

COMPARATIVE STUDY OF CHLORIDE, CALCIUM, MAGNESIUM, POTASSIUM, AND SODIUM CONTENT OF SEEDS IN TEMPERATE AND TROPICAL HALOPHYTES

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ABSTRACT: The seeds of forbs, grass, and woody halophytes were collected from a cool moist temperate habitat of North America and subtropical maritime desert conditions of Karachi, Pakistan. Sodium, potassium, calcium, magnesium, and chloride concentrations as well as total ash content were determined. Ion concentrations of seeds are expressed both as relative values and on a dry weight basis. Plants were found to vary in the total ash content of seeds and the relative distribution of ions. In general, temperate forbs and grasses had lower ion content of seeds and several tropical shrub species had the highest ionic content.

INTRODUCTION

Halophytes can grow and develop successfully in the presence of high salinity and are found growing in coastal and inland saline habitats throughout the world (Ungar, 1991). Presence of high concentrations of ions in the seeds may have a negative effect on the germination and establishment of halophytes. This effect will be more important in temperate marshes which are primarily dominated by annuals that depend exclusively on the seed for future propagation. However, for tropical salt marshes and salt deserts that are dominated by woody perennials and are predominantly propagated through vegetative growth (by producing ramets), high ion concentrations in seeds may have less of an impact on population dynamics.

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Few studies have reported the ion concentration in halophyte seeds (Poulin et al., 1978; Iganciuk and Lee, 1980; Hocking, 1982; Khan and Ungar, 1984; Khan et al., 1985, 1987; Lanning and Eleuterius, 1992). Lanning and Eleuterius (1992) reported the total ash content of halophytes ranged from 0.30% (*Spartina alterniflora* Loisel.) to 24.2% (*Salicornia bigelovii* Torr.). Halophytic grasses contain less ash as compared to chenopods. The sodium content of the seeds varied from 0.02% in *Cakile maritima* Scop. (Hocking, 1982) to 0.07% in *Atriplex triangularis* Willd. (Khan and Ungar, 1984) and 0.77% in *Salicornia europaea* L. (Poulin et al. 1978). Seeds are reported to partition sodium and chloride with higher amounts in seed coat than in endosperm or embryo tissues of *Atriplex canescens* (Pursh.) Nutt., *A. triangularis*, *A. confertifolia* (Torr. and Ferm.) S. Wats. and *Salicornia pacifica* (Tidestrom) Munz. (Khan et al., 1985, 1987).

Previous research with halophytes indicates that a number of herbaceous salt marsh species have a relatively low ash content (5-10%) in seeds when compared to leaves and stems (20-50 %, Ungar, 1991). Little data is available concerning the seed ion contents of salt marsh species, and for grasses, forbs, and woody halophytes of the salt desert regions of Pakistan. In this investigation of halophyte seeds collected from temperate and tropical saline environments, we are attempting to determine if there are significant differences in the accumulation of ions in seeds among species from salt desert and salt marsh habitats, herb versus shrubs, and perennials versus annuals.

MATERIALS AND METHODS

Seeds of *Salicornia europaea* L., *Atriplex prostrata* Boucher ex DC, *Spergularia marina* (L.) Griseb., and *Hordeum jubatum* L. were collected from a salt marsh located at Rittman, Ohio. Seeds of *Puccinellia nuttalliana* (Schultes) Hitchc. were collected from Stink Lake, South Dakota. Seeds of *Arthrocnemum indicum* (Willd.) Moq. were collected from coastal marshes, *Halopyrum mucronatum* (L.) Stapf. from coastal dunes, and *Atriplex griffithii* Moq., *Cleome viscosa* L., *Haloxylon recurvum* (Moq.) Bunge ex Boiss., *Sporobolus marginatus* Boiss., *Suaeda fruticosa* (L.) Forssk. and *Zygophyllum simplex* L. from inland saline deserts located at Karachi, Pakistan.

Three replicates of 0.5 g of seeds were used for each species and ashed overnight in a muffle furnace at 500°C. Ash weight was recorded, and then the ash was dissolved in sulphuric acid (20%). The dissolved ash solution was then diluted to

100 mL with distilled water. The solution was filtered through a Whatman No. 42 filter paper. Sodium and potassium were determined in the ash solution by flame emission photometry and magnesium and calcium by atomic absorption spectrophotometry (Varian-Spectr AA20). The chloride concentration was determined using a Beckman Cl specific-ion electrode.

RESULTS

The results presented in Figure 1 give the total ash content of the different forbs, grass, and woody halophyte seeds collected from various temperate and subtropical habitats. Seeds of the species (*Atriplex prostrata*, *Salicornia europaea*, *Spergularia marina*, *Hordeum jubatum*, and *Puccinellia nuttalliana*) collected from cool moist salt marshes were generally low (< 100 mg/g dry weight) in ash content as compared to species collected from arid habitats. Species collected from the subtropical maritime desert environment were generally higher in salt content of seeds. Achenes of grasses generally had low ash content, except for *Sporobolus marginatus*. Perennial woody shrubs show very high ash content of seeds. Ash content of *Arthrocnemum indicum* collected from a coastal salt marsh is above 40% of the total dry weight and *Haloxylon recurvum* (30%) and *Salsola baryosma* (20%). However, species, like *Atriplex griffithii* and *Suaeda fruticosa*, collected from the same community had ash contents similar to that in the temperate species.

The data presented in Table 1 show the elemental content (mmol/g dry weight) of various seed samples. Chloride content of *Arthrocnemum indicum* is very high followed by *Zygophyllum simplex*, and *Salsola baryosma*. Concentration of chloride in all the other species are low and are not significantly different from that in the glycophytic (*Cleome visosa*) seed. Sodium content was highest in *Arthrocnemum indicum*, followed by *Haloxylon recurvum*, *Salsola baryosma*, and *Zygophyllum simplex*. The other species studied had a sodium content similar to the glycophytes. Potassium, magnesium, and calcium concentrations were low in all seeds, with small variation. Table 2 shows the result of a one-way analysis of variance for ash, calcium, chloride, potassium, magnesium, and sodium among various species. These concentrations were found to vary significantly among the species.

The relative ion distribution in the seeds is presented in Figure 2. Grasses are conspicuous due to their relatively high potassium and low chloride concentrations, except for *Sporobolus marginatus*. Among the forb species, those collected from

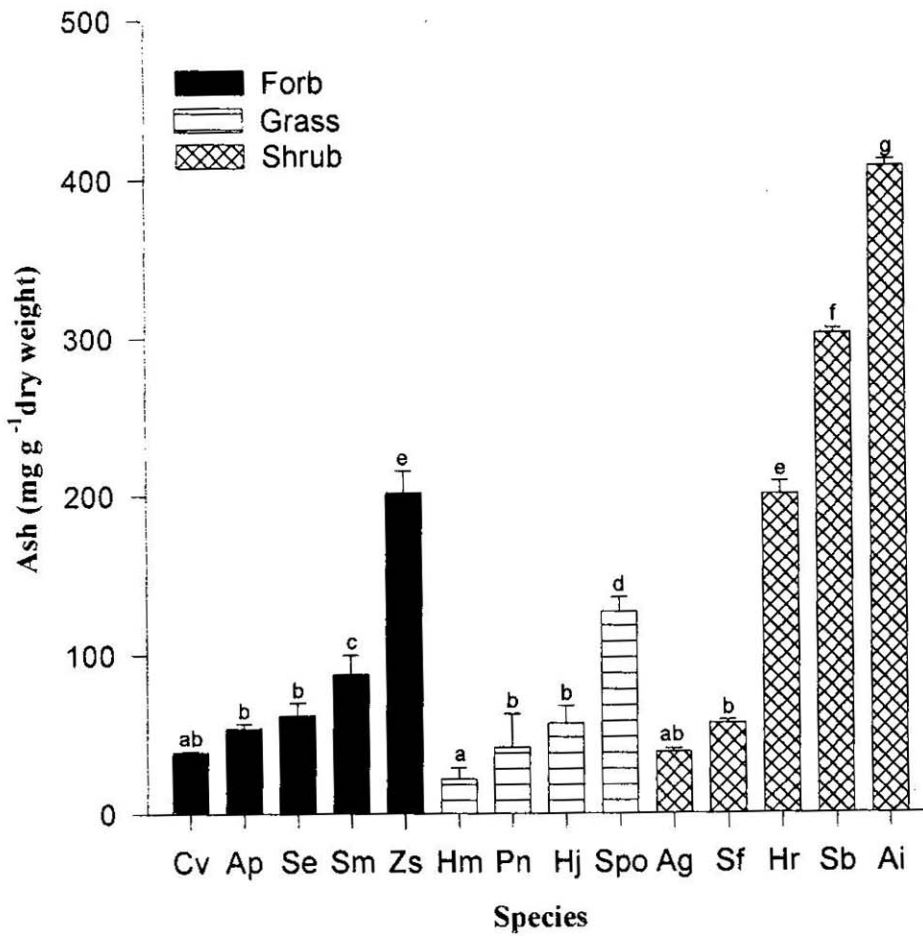


FIGURE 1. Ash content (mg/g dry weight \pm S.E.) of seeds in temperate and tropical halophytes.

cool moist habitats had high sodium and chloride concentrations. However, the desert species *Zygophyllum simplex* had a very high chloride concentration and relatively low sodium concentration. All of the five perennial species differed in their relative distribution of elemental content. *Arthrocnemum indicum*, a coastal salt marsh species, had equal amounts of sodium and chloride which constituted about 90% of the total elements present. *Haloxylon recurvum* had very little chloride but very high sodium. *Suaeda fruticosa* and *Salsola barryosma* had low chloride, high sodium, and a significant amount of potassium.

DISCUSSION

Ash content in the seeds of forbs, grass, and woody halophytes collected from a cool moist temperate region and subtropical maritime desert environments showed different patterns. Total ash content of seeds for temperate species was less than

Table 1. Ion content (mmol g⁻¹ dry weight ± S. E.) of seeds of some halophytes.

Name of Species	habit	Cl	Na	Mg	K	Ca
<i>Cleome viscosa</i>	forb	0.32 ^a ±0.01	0.29 ^{ab} ±0.03	0.11 ^{bcd} ±0.03	0.18 ^a ±0.02	0.061 ^a ±0.01
<i>Atriplex prostrata</i>	forb	0.27 ^{abc} ±0.01	0.46 ^{ab} ±0.04	0.09 ^{bc} ±0.01	0.29 ^{bc} ±0.01	0.013 ^a ±0.001
<i>Salicornia europaea</i>	forb	0.86 ^{bc} ±0.14	0.72 ^b ±0.15	0.10 ^{bcd} ±0.005	0.32 ^{bc} ±0.03	0.012 ^a ±0.002
<i>Spergularia marina</i>	forb	0.56 ^{abc} ±0.03	0.69 ^b ±0.06	0.12 ^{bcd} ±0.01	0.24 ^{abc} ±0.04	0.020 ^a ±0.001
<i>Zygophyllum simplex</i>	forb	4.14 ^d ±0.94	1.16 ^c ±0.2	0.16 ^e ±0.006	0.33 ^{bc} ±0.02	0.581 ^c ±0.007
<i>Halopyrum mucronatum</i>	grass	0.05 ^a ±0.009	0.19 ^{ab} ±0.01	0.08 ^b ±0.007	0.17 ^a ±0.016	0.012 ^a ±0.001
<i>Puccinnellia nuttalliana</i>	grass	0.02 ^a ±0.007	0.06 ^a ±0.01	0.06 ^a ±0.03	0.53 ^c ±0.12	0.003 ^a ±0.0001
<i>Hordeum jubatum</i>	grass	0.07 ^a ±0.004	0.33 ^{ab} ±0.04	0.03 ^a ±0.003	0.25 ^{abc} ±0.03	0.013 ^a ±0.001
<i>Sporobolus marginatus</i>	grass	0.01 ^{abc} ±0.001	0.33 ^{ab} ±0.008	0.13 ^d ±0.004	0.23 ^{ab} ±0.02	0.095 ^a ±0.006
<i>Atriplex griffithii</i>	shrub	0.55 ^{abc} ±0.02	0.45 ^{ab} ±0.01	0.11 ^{bcd} ±0.003	0.25 ^{abc} ±0.01	0.013 ^a ±0.003
<i>Suaeda fruticosa</i>	shrub	0.24 ^{ab} ±0.14	0.36 ^{ab} ±0.05	0.11 ^{bcd} ±0.003	0.23 ^{ab} ±0.02	0.024 ^a ±0.0009
<i>Haloxylon recurvum</i>	shrub	0.27 ^{abc} ±0.05	3.79 ^e ±0.58	0.13 ^{cd} ±0.01	0.44 ^d ±0.04	0.062 ^a ±0.002
<i>Salsola baryosma</i>	shrub	0.98 ^c ±0.10	3.09 ^d ±0.1	0.40 ^g ±0.03	0.62 ^e ±0.03	0.285 ^b ±0.172
<i>Arthrocnemum indicum</i>	shrub	7.75 ^e ±0.34	6.57 ^f ±0.32	0.27 ^f ±0.009	0.26 ^{abc} ±0.02	0.062 ^a ±0.001

Values in column for each ion having the same letter are not different at 0.05 significance level by Student-Newman-Keuls test.

Table 2. Results of one way analysis of variance of seed ion characteristics by species.

Source of variation	df	MS	F	P
Ash	13	0.405	469.1	0.0001
Calcium	13	75860.8	35.7	0.0001
Chloride	13	14145587.1	187.3	0.0001
Potassium	13	51178.5	33.1	0.0001
Magnesium	13	26560.5	127.7	0.0001
Sodium	13	10595220.5	284.8	0.0001

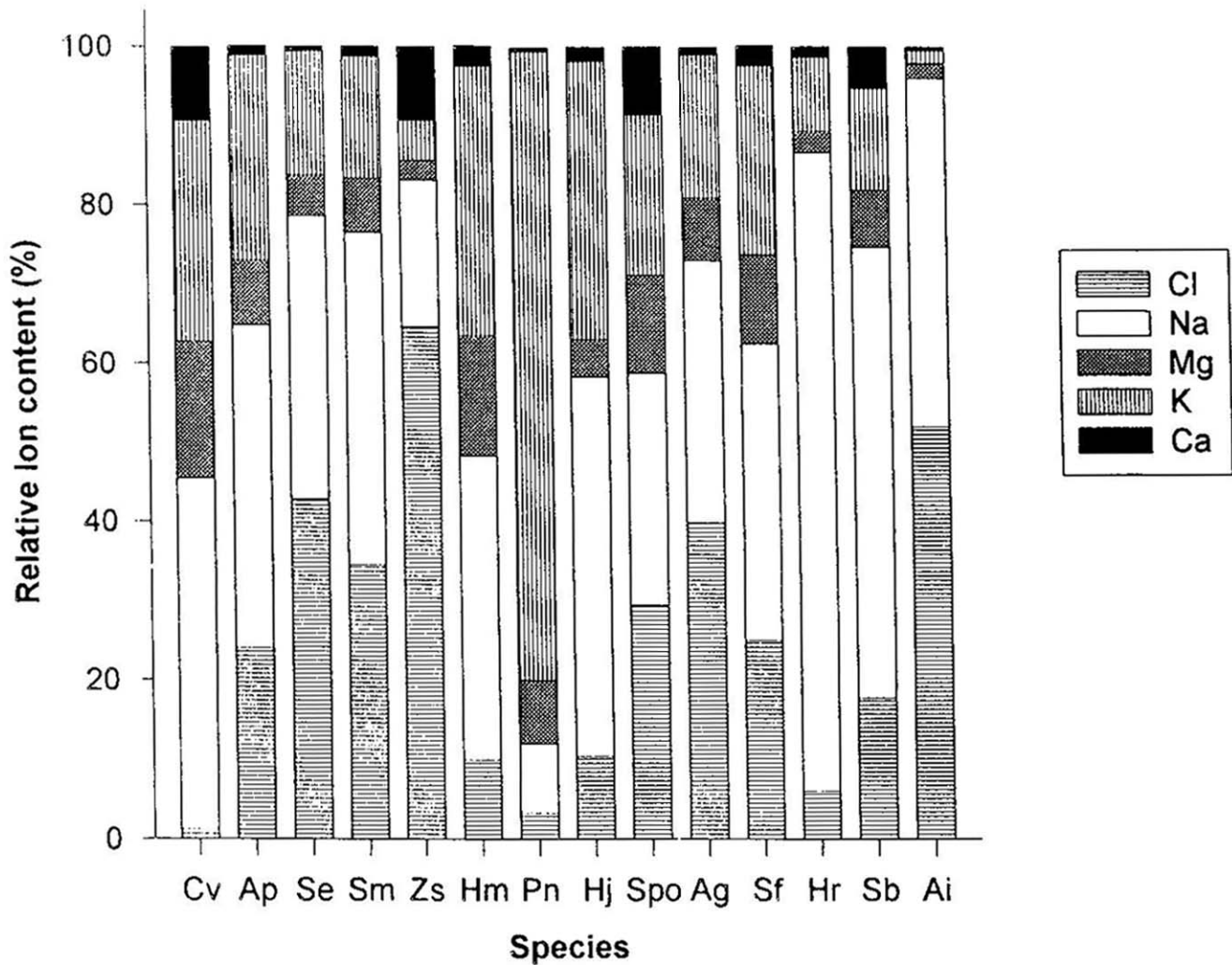


FIGURE 2. Relative elemental content (%) of seeds in temperate and tropical halophytes.

10% of the total dry weight. However, ash content of sub-tropical maritime desert species ranges from less than 3% to more than 40%. Grasses, in general, were low in ash content and perennials high in ash content of seeds. Lanning and Eleuterius (1992) reported the total ash content ranged from 0.3% (*Spartina alterniflora*), 2.6% [*S. patens* (Aitons) Muhl.], 3.6% [*Suaeda linearis* (L) Moq.] to 24.2% in (*Salicornia bigelovii*). Seeds of *Atriplex triangularis* collected from highly saline areas had a mean total inorganic elemental content of 2.1%, while seeds collected from low salt habitats had 1.7% total salt (Ungar, 1984).

Chloride ion content of grasses ranged from 0.05% to 1.14% and herbs ranged from 0.03% to 3%, except for a tropical herb *Zygophyllum simplex* which had a chloride content of about 15% of its dry weight. Woody plants also had low chloride (0.87 to 3.47%) content except for the 28% in *Arthrocnemum indicum* seeds. Sodium concentration was low in grasses (0.096 to 0.77%) followed by forbs (0.67 to 2.68%). Seeds of woody plants had a great deal of variation in sodium content, which ranged from 0.82% in *Suaeda fruticosa* to 15.1% in *Arthrocnemum indicum*.

Elemental content of *Atriplex triangularis* seeds showed a chloride content of 1.6% and a sodium content of 0.7% (Khan and Ungar, 1984). Booth (1989) reported the elemental content of the seeds of *Eurotia lanata* (Pursh) Moq. collected from nine locations in Wyoming, Colorado, and Utah. The sodium content of seeds ranged from 0.29 to 0.54% with a mean value of 0.42%. Seeds of *Salicornia europaea* collected from saline environment contained 0.77% sodium (Poulin et al., 1982), whereas Austenfeld (1988) found 0.15% sodium and 0.31% chloride. Seeds of *Cakile maritima* also had a relatively low elemental content, 0.02% for sodium and 0.07% for chloride.

Data on the relative distribution of elements in halophytic forb seeds had a predominance of sodium. Whereas, chloride constituted only 2% of the relative element content in *Cleome viscosa*, which is as high as 65% of the total element content in *Zygophyllum simplex*. Relative presence of potassium also ranged from 5% to 35% of the total elements in forbs. Potassium concentration was about 80% in *Puccinnella nuttalliana*, and other grasses also contained a relatively high potassium content. All of the woody plants had relatively high sodium content in seeds, but the distribution of chloride varied from 7% to 52% of the total elements.

There was a significant difference in total ash content among species. In general, the seeds of herbs from temperate and tropical zones had relatively low ash

contents compared to some of the perennial shrubs. Elemental content of seeds varied among species, with three of the perennial shrubs investigated having the highest sodium content. The ability of species to regulate their elemental content in seeds is significant. High element contents in seeds could lead to a specific ion toxicity or an osmotically induced dormancy, which would only be alleviated by a period of precipitation. It is possible that salt desert shrubs may have evolved a mechanism to accumulate high elemental concentrations in seeds in order to delay germination until a period of sufficient precipitation is present to leach the salts from seeds. This would ensure that seedlings, which are apparently more sensitive to salinity stress than older plants, would be exposed to less saline conditions and have a better chance to survive to maturity. Maintaining a relatively low elemental content in seeds of salt marsh species compared to vegetative structures may prevent specific ion toxicity effects from injuring developing embryos.

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