Journal of Coastal Research	3	4	531-534	Charlottesville, Virginia	Autumn 1987

Silica in Relation to Leaf Decomposition of *Juncus roemerianus*

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ABSTRACT

ELEUTERIUS, L.M. and LANNING, F.C., 1987. Silica in relation to leaf decomposition of *Juncus Roemerianus*. *Journal of Coastal Research*, 3(4), 531-534. Charlottesville, ISSN 0749-0208.

Silica content was examined in relation to the age of living and dead-standing leaves of the intertidal rush, *Juncus roemerianus*. The percentage of silica increases as the leaf decomposes, the leaves ranging from one to eight years of age. Saprophytic fungi are the primary decomposition organisms. As the cellulose cell walls of the structural and supportive tissues come under attack, the fungal mycellium increases within the leaf. This is directly indicated by an increase in ash content as the leaf dry mass weight approaches zero. Dead-standing leaves at eight years of age are essentially a siliceous cast of the leaf. This study suggests an alternative view to the decomposition process of *Juncus roemerianus* and estuarine energetics.

ADDITIONAL INDEX WORDS: *Intertidal rush, saprophytic fungi, tidal marsh, fungal hyphae, phytoliths, coastal plants.*

INTRODUCTION

Juncus roemerianus Scheele, black needlerush, is a major vegetational component of tidal marshes from New Jersey to Texas (ELEUTERIUS, 1976a). The rush often occurs in copious stands of closely spaced shoots. Populations of *J. roemerianus* located in the lower portion of estuaries and on barrier islands are exposed frequently to strong winds, heavy waves and vigorous tidal action which remove dead standing leaves periodically. Tidal marshes exposed to such high energy forces are swept clean of most plant detritus and consist mostly of green, living leaves. However, many large tracts of marsh located in the upper parts of tidal bayous are protected from strong wind, wave and tidal action and consequently dead-standing leaves are seldom removed, resulting in a densely crowded, upright mass of living and dead leaves. Here leaf decomposition by saprophytic fungi takes place in an upright position.

Leaves in all stages of growth and decomposition are found in these protected marshes. In the most advanced stages of decomposition the leaves collapse into dust when gently rubbed between the fingers. From previous work, we hypothesized that silica may be the primary material holding these powder-like leaves together (LANNING and ELEUTERIUS, 1981, 1983, 1985). If our hypothesis was true, the percentage of silica based on dry weight would be expected to be relatively high in relation to the ash content. The paper reports upon our study of the relationships between silica, ash and dry matter (weight) of living and dead leaves of different ages.

86032 received 10 September, 1986; accepted in revision 14 November 1987.

METHODS

Leaves of *Juncus roemerianus* were collected from a tidal marsh in a very protected location behind a barrier of high sand dunes at Belle Fontaine Beach, which lies six miles east of Ocean Springs in Jackson County, Mississippi. The dunes are covered by *Quercus virginiana* (live oak), (Southern red cedar), *Uniola paniculata* (sea oats), *Ceratiola eracoides* (rosemary) and a host of other sandy beach and dune plants. Selection of living leaves were based on the chronological pattern worked out for *Juncus roemerianus* by ELEUTERIUS and CALDWELL (1981). From this same work we were also easily able to determine the chronological age of dead leaves because the pattern of leaf production remains essentially the same for each shoot in this particular population as previously determined. Leaves from one to eight years old were collected and analyzed for silica and ash. A 25 cm section was taken from the middle of 25 leaves of the same age for a composite sample. Eight composite samples were collected representing leaves from one to eight years old.

The plant materials were thoroughly washed and then air dried at 110° C. The leaves were ground in a Wiley mill before analysis. Ash and silica content of the leaves was determined by standard gravimetric techniques (KOLTHOFF and SANDELL, 1952). Tissue samples were ashed in platinum crucibles at about 500° C, and the weight of the ash determined. The ash was then treated with 6 N hydrochloric acid to remove other mineral impurities. The silica was then filtered out and ignited in platinum crucibles. The silicon dioxide content was determined by difference in weights before and after treatment with hydrochloric acid. All determinations were made in duplicate or triplicate.

RESULTS AND DISCUSSION

Leaf production in *Juncus roemerianus* is from basal meristematic tissue. The oldest part of the leaf is the tip. In the mature leaf death first occurs at the tip and slowly proceeds downward (ELEUTERIUS, 1976b).

The growth curve based on dry weight is shown in Figure 1. The average maximum growth was reached at year four, and because the leaf tip was dying before leaf growth ceased, the entire leaf was dead by year 6.

In the one year old leaf, silica content was low and characteristic of rapidly growing, young plant tissue (Figure 1). The corresponding high ash content indicates the presence of a considerable amount of organic nutrients, also characteristic of young leaves. Silica content increases to about six times when the leaves are four years old. After year four the dry mass (weight) of the dead leaves decreases rapidly. Correspondingly, the relative ash or organic content of the leaves begins to decrease from year two to year six. Microscopic examination of these leaves reveals that fungal hyphae invade the dead leaf cells immediately after death, that the soft tissues of the mesophyll and parenchyma are first destroyed (ELEUTERIUS, unpublished data). Utilization of leaf nutrients by fungi and the increase in fungal mycellium account for the ash content to increase relative to a decrease in dry mass. However, the loss through leaching of elemental nutrients obviously also accounts for a major decrease in leaf weight.

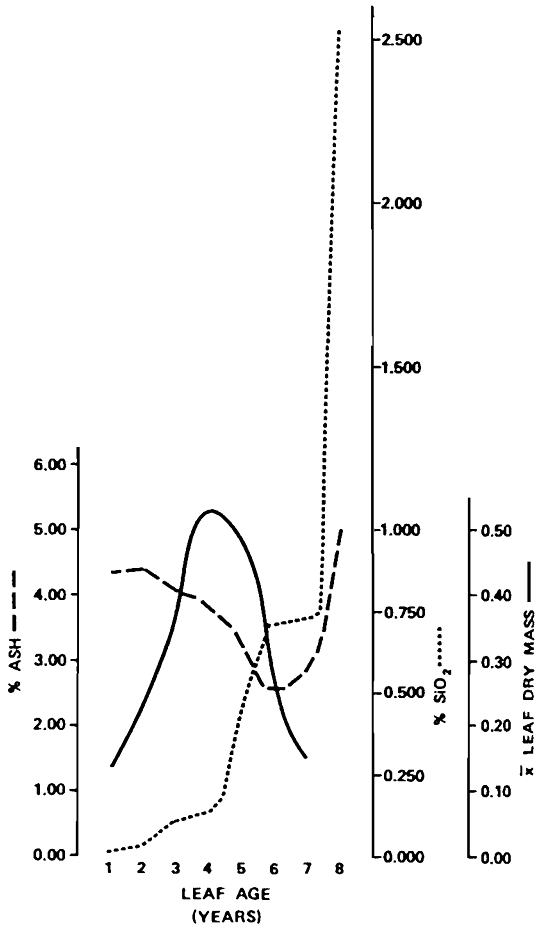

Figure 1. The growth and decomposition curve, based on dry weight in grams, of *Juncus roemerianus* in relation to the silica and ash content.

Consequently, as the cellulose structures of the leaf are stripped away by fungi, the silica plates, layers and structures remain intact. Ultimately, essentially all that remains is a siliceous cast of each leaf. This explains the easy fragmentation of leaves into small particles and dust. The cylinder of hard, thick walled fibers of the scherenclyma girders located near the leaf surface and internal vascular bundles that run length-wise of the leaf are the last structures attacked by cellulose decomposing fungi.

Dead-standing leaves that are several years old are silver in color and when very dry become almost white in bright sunlight. When these leaves are wet they become light grey in color. The wetting and drying process of dead-standing leaves favors fungal development. These leaves also become wet by rain or dew more often than by tide (salt) water, another factor favoring fungal growth. Terrestrial fungi are prevalent in tidal marshes, whereas marine fungi comprise about 1% of the mycota. The saprophytic fungi causing decomposition of dead-standing leaves of *Juncus roemerianus* appear to be successional, corresponding to leaf age old, seasonal and taxonomically complex entailing from several to many species. We are uncertain at this time of the identity of the fungal species involved.

KOHLMEYER and KOHLMEYER (1979) state that *Juncus roemerianus* harbors at least 30 higher fungi but does not list them. However, they point out that the mycota of halophytes is a conglomeration of species, composed of unrelated genera. Furthermore, they state that fungal taxa attacking the basal parts of marsh plants differ from those attacking the upper, more immersed parts. They use *Spartina alterniflora* and *Juncus roemerianus* growing in North Carolina as examples. Marine fungal species are found mainly in the lower portion of the plant, which is submerged regularly by the tides, whereas terrestrial fungi inhabit the upper part of the host which is not immersed during regular high tides (GESSNER, 1977). *Juncus roemerianus* occupies a position of higher elevation and, thus, is less frequently flooded than *Spartina alterniflora* (ELEUTERIUS and ELEUTERIUS, 1979), so whether or not there is a separation of marine and terrestrial fungal types encountered along the upright leaves of plants in the present study is not known.

Silica deposits in plants has been shown to provide protection against fungus and insect attack by a number of studies (MIJAKE and IHEDA, 1932; ISHIZUKA, 1971; JONES and HANDRECK, 1967; KUNOH and ISHIZAKI, 1975). LANNING (1963), in a study of silicon in rice, referenced a number of papers which indicated that a low available supply of silicon in the soil increased the susceptibility of rice to diseases and insects. And that application of suitable silicon compounds to the soil greatly diminished the attack of rice by blast and brow spot fungi and increased the yield of rice grain. No parasitic fungi are known to attack *Juncus roemerianus*, but the upper portion of leaves in some populations of the species are often moderately grazed by grasshoppers (ELEUTERIUS, 1984). Our study supports the view that fungi, insects, and probably bacteria, do not attack silica plates, fibers, layers or other silica deposits in plants.

TWISS (1983) and TWISS and SMITH 1969) have shown that silica phytoliths of plants do not decompose in the soil after the plants decay which further supports the present study that microorganisms do not attack nor destroy silica deposits. They also found that these phytoliths could be classified to specific plant types and used to distinguish changes in climate and vegetation over long periods of geological time. LANNING and ELEUTERIUS (1985, 1983, 1981, 1978) have described a number of silica deposits in coastal plants. PARRY and SMITHSON (1964) also have reported the types of opal silica deposits found in the leaves of British grasses. Application of silica phytoliths morphology to sedimentology studies in tidal marshes may prove useful in reconstructing the geological and climatic history of marshes and other coastal environments including archeaological sites.

In a previous paper (LANNING and ELEUTERIUS, 1978), we reported that the amount of silica varied among populations of *Juncus roemerianus*, but the depositional pattern of the silica remained the same. This study shows that dead leaves held erect by dense stands of leaves are decomposed primarily by fungi. Such aerial decomposition provides an alternate view of how inorganic and organic materials resulting from *Juncus roemerianus* growth enters the estuarine food chain and contributes to the energetics of estuaries.

In contrast to *Juncus roemerianus*, fungal decomposition of dead-standing shoots (leaves and stems) of smooth cord grass, *Spartina alterniflora*, is well documented (NEWELL and FALLON, 1983; NEWELL and STATZELL-TALLMAN, 1982; GESSNER, 1977; GESSNER and KOHLMEYER, 1976; WAGNER, 1969).

ODUM and DE LA CRUZ (1967) attribute estuarine enrichment to the decomposition of vascular plants by bacteria, but recent mycological investigations indicate that fungi are important decomposers in salt marshes equal to or greater than the bacteria (GESSNER, 1977; GESSNER and GOOS, 1973a, b; MEYERS *et al.*, 1970; MEYERS *et al.*, 1972; MEYERS *et al.*, 1975). The present study corroborates that contention.

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□ RESUMEN □

Se ha examinado el contenido en sílice del junco intermareal, *Juncus roemerianus*, en relación con su edad y grado de marchitamiento de las hojas. El porcentaje de sílice aumenta a medida que se descomponen las hojas. El período de vida de las hojas varía entre uno y ocho años. Los organismos primarios de descomposición son los hongos saprofíticos. A medida que son atacados los tejidos celulósicos de las paredes de las células estructurales y de soporte, el hongo micellium se incrementa dentro de las hojas. Este proceso queda reflejado en incremento en contenido de cenizas a medida que el peso seco de la hoja se aproxima a cero. Las hojas marchitas a los ocho años de edad son esencialmente un vaciado en sílice de la hoja.--*Miguel A. Losada, Universidad de Cantabria, Santander, Spain*

□ ZUSAMMENFASSUNG □

Der Silikastgehalt der Binse *Juncus roemerianus* wurden untersucht, um die Beziehung zwischen dem Alter der lebenden und gestorbenen Blätter zu finden. Der Silikatgehalt steigt im Lauf der Zerlegung der Blätter (das Alter der Blätter wird von 1 bis 8 Jahre geordnet). Die wichtigste Zerlegungsorganismen sind saprophytische Schwämmen. Als die Zellwände der Struktur- und Unterstützungsgeweben angefallen werden, steigt die Zahl der Myzelien drinnen den Blätter. Dieses Punkt wird durch eine Zunahme des Aschgehalts direkt gezeigt, wenn das getrockene Blattgewicht dem Nullwert nahekommt. Nachdem 8 Jahre sind gestorbene Blätter wesentlich kieselartige Formen.--*Stephen A Murdock, CERF, Charlottesville, Virginia, USA*

□ RÉSUMÉ □

Dans le domaine intertidal, la fraction siliceuse de *Juncus roemerianus* est examinée en fonction de l'âge des feuilles vivantes ou mortes en place. Le poucentage de silice croît avec la décomposition des feuilles. Celles-ci ont de 1 à 8 ans. Les organismes primaires de la décomposition sont des champignons saprophytes. Une fois la membrane de cellulose des tissus cellulaires attaquée, le mycellium fongique croît à l'intérieur de la feuille, comme l'indique directement la croissance de la teneur en cendres, tandis que la masse sèche de la feuille (poids) tend vers zéro. Les feuilles mortes en place à 8 ans d'âge sont la dépouille siliceuse de la feuille.--*Catherine Bressolier, EPHE, Montrouge, France*