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The effects of elevated carbon dioxide concentrations on the stomata of *Spartina patens* and *Scirpus olneyi*

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ABSTRACT

Two different species of plants *Spartina patens* and *Scirpus olneyi*, a C_4 grass and a C_3 sedge respectively, were grown in controlled environments with ambient levels of CO_2 and elevated levels of CO_2. The effects of the stomatal densities of the plants grown in the elevated CO_2 environment were similar for both species. The stomatal densities of both species decreased. Stomata have two major functions: let CO_2 in and let H_2O out. The more stomata there are the more H_2O that the plant will lose. If there are less stomata due to increased [CO_2], the plant will retain water much better.

Keywords: *atmospheric CO_2, elevated CO_2, Scirpus olneyi, Spartina patens, stomata, stomatal density*.

INTRODUCTION

The carbon dioxide concentration ([CO_2]) in the atmosphere is rising. During the pre-industrial period, the [CO_2] was around 280 parts per million (ppm) (Luo and Mooney, 1995). In 1994, the [CO_2] was approximately 360 ppm and is expected to at least double by the next century (Luo and Mooney, 1995).

This rise in [CO_2] should have an affect on the density of stomata in plants. Stomata are spaces between the epidermal cells that can open or close. (McFadden and Keeton 1995). One of the main functions of the stomata is letting CO_2 enter the leaf for photosynthesis and the other function is letting H_2O out for transpiration. The plants have a dilemma, though. They need to get as much CO_2 from the atmosphere as possible without losing too much H_2O. If the [CO_2] in the atmosphere increases and causes more stomata on the leaves, then the plants would lose too much H_2O. If the stomatal density decreases, then the plant would get just as much (or more) CO_2 and would lose less H_2O (Salisbury and Ross, 1992).

My question is, will the stomatal density be affected with the increased levels of [CO_2]? The stomatal density depends on a number of environmental factors, including climate, latitude and longitude, shade leaves and sun leaves, and the position on the leaf (Woodward and Kelly, 1995). Woodward and Kelly (1995) showed that amphistomatous (having stomata on both sides of the leaf) plants showed a more significant change in stomatal density than the hypostomatous (having stomata only on the lower surface of the leaf) plants. Also, different species respond differently to increases in [CO_2] (Boetsch, et al., 1996).

The two different species that I am looking at are *Spartina patens* and *Scirpus olneyi*. *Spartina* is a C_4 plant, and *Scirpus* is a C_3 plant. The difference between a C_4 plant and a C_3 plant is that the C_4 plants have a CO_2 concentrating mechanism that is helpful at low concentrations of CO_2, but it is costly for the C_4 plants at higher concentrations (Farquhar, 1997). Another difference is that C_4 plants have a better water use efficiency than the C_3 plants (Salisbury and Ross, 1992). Therefore, the C_4 plant is less likely to have a big change in its stomatal density. The C_3 plant, on the other hand, should show a significant change in the density of stomata with the increased levels of [CO_2].

My hypothesis is that both species will show a decrease in stomatal density as the CO_2 levels increase, but the C_4 plant will decrease less than the C_3 plant. Knapp et al. (1994) show that the average stomatal density was lower in C_3 and C_4 plants that were grown under elevated CO_2 levels.

MATERIALS AND METHODS

The plants used were obtained from Dr. Bert Drake from the Smithsonian Environmental Research Center (SERC). He has tested these plants for the past ten years using experimental chambers where he was able to regulate the amount of CO_2 in the air. There were 20 different plots where the plants were being treated. Ten of them were grown under ambient levels of CO_2 (≈350 ppm) and ten were grown under elevated levels, (≈700 ppm) (http://serc.si.edu/).

The method that I started out using was taking a leaf from a plant and taking four different sections from it. One section was taken close to the tip, two from the middle and another one closer to the bottom. I took data from ten different plants using this method and plotted the data. After the initial plants, I designated the spot to be examined 7 cm from the culm for *Spartina* and 20 cm from the base for *Scirpus*. When looking at the leaf under the microscope at 400x, I counted stomata using an optical reticle with a field of view of 0.25mm by 0.25mm. I counted ten different fields per leaf, ten plants per plot (or as many as were available), five plots per treatment, and two treatments per species.

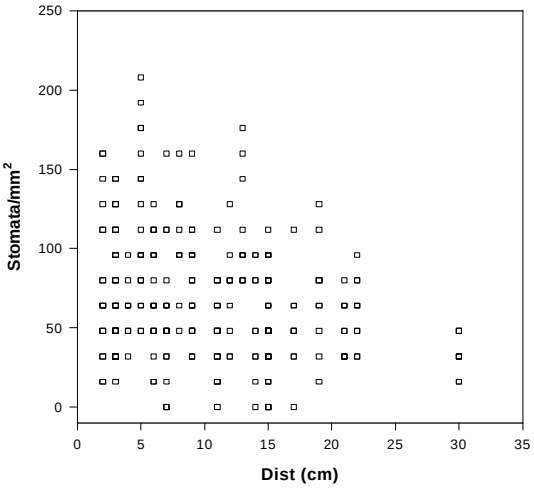

Figure 1. The distance from the culm vs. the stomatal density in *Spartina patens*. Shows that it makes no difference on what part of the leaf the count is made.

RESULTS

When I was doing the sampling, I found that there was no difference in the stomatal density regarding the distance from the culm (see Figure 1). That is the reason why I designated a certain distance for the rest of the plants.

After taking many counts of stomata of all the plants, I found that there was a lot of variation in the numbers of stomata, but I found a general decrease in the stomatal densities of the elevated treatment in each species (see Figure 2). The difference in the densities of the C_3 plants, *Scirpus*, was significant according to a t-test with P=0.036767. The difference between the numbers of stomata in the ambient and elevated levels in *Spartina* was not considered significant according to a t-test, but it was really close to being significant with P=0.05932.

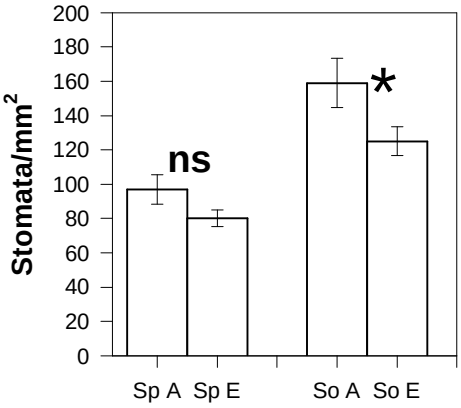

Figure 2. The mean stomatal densities of *Spartina patens* and *Scirpus olneyi* with the ambient treatment of CO2 and the elevated treatment with one standard error. Significance identified by the * (P=0.036767), and ns is not significant (P=0.05932).

DISCUSSION

In this study, the increased levels of CO_2 affected the stomatal densities of both *Spartina patens* and *Scirpus olneyi*. Drake et al. (1996) found an average of 20% decrease in stomatal density in 28 different species. Although, it is common to show a decrease in stomatal density with the increase of atmospheric CO_2, it is not the same for all species (Drake, et al., 1996).

A reason for the decrease in stomatal densities as the [CO_2] increases is because the plants aren't going to need as many stomata to get the CO_2 that they need for photosynthesis. "The rate of diffusion into the leaf will be a decreasing limitation to photosynthesis as atmospheric [CO_2] rises," (Drake, et al. 1996). Therefore, a plant can get by with fewer stomata when the CO_2 levels are high. Also, it's better for a plant to have fewer stomata because it won't lose as much water during transpiration (Salisbury and Ross, 1992).

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