

ELEMENTAL COMPARTMENTALIZATION IN SEEDS OF *ATRIPLEX TRIANGULARIS* AND *ATRIPLEX CONFERTIFOLIA*

M. A. Khan¹, D. J. Weber², and W. M. Hess²

ABSTRACT.—Seeds of two halophytes, *Atriplex triangularis*, which grows in a mesic saline marsh environment, and *Atriplex confertifolia*, which grows in a xeric desert environment, were analyzed by energy-dispersive X-ray microanalysis for the distribution of elements. The highest concentration of sodium, chlorine, potassium, and calcium was present in seed coats of *A. triangularis*. All of the elements detected were at low concentrations in the endosperm. Embryos contained the highest amount of phosphorus that is probably associated with organophosphate compounds. Potassium was also high in embryos. The total amount of elements in all regions of *A. confertifolia* was low as compared to *A. triangularis*. In a similar pattern sodium, chlorine, potassium, and calcium were the highest in seed coats of *A. confertifolia*. Elemental concentration was also low in the endosperm. Likewise, the phosphorus level was the highest in the embryo. The results support the concept of elemental compartmentalization in seeds of these halophytes.

Halophytes are plants that grow and complete their life cycles in habitats of high salinity. Although *Atriplex* spp. do not require other than trace amounts of Na⁺ for normal growth, they frequently grow better in the presence of NaCl (Osmond et al. 1980). *Atriplex* spp. from different environments are characterized by high levels of NaCl in shoots, particularly in halophytes of arid shrublands (Hansen and Weber 1975, Osmond et al. 1980). However, few reports are available on the status of ions present in *Atriplex* seeds. Ungar (1984) reported that the ions of seeds of *Atriplex triangularis* constitute 2% of the total dry weight as compared to about 14% in leaves. He suggested that halophytes regulate ion distribution so that the ion concentration in seeds is low. Several studies have been done on the distribution of elements in seeds of glycophytes (Lott et al. 1982, Tanaka et al. 1977, Hofsten 1973). However, little information is available on the ion compartmentalization within different parts of seeds of halophytes. Other plant parts of glycophytes have been studied using energy-dispersive X-ray microanalyses (Bennett and Wynn Parry 1981, Saka 1982, Strullu et al. 1981). Therefore, the purpose of this investigation was to determine the elemental distribution in the seeds of these two halophytes (*Atriplex* spp.) grown in different saline environments. A clear understanding of the type and distribution of elements is needed to understand the

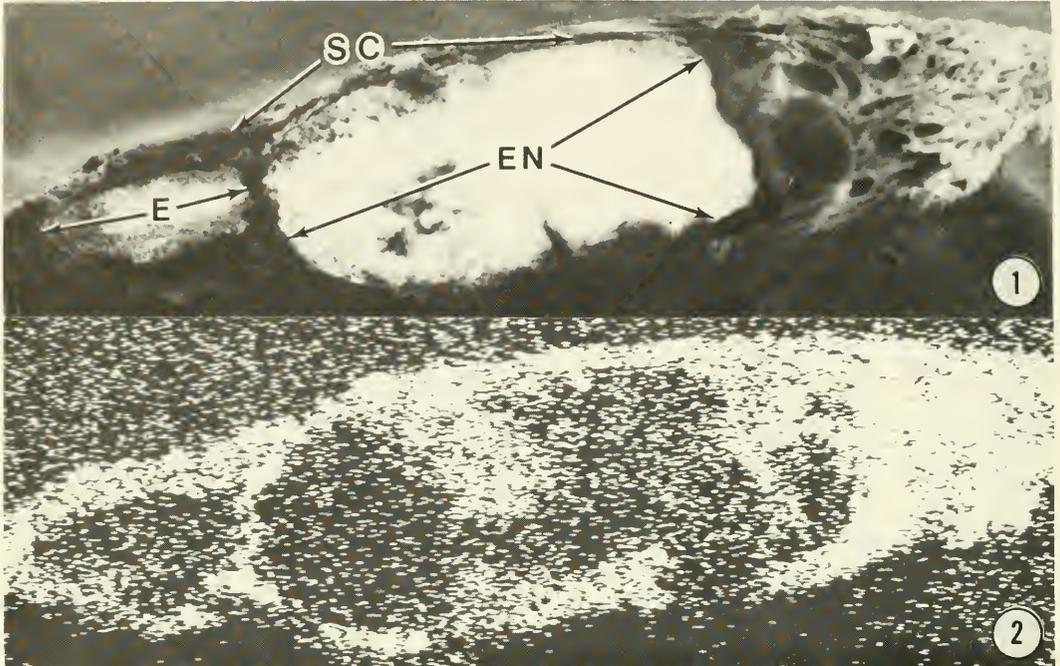
factors involved in seed germination of halophytic plants.

MATERIALS AND METHODS

Seeds of *Atriplex triangularis* Willd. were collected from a salt marsh at Rittman, Ohio, and seeds of *Atriplex confertifolia* (Torr. and Frem) S. Wats were obtained from Howard Stutz (Brigham Young University), who collected them from the desert areas of central Utah. These seeds were sectioned with razor blades and mounted on carbon stubs with graphite glue. Energy-dispersive X-ray microanalysis (EDS) was conducted with an EDAX 9100/70 with auto-calibration for automated analysis. The background was subtracted automatically. The X-ray analysis system was interfaced with an AMRay, 1000 A SEM. The seeds were not coated since the coating interferes with EDS analyses. The accelerating voltage for analysis was 20 Kv, the beam current was 75 uA, and analysis times were 100 sec at about 3,000 cps. The take-off angle was 45° with respect to the cut surface. Four different seeds for each species were analyzed in three different regions. Each region of each seed was analyzed four times at four different locations to provide a statistical basis for determining variability. Oneway ANOVA and Fischer's LSD multiple comparison tests were used for statistical analyses.

¹Department of Botany, University of Karachi 32, Pakistan.

²Department of Botany and Range Science, Brigham Young University, Provo, Utah 84602.



Figs. 1–2. *Atriplex triangularis*: 1, Scanning electron micrograph of a cross section of an uncoated seed showing the embryo (E), endosperm (EN), and seed coat (SC), 120X; 2, Scanning image of X-ray signals for chlorine (white image) of the same cross section of the seed shown in Fig. 1, 120X.

RESULTS

Results obtained with both species of *Atriplex* are shown in Figures 1–4. Higher concentrations of some elements were present in *A. triangularis* seed coats and embryos than in seed coats and embryos of *A. confertifolia*, but endosperms of seeds of both species were low in all elements. There were no significant differences in elemental content of the endosperm of the two species.

Sodium, chlorine, and calcium in the seed coats of *A. triangularis* were significantly higher (5% level) than in the endosperm and embryo. On the other hand, the elements that were higher (5% level) in the embryo than in the seed coat were magnesium, aluminum, phosphorus, and sulfur. Potassium was significantly different in seed coats and embryos as compared to the endosperm.

A. confertifolia seeds contained more potassium and calcium in the seed coat (5% level) than in the embryo. The highest concentration of phosphorus was in the embryo (5% level), and the amount of potassium in the embryo and seed coat was significantly higher (5% level) than in the endosperm.

DISCUSSION

The regions of the seed studied not only differed in elemental composition but also in relative concentrations. A comparison of these two halophytic plants indicates the concentrations of elements present in *A. triangularis* seeds were much higher than in *A. confertifolia* seeds, particularly chlorine and potassium. The high concentrations of potassium may be related to the large number of enzymes where potassium is a cofactor (Wyn-Jones and Pollard 1983).

Khan and Ungar (1984) reported that seeds of *A. triangularis* collected from a salt marsh at Rittman, Ohio, where soil salinity was about 3%, have sodium and chlorine concentrations in seeds ranging from 0.7 to 2% of the dry weight. The concentrations of these elements after analysis with X-ray microanalysis (Fig. 3) are much lower considering the fact that ionic content of leaves of *A. triangularis* may be 15% in plants growing in 3% salinity (Ungar 1984). Seeds of *Salicornia europaea* have 0.77% sodium as compared to 14.8% sodium in other parts of the plant (Poulin et al. 1978). Hocking (1982) reported that seeds of

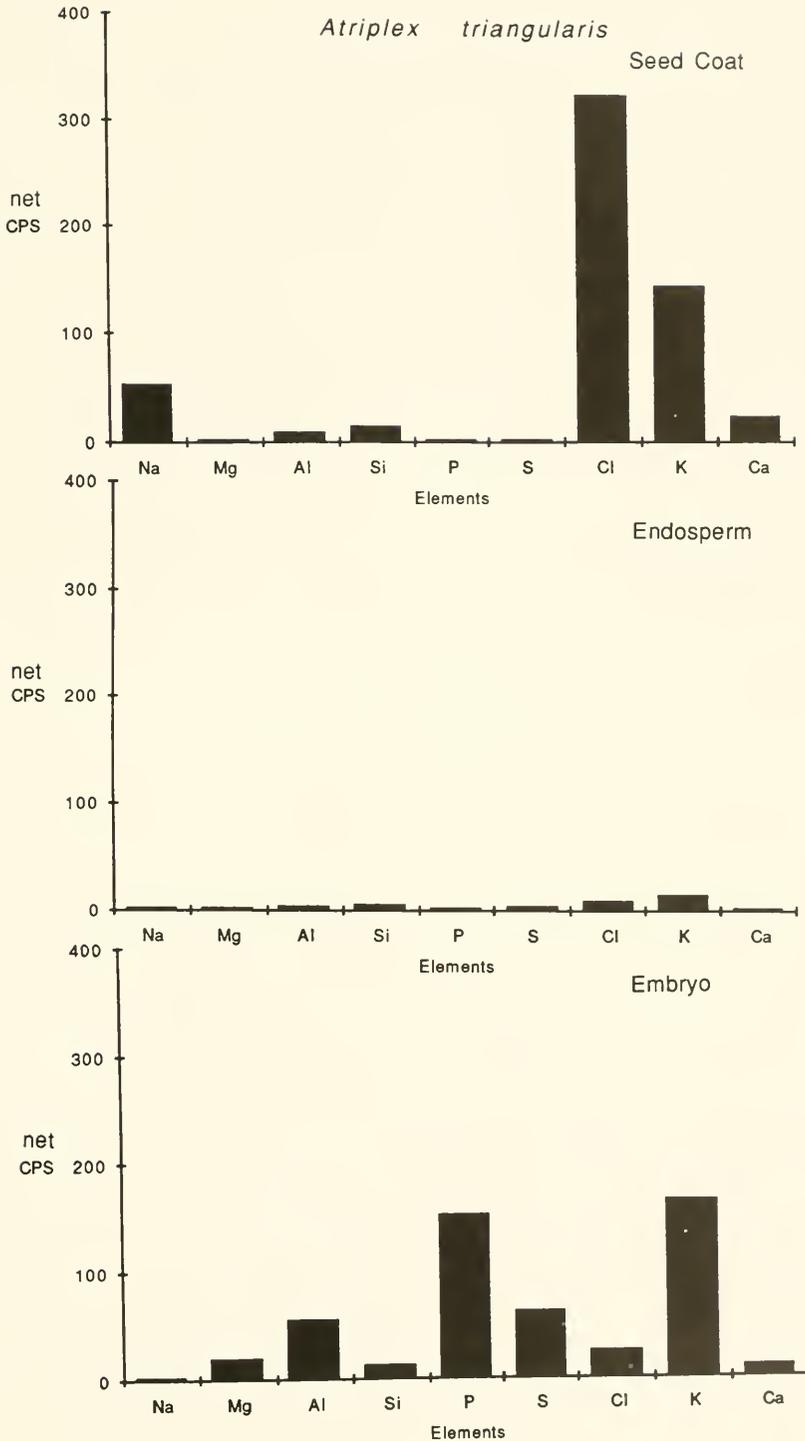


Fig. 3. Distribution of nine elements in the seed coat, endosperm, and embryo of *Atriplex triangularis* as determined by energy-dispersive X-ray microanalysis. Data is in net counts per second.

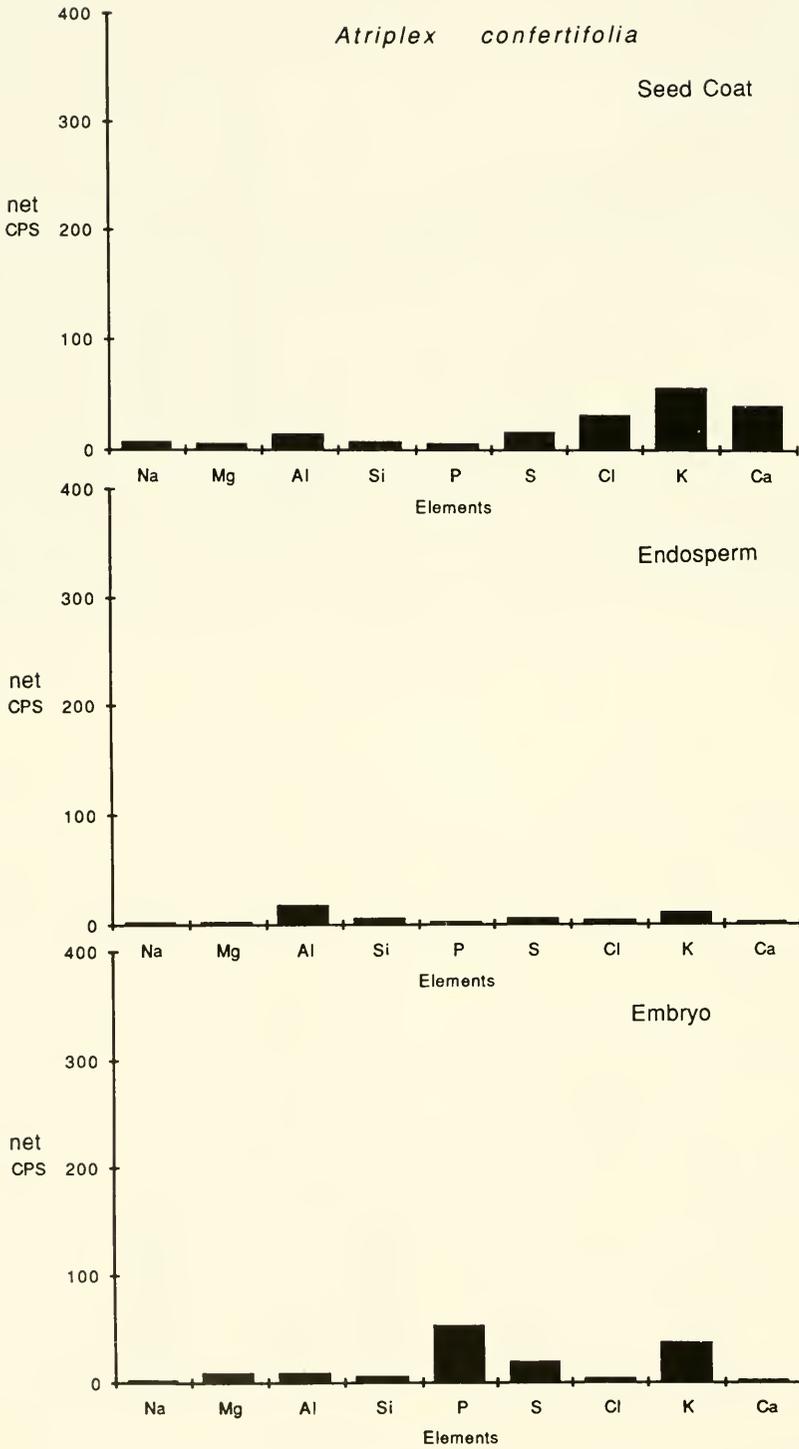


Fig. 4. Distribution of nine elements in the seed coat, endosperm, and embryo of *Atriplex confertifolia* as determined by energy-dispersive X-ray microanalysis. Data is in net counts per second.

Cakile maritima have a sodium content of 0.02% and a chlorine concentration of 0.07% compared to 14.1% chlorine and 6.8% sodium in leaves. Thus, the pattern of elemental distribution of these two species of *Atriplex* is consistent with these reports. Lott et al. (1982) observed low calcium content in the endosperm and embryo of castor bean seeds. The calcium level was also very low in the endosperm and embryo in both *Atriplex* seeds that we analyzed.

The concentration of elements in embryos was higher in *A. triangularis* seeds than in *A. confertifolia* seeds, which suggests that desert plants do not absorb or store as many elements in seeds as do salt marsh plants. These results indicate that the *Atriplex* species studied were able to compartmentalize sodium and chlorine in seed coats but reduce the levels of sodium and chlorine in embryos of their seeds. Similar results were obtained with seeds of *Salicornia pacifica* and *Atriplex canescens* by Khan, Weber, and Hess (1985).

ACKNOWLEDGMENTS

We appreciate the cooperation of Howard Stutz in providing the seeds of *Atriplex confertifolia*. This research was supported by a grant from the National Science Foundation No. 8403768.

LITERATURE CITED

- BENNETT, D. M., AND D. WYNN PARRY. 1981. Electron-probe microanalysis studies of silicon in the epicarp hairs of the caryopses of *Hordeum sativum* Jess., *Avena sativa* L., *Secale cereale* L. and *Triticum aestivum* L. *Ann. of Bot.* 48: 645-654.
- HANSEN, D. J., AND D. J. WEBER. 1975. Environmental factors in relation to the salt content of *Salicornia pacifica* var. *utahensis*. *Great Basin Nat.* 35: 86-96.
- HOCKING, P. J. 1982. Salt and mineral nutrient levels in fruits of two strand species, *Cakile maritima* and *Arctotheca populifolia*, with special reference to effect of salt on the germination of *Cakile*. *Ann. of Bot.* 50: 335-343.
- HOFSTEN, A. V. 1973. X-ray analysis of microelements in seeds of *Crambe abyssinica*. *Physiol. Plant.* 29: 76-81.
- KHAN, M. A., AND I. A. UNGAR. 1984. Seed polymorphism and germination responses to salinity stress in *Atriplex triangularis* Willd. *Bot. Gaz.* 145: 487-494.
- KHAN, M. A., D. J. WEBER, AND W. M. HESS. 1985. Elemental distribution in seeds of the halophytes *Salicornia pacifica* var. *utahensis* and *Atriplex canescens*. *Amer. J. Bot.* 72: 1672-1675.
- LOTT, J. N. A., J. S. GREENWOOD, AND C. M. VOOLMER. 1982. Mineral reserve in castor beans: the dry seed. *Plant Physiol.* 69: 829-933.
- OSMOND, C. B., O. BJORKMAN, AND D. J. ANDERSON. 1980. Pages 154-190 in *Physiological processes in plant ecology*. Springer-Verlag, Berlin.
- POULIN, G., D. BOURQUE, S. EID, AND K. JANKOWSKI. 1978. Composition chimique de *Salicornia europaea* L. *Naturaliste Canadien* 105: 473-478.
- SAKA, S. 1982. A study of lignification in loblolly pine tracheids by the SEM-EDAX technique. *Science Technol.* 16: 167-179.
- STRULLU, D. G., J. P. GOURRET, J. P. GARREC, AND A. FOURCY. 1981. Ultrastructure and electron-probe microanalysis of the metachromatic vacuolar granules occurring in *Taxus mycorrhizas*. *The New Phytol.* 87: 537-545.
- TANAKA, K., M. OGAWA, AND Z. KASAI. 1977. The rice scutellum. II. A comparison of scutellar and aleuron electron-dense particles by transmission electron microscopy including energy-dispersive X-ray analysis. *Cereal Chem.* 54: 684-689.
- UNGAR, I. A. 1984. Autecological studies with *Atriplex triangularis* Willdenow. Pages 40-52 in A. R. Tiedemann, E. D. McArthur, H. C. Stutz, R. Stevens, and K. L. Johnson, eds., *Biology of Atriplex* and related chenopods. Symposium, USDA, Intermountain Forest and Range Experimental Station, Ogden, Utah.
- WYN-JONES, R. G., AND A. POLLARD. 1983. Proteins, enzymes and inorganic ions. Pages 528-562 in A. Läuchli and R. L. Bielecki, eds., *Encyclopedia plant physiology*. Vol. 15. New York.