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FREQUENCY DOMAIN MEASUREMENTS ON LEAVES OF *AVICENNIA MARINA*

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Summary

Frequency domain measurements on the leaves of *Avicennia marina* grown with different sea water concentration have been performed in the range 10^{-2} to 10^{5} Hz. The measured leaf samples show, at low frequencies, a tendency to low frequency dispersion. The normalized complex capacitance data has shown domination of single process.

INTRODUCTION

In recent years there has been an increase in research activity concerning the physiological ecology of halophytes, which have been stimulated by a number of significant problems. The natural coastal and salt marsh habitats have been strongly affected by human activity and effort are being made to conserve existing salt marshes and their new creation. The need for more food and fiber stimulated efforts to find suitable halophytes. Efforts have also been directed towards determining the mechanisms responsible for salt tolerance in plants. Partridge and Wilson (1987) determined that the salt tolerance of twenty nine halophyte species decreased from the lower to the upper marsh, which correlated well with changes in field salinity conditions. Researchers (Clough, 1984; Partidge and Wilson, 1987; Burchett, 1989) have reported the growth and salt balance of Avicennia marina and other mangrove species.

Use of electrical properties of agricultural products for moisture measurement has been the most prominent agricultural application for dielectric properties data. The dielectric properties, e.g. dielectric constant and dielectric loss factor, are measured at very high frequencies in the range of MHz and GHz (Nelson, 1991).

At such high frequencies the contribution of heavy charge carriers such as ions is almost zero. This is an important factor which can give more insight to the physical system of the products. It can only be possible 1 MHz down to < 1Hz.

In the present paper dynamic response of transport processes has been studied in the frequency range 10^{-2} to 10^{5} Hz, on leaves of *Avicennia marina,* grown with different sea water concentrations.

PHYSICAL BACKGROUND

The dielectric properties of a material are those characteristic that determine the materials behaviors when it become part of an electrical circuit or when it is exposed to electric or electromagnetic fields. The dielectric properties depend not only upon chemical composition of materials, but also upon their temperature, the frequency of applied electric field and moisture content.

Dielectric spectroscopy is an analytical technique that has been used in the study of physical systems such as polymers (Black, 1979), semi-conductors (Joscher *et al.*, 1986; Anis *et al.*, 1992), glasses (Haque *et al.*, 1994) and soil (Anis and Jonscher, 1993) as well as in the study of biological systems such as nerve tissue (Dissado, 1987) and plant leaves (Hill *et al.*, 1987).

When an ac is applied across a dielectric material, dipoles attempt to reorient at the same rate as the field. In an ideal system the polarization current would be 90°out of phase with the applied voltage, and no energy is lost. In reality there is an in-phase and out of phase component to the polarization current with respect to the applied field. Because the dipoles are restricted by their local environment and may not keep up with the applied field. The energy stored, by the out of phase component, is measured via the capacitance (C'). The energy lost, by the in-phase component, in measured via the dielectric loss (C") i.e. ac conductance divided by angular frequency (ω).

The frequency dependence of the real and imaginary components of the effective complex susceptibility, $\tilde{x}$ can be expressed as (Johscher 1983, 1991).

$$\tilde{x}(\omega) = C'(\omega) - iC''(\omega) \qquad (1)$$

where

$$\tilde{C}(\omega) = C'(\omega) - i\, C''(\omega) \qquad (2)$$

C(ω) is the measured complex capacitance and C_∞ is the high frequency limit of the capacitance where the losses are insignificant. The universal form of dielectric response is characterized by a fractional power law dependence on frequency

$$x(\omega) = A(i\omega)^{n-1} \qquad (3)$$

where A is a constant and exponent falls in the range $0<n<1$ The Kramers-Kronig relation required that real and imaginary components of $\tilde{x}(\omega)$ are same function of frequency, differing only by a constant, so that

$$[x''(\omega)/x'(\omega)] = \cot(n\pi/2) \qquad (4)$$

which is the general property of the so called "*Universal*" dielectric relation.

The limiting case of dielectric relaxation for which the exponent n assumes value close to zero is referred to as Low Frequency Dispersion (LFD), which implies that the system's loss is high and that both the loss and the real part increase rapidly towards low frequencies almost as ω^{-1}.

EXPERIMENTAL TECHNIQUES

Seedlings of *Avicennia marina* were grown for about a year. They were treated with brackish water for first six months and subsequently with different sea water concentrations viz 0%, 50%, 75% and 100%. These concentration were fortified with nutrient solution. Fourth leaf from the apex was considered to be matured and plucked for dielectric spectroscopy. This was suppose to give the same growth conditions and a reasonable size of the leaf to fit into the sample holder with 12 mm contact diameter. Each leaf was cut to the size of the disc shape brass contacts and pressed between the two contacts for volume measurements.

Measurements in the frequency range 10^{-2} to 10^{5} Hz were carried out using a Frequency Response Analyzer (FRA), (Solatron 1255) in conjunction with a special Chelsea dielectric interface. The experimental procedure is same as reported by Anis *et al.*, (1992). The measurements were made with 0.1 V rms and zero dc bias.

RESULTS AND DISCUSSIONS

Figure 1 show the log-log plots of frequency dependence of the real $C'(\omega)$ and imaginary $C''(\omega)$ of the complex capacitance of the leaves of Avicennia marina with four different salt concentrations. The individual sets of data are displayed vertically for clarity and typical capacitance value are indicated.

Both $C'(\omega)$ and $C''(\omega)$ increase, at low frequencies, with an increase in salt concentration. Although $C'(\omega)$ and $C''(\omega)$ in individual sets do not seem to be parallel, the data has been normalized.

Figure 2 shows the normalization of all four $\tilde{C}(\omega)$ plots. From the slop, the value of cot $(n\pi/2)$ is found to be 2.31 and the two lines with the slope -0.74 represent low frequency dispersion behaviour. A single process seems to be contributing in all concentrations, but the leaf with 100% sea water has shown possible contribution of contact effect at lowest measured frequencies.

Three lower concentrations, 0%, 50% and 75% are showing a parallel combination of a conductive and capacitive elements. The 100% $\tilde{C}(\omega)$ plot is representing combination of two parallel conductive and capacitive elements connected in series. Where one element at higher frequencies represent "*volume*" and the other element at lower frequencies a possible "*interface*" effect.

The cross over frequency ω_c is shifting towards higher frequencies (Fig. 1) with an increase in salt concentration, from 10 Hz for 0% to 5×10^3 Hz for 100%. It has been reported (Hill *et al* 1986) that the dispersion below ω_c arises from imperfect ionic transport through the matrix of cells that form the body of the leaf and occurs following charge accumulation on the cell walls.

As the salt concentration increases the water potential is lowered in the leaf and in response to salt stress, organic compounds are produced within the cells. This behavior is reflected at the highest concentration where loss, $\tilde{C}(\omega)$ is lower than the other concentrations.

CONCLUSION

The leaf samples of *Avicennia marina* with different sea water concentrations have shown, at low frequencies, a tendency to low frequency dispersion with domination of a single process. The $\tilde{C}(\omega)$ behaviours is a signature representing structure components of a particular leaf.

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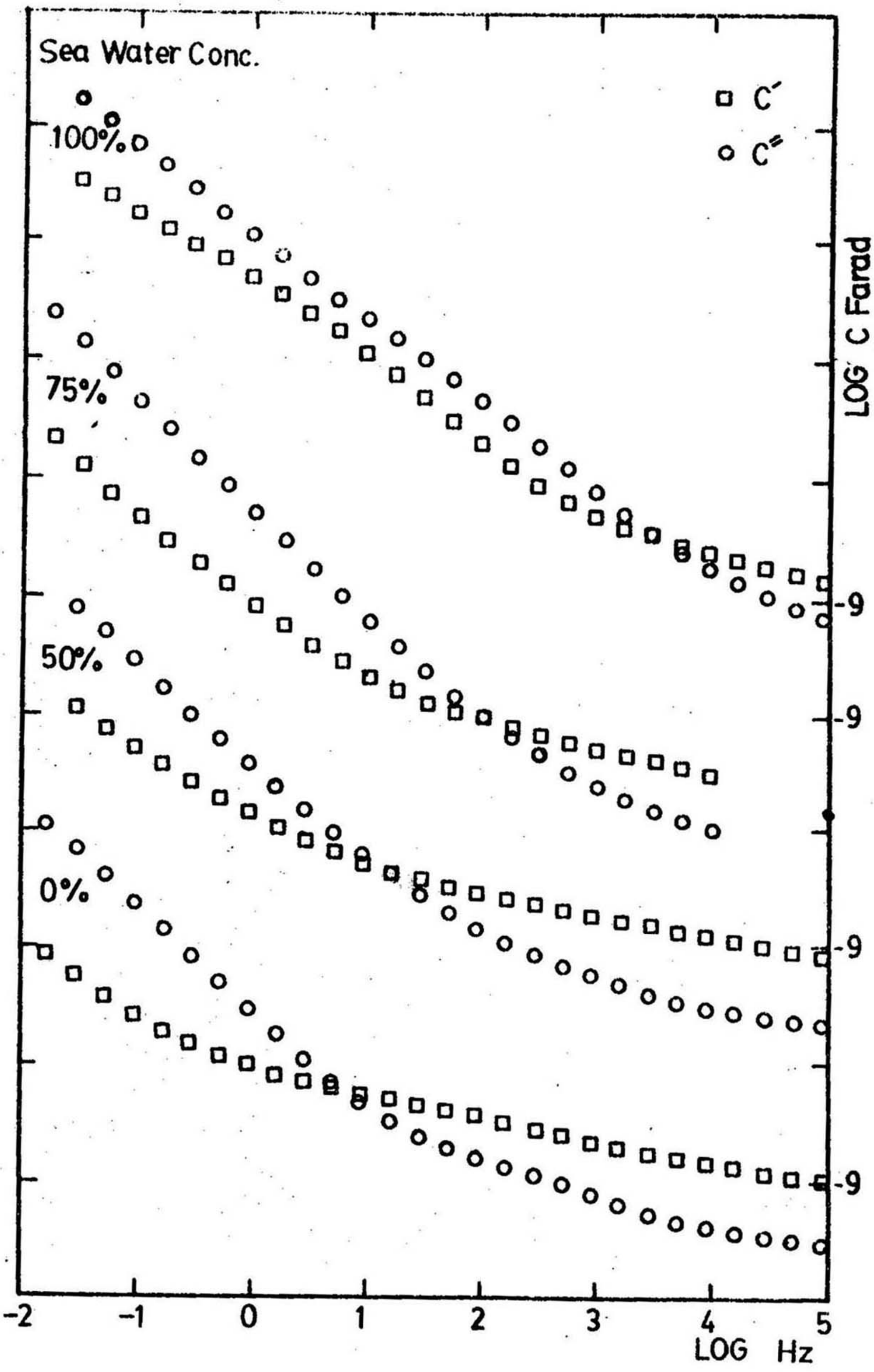

Figure 1: Log of frequencyversus log of the complex capacitance, the real part C' and imaginary part C", of leaves of *Avicennia marina* grown with different sea sater concentrations. The individual sets of data are vertically shifted for clarity and typical capacitance values are indicates.

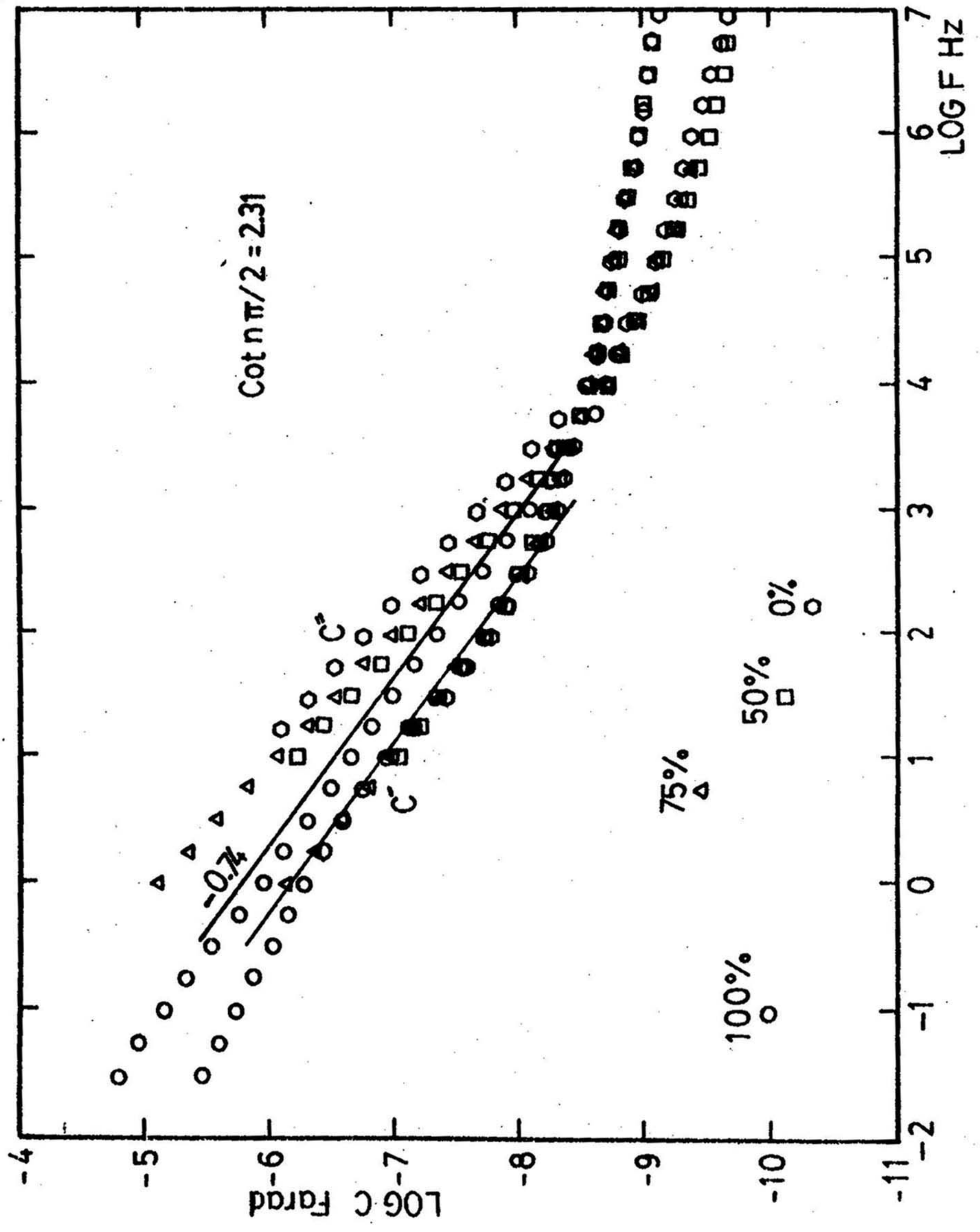

Figure 2: The normalized freauency dependence of the component of complex capacitance of leaves of *Avicennia marina* grown with different salt concentrations. The two lines of -0.74±0.02 are drawn at the Karamers-Kronig compatible position.