 1983).

As per earlier studies number of species reported at and nearby areas of LRK were; 19 species at Morbi district near LRK (Pilania *et al.*, 2014), 17 species at North part of LRK (Pilania and Panchal, 2014), 9 species at LRK near Maliya tehasil (Pilania and Panchal, 2013), 35 species at Great Rann of Kutch near the border of LRK (Vaghasiya *et al.*, 2015) and 12 species at South part of LRK (Pilania and Panchal, 2014a). Parejiya *et al.*, 2015 reported approx 20 species for each studied site at Bandiyabedi forest grassland of Surendranagar district in Gujarat (India) and Pilania *et al.*, (2014a) documented 65 species of 57 genera belonging to 31 families at Dahod district of Gujarat. Thar Desert comprises 682 plant species belonging to 350 genera and 87 families (Khan *et al.*, 2003; Mathur and Sundaramoorthy, 2013). Qureshi, 2008 reported 46 plant species with leading family Poaceae from Desert habitat of Nara Desert (Thar Desert). Chaudhary and Chuttar, 1966 reported 122 species from Thar Desert, Sindh. Rajput *et al*., 1991 reported 40 plant species (23 families) from Thar Desert. Bhatti *et al*., 1998-2001 reported 149 plant species (110 genera and 42 families) from Nara desert, a North-eastern part of greater Thar Desert. Parveen and Hussain, 2007 recorded 74 species belonging to 62 genera and 34 families from Gorakh hill (Khirthar range). Ghani and Amer, 2003 reported 203 species (129 genera and 29 families) in Sinai (coastal desert plain) which shows that LRK (saline desert) have low species richness. Floristic composition in the different geomorphologic landscape units showed differences in species richness (Ghani and Amer, 2003).

Herbs analysis:

Herbs species found were 12, 46, 9, 13 and 35 respectively at site 1 to 5. Density was found maximum for *C. ciliaris* (2.688 plants m^{-2}) at site 1, *A. lagopoides* (4.104 plants m^{-2}) at site 2, *C. cretica* (0.458 plants m^{-2}) at site 3, *A. adscensionis* (2.146 plants m^{-2}) at site 4 and *C. rotundus* (4.438 plants m^{-2}) at site 5 (Table 2). IVI was found maximum for *C. ciliaris* 57.880 (site 1), *A. lagopoides* 28.847 (site 2), *C. cretica* 56.853 (site 3), *A. adscensionis* 35.561 (site 4) and *C. rotundus* 28.803 (site 5). CD was found maximum on the base of density (0.015) at site 1, on the base of basal cover (0.016) and IVI

Table 1: Floral diversity at the studied area of Saline Desert

Sr. No.	SPECIES	FAMILY	HABIT
1	*Ipomoea pes-tigridis* Linn.	Convolvulaceae	Climbers
2	*Rivea hypocrateriformis* (Desr.) Choisy	Convolvulaceae	Climbers
3	*Mukia maderaspatana* (Linn.) M. Roem.	Cucurbitaceae	Climbers
4	*Aeluropus lagopoides* (Linn.) Trin.ex Thw	Poaceae	Grass
5	*Aristida adscensionis* Linn.	Poaceae	Grass
6	*Aristida hystrix* Thunb.	Poaceae	Grass
7	*Arundo donax* Linn.	Poaceae	Grass
8	*Brachiaria ramose* (Linn.) Stapf	Poaceae	Grass
9	*Cenchrus ciliaris* Linn.	Poaceae	Grass
10	*Cenchrus setigerus* Vahl	Poaceae	Grass
11	*Chloris barbata* Sw.	Poaceae	Grass
12	*Chloris virgata* Sw.	Poaceae	Grass
13	*Cynodon dactylon* (Linn.) Pers.	Poaceae	Grass
14	*Dactyloctenium aegyptium* (Linn.) Willd.	Poaceae	Grass
15	*Dactyloctenium sindicum* Boiss.	Poaceae	Grass
16	*Desmostachya bipinnata* (Linn.) Stapf	Poaceae	Grass
17	*Dichanthium glabrum* (Roxb.) Jain & Deshpande	Poaceae	Grass
18	*Digitaria ciliaris* (Retz.) Koel.	Poaceae	Grass
19	*Dinebra retroflexa* (Vahl) Panz.	Poaceae	Grass
20	*Echinochloa colona* (Linn.) Link	Poaceae	Grass
21	*Eragrostis ciliaris* (Linn.) R. Br.	Poaceae	Grass
22	*Eragrostis pilosa* (Thunb.) P. Beauv.	Poaceae	Grass
23	*Eragrostis tenella* (Linn.) P. Beauv. ex. R. & S.	Poaceae	Grass
24	*Eragrostis unioloides* (Retz.) Nees ex. Steud.	Poaceae	Grass
25	*Heteropogon contortus* (Linn.) P. Beauv.	Poaceae	Grass
26	*Melanocenchris jacquemontii* J. & S.	Poaceae	Grass
27	*Octhochloa compressa* (Forsk.) Hilu	Poaceae	Grass
28	*Panicum turgidum* Forsk.	Poaceae	Grass
29	*Saccharum spontaneum* Linn.	Poaceae	Grass
30	*Setaria intermedia* R. & S.	Poaceae	Grass
31	*Tetrapogon tenelius* (Koen. Ex Roxb.) Chiov.	Poaceae	Grass
32	*Urochondra setulosus* (Trin.) C.E. Hubb.	Poaceae	Grass
33	*Abutilon indicum* (Linn.) Sw.	Malvaceae	Herb
34	*Alysicarpus tetragonolobus* Edgew.	Papilionaceae	Herb
35	*Argemone mexicana* Linn.	Papaveraceae	Herb
36	*Aristolochia bracteolate* Lam.	Aristolochiaceae	Herb
37	*Arthrocnemum indicum* (Willd.) Moq.	Chenopodiaceae	Herb
38	*Boerhavia diffusa* Linn.	Nyctanginaceae	Herb
39	*Bulbostylis barbata* (Rottl.) Cl.	Cyperaceae	Herb
40	*Calotropis procera* (Aiton)	Apocynaceae	Herb
41	*Commelina diffusa* Burn. f.	Commelinaceae	Herb

Sr. No.	SPECIES	FAMILY	HABIT
42	*Convolvulus prostrates* Forsk.	Convolvulaceae	Herb
43	*Corchorus fascicularis* Lam.	Tiliaceae	Herb
44	*Cressa cretica* Linn.	Convolvulaceae	Herb
45	*Crotalaria burhia* Buch. Ham. ex Benth.	Papilionaceae	Herb
46	*Crotalaria hebecarpa* (DC.) Rudd	Papilionaceae	Herb
47	*Crotalaria medicaginea* Lam.	Papilionaceae	Herb
48	*Cyperus bulbosus* Vahl	Cyperaceae	Herb
49	*Cyperus compressus* Linn.	Cyperaceae	Herb
50	*Cyperus nutans* Linn.	Cyperaceae	Herb
51	*Cyperus rotundus* Linn.	Cyperaceae	Herb
52	*Datura metel* Linn.	Solanaceae	Herb
53	*Digera muricata* (Linn.) Mart.	Amaranthaceae	Herb
54	*Eriophorum comosum* (Wall.) Wall. ex. Nees	Cyperaceae	Herb
55	*Euphorbia hirta* Linn.	Euphorbiaceae	Herb
56	*Fagonia schweinfurthi* (Hadidi) Hadidi ex Ghafoor	Zygophyllaceae	Herb
57	*Heliotropium ovalifolium* Forsk.	Boraginaceae	Herb
58	*Heliotropium supinum* Linn.	Boraginaceae	Herb
59	*Indigofera cordifolia* Heyne ex Roth	Papilionaceae	Herb
60	*Phyllanthus fraternus* Webster	Euphorbiaceae	Herb
61	*Rhynchosia minima* (Linn.) DC.	Papilionaceae	Herb
62	*Rikliella squarrosa* (Linn.) Raynal	Cyperaceae	Herb
63	*Senna italic* Mill. subsp. *micrantha* Brenan	Papilionaceae	Herb
64	*Solanum virginianum* L.	Solanaceae	Herb
65	*Spermacoce pusilla* Wall.	Rubiaceae	Herb
66	*Suaeda fruticosa* (Linn.) Forsk.	Chenopodiaceae	Herb
67	*Suaeda nudiflora* (Willd.) Moq.	Chenopodiaceae	Herb
68	*Taverniera cuneifolia* (Roth) Arn.	Papilionaceae	Herb
69	*Tribulus terrestris* Linn.	Zygophyllaceae	Herb
70	*Zornia gibbosa* Span.	Papilionaceae	Herb
71	*Cadaba fruticosa* (Linn.) Druce	Capparaceae	Shrub
72	*Capparis deciduas* (Forsk.) Edgew.	Capparaceae	Shrub
73	*Euphorbia nivulia Buch. Ham.*	Euphorbiaceae	Shrub
74	*Grewia tenax* (Forsk.) Fiori	Tiliaceae	Shrub
75	*Senna auriculata* (Linn.) Roxb.	Caesalpiniaceae	Shrub
76	*Ziziphus nummularia* (Burm. f.) W. & A.	Rhamnaceae	Shrub
77	*Acacia nilotica* (Linn.) Del.	Mimosaceae	Tree
78	*Azadirachta indica* A. Juss.	Meliaceae	Tree
79	*Prosopis cineraria* (Linn.) Druce	Mimosaceae	Tree
80	*Prosopis juliflora* (Sw.) DC.	Mimosaceae	Tree
81	*Salvadora oleoides* Decne.	Salvadoraceae	Tree
82	*Salvadora persica* Linn.	Salvadoraceae	Tree

Table 2: Herb analysis at different sites of Saline Desert

Sr. No.	Species	Density (plants/m^2)			Frequency (%)	Abundance (plants/m^2)	A/F	IVI
SITE 1								
1	*A. lagopoides*	2.271	±	0.794	29.167	7.786	0.267	46.057
2	*A. adscensionis*	0.625	±	0.354	12.500	5.000	0.400	14.844
3	*C. ciliaris*	2.688	±	2.352	28.125	9.556	0.340	57.880
4	*C. cretica*	1.800	±	2.049	40.000	4.500	0.113	47.163
5	*C. medicaginea*	0.313	±	0.530	12.500	2.500	0.200	13.239
6	*C. dactylon*	0.188	±	0.177	12.500	1.500	0.120	15.144
7	*D. muricata*	0.250	±	0.354	12.500	2.000	0.160	13.269
8	*E. colona*	0.563	±	0.884	12.500	4.500	0.360	15.037
9	*E. ciliaris*	0.250	±	0.354	6.250	4.000	0.640	8.406
10	*E. unioloides*	0.250	±	1.061	6.250	4.000	0.640	16.821
11	*M. maderaspatana*	0.188	±	0.177	12.500	1.500	0.120	35.365
12	*S. fruticosa*	0.375	±	0.250	18.750	2.000	0.107	16.774
SITE 2								
1	*A. indicum*	0.223	±	0.225	17.857	1.250	0.070	9.716
2	*A. lagopoides*	4.104	±	2.434	58.333	7.036	0.121	28.847
3	*A. tetragonolobus*	0.313	±	0.177	12.500	2.500	0.200	3.277
4	*A. mexicana*	0.325	±	0.363	21.250	1.529	0.072	8.709
5	*A. donax*	0.188	±	0.177	12.500	1.500	0.120	7.645
6	*B. diffusa*	0.188	±	0.177	12.500	1.500	0.120	3.477
7	*B. ramose*	0.250	±	0.094	21.875	1.143	0.052	5.111
8	*B. barbata*	0.500	±	0.707	12.500	4.000	0.320	4.257
9	*C. procera*	0.188	±	0.177	12.500	1.500	0.120	10.462
10	*C. prostrates*	0.250	±	0.354	12.500	2.000	0.160	4.237
11	*C. barbata*	0.500	±	0.354	12.500	4.000	0.320	4.302
12	*C. virgata*	0.313	±	0.289	18.750	1.667	0.089	5.261
13	*C. diffusa*	0.375	±	0.250	18.750	2.000	0.107	4.539
14	*C. fascicularis*	0.188	±	0.177	12.500	1.500	0.120	4.072
15	*C. cretica*	1.656	±	1.479	66.406	2.494	0.038	18.614
16	*C. burhia*	0.125	±	0.144	12.500	1.000	0.080	8.000
17	*C. hebecarpa*	0.188	±	0.177	12.500	1.500	0.120	3.348
18	*C. medicaginea*	0.313	±	0.125	25.000	1.250	0.050	6.148
19	*C. dactylon*	0.594	±	0.675	25.000	2.375	0.095	7.558
20	*C. bulbosus*	0.313	±	0.289	18.750	1.667	0.089	4.204
21	*C. compressus*	0.625	±	0.520	18.750	3.333	0.178	5.635
22	*C. nutans*	0.313	±	0.125	25.000	1.250	0.050	5.763
23	*D. aegyptium*	0.438	±	0.399	22.917	1.909	0.083	6.646
24	*D. sindicum*	0.188	±	0.177	12.500	1.500	0.120	2.639

Sr. No.	Species	Density (plants/m^2)			Frequency (%)	Abundance (plants/m^2)	A/F	IVI
25	*D. metel*	0.188	±	0.177	12.500	1.500	0.120	7.849
26	*D. muricata*	0.250	±	0.354	12.500	2.000	0.160	3.179
27	*D. ciliaris*	0.188	±	0.177	12.500	1.500	0.120	2.639
28	*D. retroflexa*	0.188	±	0.177	12.500	1.500	0.120	6.738
29	*E. comosum*	0.500	±	0.335	31.250	1.600	0.051	6.805
30	*E. hirta*	0.188	±	0.177	12.500	1.500	0.120	3.779
31	*F. schweinfurth*	0.125	±	0.144	9.375	1.333	0.142	6.114
32	*H. ovalifolium*	0.250	±	0.354	12.500	2.000	0.160	3.739
33	*I. cordifolia*	0.188	±	0.112	15.625	1.200	0.077	4.702
34	*O. Compressa*	0.688	±	0.326	31.250	2.200	0.070	8.355
35	P. turgidum	0.188	±	0.177	12.500	1.500	0.120	7.271
36	*P. fraternus*	0.313	±	0.177	12.500	2.500	0.200	4.365
37	*R. minima*	0.094	±	0.177	9.375	1.000	0.107	4.562
38	*S. spontaneum*	0.250	±	0.144	25.000	1.000	0.040	4.666
39	*S. italic*	0.188	±	0.177	12.500	1.500	0.120	6.974
40	*S. intermedia*	0.438	±	0.137	31.250	1.400	0.045	6.308
41	*S. pusilla*	0.313	±	0.530	12.500	2.500	0.200	3.338
42	*S. fruticosa*	0.500	±	0.204	37.500	1.333	0.036	7.893
43	*S. nudiflora*	0.688	±	0.283	43.750	1.571	0.036	9.099
44	*T. terrestris*	0.531	±	0.576	21.875	2.429	0.111	7.819
45	*U. setulosus*	0.125	±	0.177	12.500	1.000	0.080	2.531
46	*Z. gibbosa*	0.250	±	0.144	18.750	1.333	0.071	8.811
SITE 3								
1	*A. lagopoides*	0.188	±	0.177	12.500	1.500	0.120	24.650
2	*A. mexicana*	0.313	±	0.177	12.500	2.500	0.200	30.611
3	*C. cretica*	0.458	±	0.379	12.500	3.667	0.293	56.853
4	*D. bipinnata*	0.188	±	0.177	12.500	1.500	0.120	29.859
5	*D. retroflexa*	0.188	±	0.177	12.500	1.500	0.120	23.328
6	*A. indicum*	0.188	±	0.177	12.500	1.500	0.120	29.298
7	*R. hypocrateriformis*	0.188	±	0.177	12.500	1.500	0.120	34.507
8	*S. spontaneum*	0.188	±	0.177	12.500	1.500	0.120	36.550
9	*T. tenelius*	0.313	±	0.177	12.500	2.500	0.200	34.343
SITE 4								
1	*A. lagopoides*	1.047	±	1.198	28.125	3.722	0.132	32.287
2	*A. adscensionis*	2.146	±	1.370	20.833	10.300	0.494	35.561
3	*A. hystrix*	0.500	±	1.061	12.500	4.000	0.320	14.660
4	*C. ciliaris*	0.438	±	0.144	12.500	3.500	0.280	16.092
5	*C. cretica*	0.750	±	0.632	29.688	2.526	0.085	33.084

Sr. No.	Species	Density (plants/m^2)			Frequency (%)	Abundance (plants/m^2)	A/F	IVI
6	*D. aegyptium*	0.875	±	0.354	12.500	7.000	0.560	15.172
7	*D. glabrum*	0.313	±	0.530	12.500	2.500	0.200	21.273
8	*D. ciliaris*	0.375	±	0.661	9.375	4.000	0.427	14.026
9	*E. ciliaris*	1.229	±	1.382	22.917	5.364	0.234	32.987
10	*E. pilosa*	1.313	±	1.242	31.250	4.200	0.134	28.893
11	*H. contortus*	1.438	±	1.595	15.625	9.200	0.589	22.856
12	*M. jacquemontii*	1.438	±	3.359	12.500	11.500	0.920	17.960
13	*S. nudiflora*	0.313	±	0.530	12.500	2.500	0.200	15.149
SITE 5								
1	*A. indicum*	0.563	±	0.137	37.500	1.500	0.040	7.444
2	*A. lagopoides*	2.144	±	3.203	43.125	4.971	0.115	18.459
3	*A. tetragonolobus*	0.313	±	0.303	25.000	1.250	0.050	5.499
4	*A. mexican*	0.229	±	0.246	16.667	1.375	0.083	5.879
5	*A. adscensionis*	0.734	±	1.041	28.125	2.611	0.093	12.025
6	*A. bracteolate*	0.375	±	0.122	25.000	1.500	0.060	9.470
7	*B. ramose*	0.104	±	0.177	8.333	1.250	0.150	2.591
8	*B. barbata*	0.417	±	0.416	25.000	1.667	0.067	5.951
9	*C. setigerus*	0.438	±	0.382	18.750	2.333	0.124	5.183
10	*C. ciliaris*	1.875	±	0.791	31.250	6.000	0.192	13.719
11	C. cretica	1.938	±	3.574	47.727	4.060	0.085	20.219
12	*C. hebecarpa*	0.219	±	0.137	15.625	1.400	0.090	6.131
13	*C. dactylon*	0.313	±	0.325	17.188	1.818	0.106	8.586
14	*C. bulbosus*	0.875	±	0.259	50.000	1.750	0.035	10.190
15	*C. rotundus*	4.438	±	1.291	68.750	6.455	0.094	28.803
16	*D. aegyptium*	0.188	±	0.177	12.500	1.500	0.120	2.767
17	*D. muricata*	0.104	±	0.125	8.333	1.250	0.150	4.857
18	*E. colona*	0.313	±	0.144	18.750	1.667	0.089	4.312
19	*E. ciliaris*	0.625	±	0.595	25.000	2.500	0.100	6.364
20	*E. tenella*	0.250	±	0.289	9.375	2.667	0.284	2.651
21	*E. hirta*	0.688	±	0.946	18.750	3.667	0.196	7.584
22	*F. schweinfurthi*	0.438	±	0.289	28.125	1.556	0.055	7.336
23	*H. supinum*	0.250	±	0.144	18.750	1.333	0.071	6.898
24	*I. cordifolia*	0.125	±	0.144	9.375	1.333	0.142	4.153
25	*I. pes-tigridis*	0.313	±	0.177	12.500	2.500	0.200	4.198
26	P. Turgidum	0.422	±	0.411	18.750	2.250	0.120	13.407
27	*R. squarrosa*	0.250	±	0.278	14.583	1.714	0.118	4.472
28	*R. hypocrateriformis*	0.375	±	0.250	18.750	2.000	0.107	6.534
29	*S. italic*	0.104	±	0.125	10.417	1.000	0.096	9.577

Sr. No.	Species	Density (plants/m^2)			Frequency (%)	Abundance (plants/m^2)	A/F	IVI
30	*S. virginianum*	0.094	±	0.177	6.250	1.500	0.240	5.817
31	*S. fruticosa*	1.063	±	0.384	56.250	1.889	0.034	14.890
32	*S. nudiflora*	0.688	±	0.129	50.000	1.375	0.028	19.694
33	*T. cuneifolia*	0.146	±	0.102	12.500	1.167	0.093	4.043
34	*T. terrestris*	0.313	±	0.530	12.500	2.500	0.200	6.060
35	*Z. gibbosa*	0.250	±	0.144	18.750	1.333	0.071	4.241

(0.013) at site 3. DI was found maximum on the base of density (0.342), basal cover (0.327) and IVI (0.347) at site 3 (Table 4). Species evenness was maximum at site 3 (0.214) and minimum at site 2 (0.074). Similarity index was 13.636 to 51.852 (Table 5). Concentration of dominance and diversity index in the present study does not fall within the reported ranges for LRK. Herb's CD (0.019 to 0.039) and DI (0.303 to 0.420) for Great Rann of Kutch (Vaghasiya *et al.*, 2015) and CD (0.113 to 0.298) and DI (0.118 to 0.523) for Maliya tehsil (near the border of LRK) Pilania and Panchal, 2013 was found high and low values of CD and DI were found in LRK. Diversity index for Indian forests reported by Parthasarathy *et al.*, 1992 and Sahu *et al.*, 2012 value is 0.83 to 4.1 and for temperate forests reported value by Braun, 1950, Monk, 1967 and Pande *et al.*, 1996 was 1.16 to 3.40. This low value of CD and DI vulnerable to desertification and suggests sustainable use and conservation of biodiversity (Parejiya *et al.*, 2013; Pilania *et al.*, 2015). This suggests that these low values of CD and DI are due to the effect of salinity, sodicity and climatic condition. Total biomass was found maximum for *A. lagopoides* (173.583, 95.978 and 522.585 gm^{-2}) at site 1, 4 and 5 and *C. cretica* (219.208 and 30.756 gm^{-2}) at site 2 and 3 (Table 6). Many investigators have reported retardation of germination and growth of seedlings at high salinity (Bernstein, 1962; Garg and Gupta, 1997; Ramoliya and Pandey, 2003). However, plant species differ in their sensitivity or tolerance to salts (Brady and Weil, 1996). There are many different types of salts and almost an equally diverse set of mechanisms of avoidance or tolerance. In addition, organs, tissues and cells at different developmental stages of plants exhibit varying degrees of tolerance to environmental conditions (Munns, 1993; Ashraf, 1994). Underground biomass and leaf biomass was low at site 2, 3 and 4 then site 1 and 5. Garg & Gupta, 1997 reported that salinity causes reduction in leaf area as well as in rate of photosynthesis, which together result in reduced crop growth and yield. Also, high concentration of salt tends to slow down or stop root elongation and causes reduction in root production (Kramer 1983; Garg & Gupta 1997).

***Shrubs and Trees analysis*:**

Shrubs and trees species found were 3, 11, 2, 2 and 6 respectively at site 1 to 5 (Table 3). Density was found maximum for *P. juliflora* (7.109, 5.738, 1.156, 3.213 and 3.775 plants 10m^{-2}) at all sites. Recessive species were S. *auriculata, S. oleoides and A. indica.* Abundance, frequency and importance value index was found maximum for *P. juliflora* at study area. CD was found maximum on the base of density (0.395), abundance (0.272) and IVI (0.326) at site 4. DI was found maximum on the base of density (0.436), abundance (0.499) and IVI (0.472) at site 3 (Table 4). Species evenness was maximum at site 1 (2.713) and minimum at site 2 (0.306). Similarity index was 22.222 to 80.000 (Table 5). Density, frequency, abundance and IVI were maximum for *P. juliflora*. High value of IVI indicates its stability and adaptability to the present area (Pilania *et al.*, 2014b). Earlier it was found that at different locations of Little Rann of Kutch *P. juliflora* was dominant at "23.13°-24.68°N latitudes and 68.10°-71.80°E longitude" (Pilania and Panchal, 2014a) and "23°05'N latitudes; 70°45'E longitude" (Pilania *et al.*, 2014).

***Chemical Properties of soil and their inter-relation with vegetation*:**

EC was maximum at site 3 (14.581dSm^{-1}) followed by site 1 (10.057dSm^{-1}) and minimum (6.600dSm^{-1}) at site 5 (Table 7). Ca was maximum (194.218ppm) at site 5 followed by site 2 (170.607ppm) and minimum (84.952ppm) at site 3. Na was maximum at site 3 (137.310ppm) followed by site 1 (126.338ppm) while minimum (60.435ppm) at site 5. Species richness and density of herbs was maximum at site 2 and 5, with high concentrations of Ca and low concentrations of EC and Na. At site 1, 3 and 4; species richness and density was found less with high values of EC and Na while low values of Ca. Density of herbs with Na and EC (-0.971 and -0.948) was found to be negatively correlated (Figure 2) and shows positive correlation with Ca (0.964). High concentration of Ca (170.607 and 194.218 ppm) and low Na (77.266 and 60.435 ppm) was found with maximum plant density, which suggests that Ca have beneficial effect on vegetation and negative effects on salinity at site 2 and 5. High EC and Na affect vegetation negatively and are harmful for the growth of the vegetation (Pilania and Panchal, 2014). The application of gypsum has long been considered a common exercise in reclamation

Table 3: Shrub and Tree analysis at different sites of Saline Desert

Sr. No.	Species	Density (plants/m^2)	Frequency (%)	Abundance (plants/m^2)	A/F	IVI
SITE 1						
1	*P. juliflora*	7.109 ± 1.698	75.000	9.479	0.126	229.696
2	*S. auriculata*	0.188 ± 0.177	12.500	1.500	0.120	24.856
3	*Z. nummularia*	0.500 ± 0.447	31.250	1.600	0.051	45.448
SITE 2						
1	*A. nilotica*	0.188 ± 0.144	15.625	1.200	0.077	14.015
2	*A. indica*	0.094 ± 0.177	9.375	1.000	0.107	9.265
3	*E. nivulia*	0.250 ± 0.144	18.750	1.333	0.071	16.702
4	*C. fruticosa*	0.375 ± 0.144	25.000	1.500	0.060	21.691
5	*C. deciduas*	0.188 ± 0.177	12.500	1.500	0.120	13.727
6	*P. cineraria*	0.188 ± 0.177	12.500	1.500	0.120	13.727
7	*P. juliflora*	5.738 ± 6.469	63.750	9.000	0.141	131.317
8	*S. oleoides*	0.094 ± 0.177	9.375	1.000	0.107	9.265
9	*S. persica*	0.469 ± 0.411	18.750	2.500	0.133	23.751
10	*S. auriculata*	0.188 ± 0.177	12.500	1.500	0.120	13.727
11	*Z. nummularia*	0.750 ± 0.433	18.750	4.000	0.213	32.815
SITE 3						
1	*P. juliflora*	1.156 ± 1.096	45.313	2.552	0.056	191.799
2	*S. persica*	0.479 ± 0.189	20.833	2.300	0.110	108.201
SITE 4						
1	*P. juliflora*	3.213 ± 2.069	75.000	4.283	0.057	232.749
2	*Z. nummularia*	0.438 ± 0.530	18.750	2.333	0.124	67.251
SITE 5						
1	*A. nilotica*	1.000 ± 0.535	43.750	2.286	0.052	58.414
2	*E. nivulia*	0.188 ± 0.177	12.500	1.500	0.120	20.825
3	*G. tenax*	0.250 ± 0.144	18.750	1.333	0.071	24.386
4	*P. juliflora*	3.775 ± 3.145	61.250	6.163	0.101	143.196
5	*S. oleoides*	0.250 ± 0.144	18.750	1.333	0.071	24.386
6	*S. persica*	0.328 ± 0.661	17.188	1.909	0.111	28.792

Table 4: CD, Diversity Index, Species richness (SR) and Species evenness (SE) of Herbs and Shrubs/Trees at different sites of Saline Desert

Site	Concentration of Dominance (CD)			Diversity Index $\overline{H}$			SR	SE
	Density	Cover	IVI	Density	Cover	IVI		
HERBS								
1	0.015 ± 0.007	0.012 ± 0.006	0.010 ± 0.004	0.242 ± 0.044	0.264 ± 0.035	0.276 ± 0.031	11.833	0.187
2	0.001 ± 0.001	0.001 ± 0.000	0.001 ± 0.000	0.105 ± 0.011	0.108 ± 0.011	0.115 ± 0.007	45.848	0.074
3	0.014 ± 0.004	0.016 ± 0.007	0.013 ± 0.003	0.342 ± 0.021	0.327 ± 0.036	0.347 ± 0.016	8.744	0.214
4	0.008 ± 0.002	0.008 ± 0.002	0.007 ± 0.001	0.266 ± 0.028	0.267 ± 0.029	0.278 ± 0.017	12.835	0.158
5	0.002 ± 0.001	0.001 ± 0.000	0.001 ± 0.000	0.125 ± 0.016	0.132 ± 0.014	0.139 ± 0.011	34.857	0.087
SHRUBS / TREES								
Site	Concentration of Dominance (CD)			Diversity Index $\overline{H}$			SR	SE
	Density	Abundance	IVI	Density	Abundance	IVI		
1	0.279 ± 0.276	0.199 ± 0.184	0.205 ± 0.190	0.168 ± 0.043	0.351 ± 0.022	0.335 ± 0.039	2.838	2.713
2	0.043 ± 0.041	0.016 ± 0.011	0.021 ± 0.017	0.173 ± 0.030	0.273 ± 0.033	0.254 ± 0.032	10.840	0.306
3	0.293 ± 0.207	0.251 ± 0.026	0.269 ± 0.139	0.436 ± 0.083	0.499 ± 0.011	0.472 ± 0.059	1.781	2.572
4	0.395 ± 0.380	0.272 ± 0.147	0.326 ± 0.276	0.264 ± 0.102	0.468 ± 0.062	0.384 ± 0.100	1.821	4.626
5	0.077 ± 0.070	0.042 ± 0.028	0.049 ± 0.036	0.271 ± 0.048	0.383 ± 0.033	0.358 ± 0.041	5.829	0.500

Table 5: Soreason's similarity measure of Herbs (a) and Shrubs and Trees (b) at different sites of Saline Desert

SITES	1	2	3	4	5
1	100	13.793	19.048	40.000	38.298
2		100	14.545	16.949	51.852
3			100	18.182	13.636
4				100	29.167
5					100

a) Herbs

SITES	1	2	3	4	5
1	100	42.857	40.000	80.000	22.222
2		100	30.769	30.769	58.823
3			100	50.000	50.000
4				100	25.000
5					100

(b) Shrubs and Trees

Species	Under Ground Biomass (gm^{-2})	Stem (gm^{-2})	Leaf (gm^{-2})	Inflorescence (gm^{-2})	Above Ground Biomass (gm^{-2})	Total Biomass (gm^{-2})
Site 1						
A. lagopoides	19.89 ± 0.011	27.795 ± 0.026	138.975 ± 0.034	6.813 ± 0.018	173.583 ± 0.026	193.475 ± 0.019
E. colona	29.24 ± 0.030	21.500 ± 0.010	82.560 ± 0.010	4.730 ± 0.015	108.790 ± 0.012	138.030 ± 0.021
C. ciliaris	30.60 ± 0.030	3.240 ± 0.002	27.720 ± 0.025	2.880 ± 0.005	33.840 ± 0.011	64.440 ± 0.020
C. cretica	0.90 ± 0.010	1.170 ± 0.080	5.670 ± 0.330	0.540 ± 0.030	7.380 ± 0.147	8.280 ± 0.078
Total	80.633	53.705	254.925	14.963	323.593	404.225
Site 2						
C. fascicularis	0.54 ± 0.010	0.630 ± 0.010	0.585 ± 0.015	0.000 ± 0.000	1.215 ± 0.012	1.755 ± 0.011
C. cretica	37.31 ± 0.047	62.752 ± 0.089	152.640 ± 0.338	3.816 ± 0.001	219.208 ± 0.143	256.520 ± 0.095
D. muricata	2.36 ± 0.020	1.020 ± 0.025	3.520 ± 0.030	0.200 ± 0.010	4.740 ± 0.022	7.100 ± 0.021
P. turgidum	3.09 ± 0.015	4.790 ± 0.224	0.452 ± 0.014	0.000 ± 0.000	5.242 ± 0.119	8.332 ± 0.067
Total	43.30	69.192	157.197	4.016	230.405	273.707
Site 3						
A. lagopoides	0.525 ± 0.015	0.299 ± 0.081	2.805 ± 0.005	0.240 ± 0.010	3.344 ± 0.032	3.869 ± 0.023
C. cretica	4.180 ± 0.015	6.732 ± 0.037	21.824 ± 0.185	2.200 ± 0.058	30.756 ± 0.093	34.936 ± 0.054
Total	4.705	7.031	24.629	2.440	34.100	38.805
Site 4						
A. lagopoides	15.075 ± 0.051	16.415 ± 0.026	74.873 ± 0.088	4.690 ± 0.026	95.978 ± 0.047	111.053 ± 0.049
A. adscensionis	7.210 ± 0.018	5.511 ± 0.011	14.163 ± 0.026	3.090 ± 0.014	22.763 ± 0.017	29.973 ± 0.017
C. cretica	11.040 ± 0.060	11.280 ± 0.005	30.240 ± 0.100	0.000 ± 0.000	41.520 ± 0.052	52.560 ± 0.056
E. ciliaris	14.947 ± 0.092	10.620 ± 0.035	19.667 ± 0.088	1.180 ± 0.006	31.467 ± 0.043	46.413 ± 0.068
H. contortus	13.915 ± 0.013	3.312 ± 0.011	36.110 ± 0.020	–	39.422 ± 0.016	53.337 ± 0.014
M. jacquemontii	1.807 ± 0.006	0.332 ± 0.001	3.187 ± 0.020	0.345 ± 0.004	3.864 ± 0.008	5.671 ± 0.007
Total	63.994	47.469	178.239	9.305	235.013	299.007
Site 5						
A. lagopoides	59.780 ± 0.028	81.340 ± 0.015	405.230 ± 0.064	36.015 ± 0.008	522.585 ± 0.029	582.365 ± 0.028

Species	Under Ground Biomass (gm^{-2})	Stem (gm^{-2})	Leaf (gm^{-2})	Inflorescence (gm^{-2})	Above Ground Biomass (gm^{-2})	Total Biomass (gm^{-2})
A. tetragonolobus	1.700 ± 0.010	2.200 ± 0.030	1.550 ± 0.055	0.000 ± 0.000	3.750 ± 0.043	5.450 ± 0.026
A. adscensionis	8.773 ± 0.032	3.760 ± 0.026	9.557 ± 0.037	0.940 ± 0.006	14.257 ± 0.023	23.030 ± 0.027
C. setigerus	1.155 ± 0.025	0.455 ± 0.015	1.190 ± 0.010	0.210 ± 0.000	1.855 ± 0.013	3.010 ± 0.019
C. cretica	53.475 ± 0.018	93.620 ± 0.022	236.530 ± 0.086	64.790 ± 0.030	394.940 ± 0.046	448.415 ± 0.032
C. rotundus	12.070 ± 0.010	0.959 ± 0.002	7.100 ± 0.010	–	8.059 ± 0.006	20.129 ± 0.008
E. ciliaris	8.350 ± 0.025	0.500 ± 0.008	3.900 ± 0.070	–	4.400 ± 0.039	12.750 ± 0.032
H. supinum	0.680 ± 0.020	0.800 ± 0.010	0.920 ± 0.020	–	1.720 ± 0.015	2.400 ± 0.018
Total	145.983	183.634	665.977	101.955	951.565	1097.549

Table 7: Salinity, Sodicity and Calcium of soil at different sites of Saline Desert

Parameters	Site 1	Site 2	Site 3	Site 4	Site 5
EC (dSm^{-1})	10.057 ± 0.788	6.819 ± 0.549	14.581 ± 1.752	8.142 ± 1.024	6.660 ± 0.637
Ca (ppm)	96.689 ± 6.777	170.607 ± 2.926	84.952 ± 10.327	134.568 ± 8.911	194.218 ± 5.035
Na (ppm)	126.338 ± 6.023	77.266 ± 5.471	137.310 ± 13.704	109.559 ± 7.044	60.435 ± 5.906

of saline sodic and sodic soils (Marschner, 1995). The addition of calcium to the soil displaces Na^+

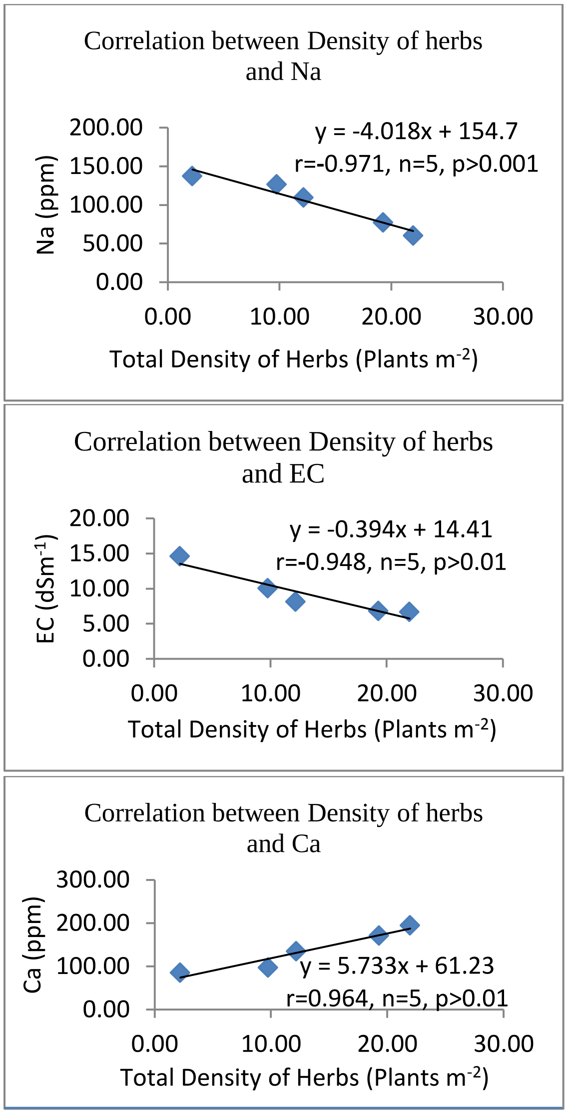

Figure 2: Correlation between different parameters of Soil and Vegetation

from clay particles. This prevents the clay from swelling and dispersing (Sumner 1993) and also makes it possible for Na^+ to be leached deeper into the soil.

Tuteja, 2007 explained that calcium is one of the prime applicant as a central node in the overall ‘‘signaling web’’ and plays a significant role in providing salinity tolerance to plants. High salinity leads to increased cytosolicCa^{2+}, which commences the stress signal transduction pathways for stress tolerance. Ca^{2+} release can be primarily from an extracellular source (apoplastic space) as the addition of EGTA or BAPTA blocks calcineurinmediated activity. High salinity (Na^+) stress commences a calcium signal that turn on the SOS pathway (Figure 3). The signal first commences phospholipase C (PLC), which hydrolyses PIP2 to generate IP3, and DAG resulting in an increased level of Ca^{2+} ions. This change in cytosolicCa^{2+} ions is sensed by a calcium sensor (SOS3), which interacts with the SOS2 protein kinase (Halfter *et al.*, 2000; Liu *et al.*, 2000). This SOS3-SOS2 complex phosphorylates SOS1, a Na^+/H^+ antiporter, resulting in an efflux of excess Na^+ ions. The SOS3-SOS2 complex interacts with and influences other salt-mediated pathways, resulting in ionic homeostasis. This complex restrain HKT1 activity (a low-affinity Na^+ transporter), thus restricting Na^+ entry into the cytosol. SOS2 also interacts and activates the vacuolar Na^+/H^+ exchanger (NHX), resulting in the sequestration of excess Na^+ ions, further contributing to Na^+ ion homeostasis. Calnexin and calmodulin (CaM) or other calcium-binding proteins can also interact and turn on the NHX or other transporters. The H^+/Ca^{2+} antiporter (CAX1) has been recognized as an additional target for SOS2 activity reinstating cytosolicCa^{2+} homeostasis. Thus, exogenously supplied calcium not only improves soil structure, but also alters soil properties (Shabala *et al.*, 2003) that benefit the vegetation and increases salinity tolerance and diminish the undesirable effects of saline conditions on vegetation (Jaleel *et al.*, 2007).

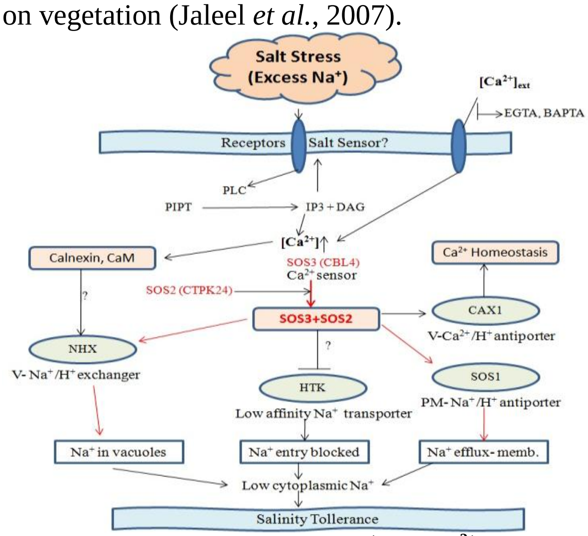

Figure 3: Ions homeostasis (*e.g.*, Na^+ and Ca^{2+}) by SOS and associated pathways in relation to salinity stress tolerance.

Conclusion

EC and Na were excess in soil at study area which retards plant density. Calcium is found beneficial to enhance vegetation growth by minimising EC and Na effect. Application of calcium and plantation of species with high tolerance capacity (*C. rotundus*, *A. lagopoides*, *A. adscensionis*, *C. cretica*, *H. contortus etc.*) and sustainable management at fringe area will enhance green belt, improve soil structure and help to combat the salinity, sodicity and desertification.

Acknowledgment

Authors are gratefully acknowledging the financial and other logistic support from UGC, New Delhi and Saurashtra University, Rajkot, India.

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