Research Article

Growth of Sphagnum Riparium Contains the Signature of Short Wavelength UV-B Passing Through the Ozone Layer

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Abstract. It follows from the negative reaction of plant growth to UV-B that the wavelengths penetrating through the ozone layer, in contrast to the absorbed ones, should leave a specific signature in the form of growth inhibition. This signature is expected, for example, for peat mosses of the *Sphagnum* genus. To test this hypothesis, we studied the growth response of *Sphagnum riparium* Ångstr. to solar UV in the 200-310 nmrange, recorded outside the Earth's atmosphere. It was found that wavelengths starting from 286 nm significantly inhibited the growth of *Sphagnum*, while shorter wavelengths hadno significant effect. It follows that wavelengths starting from 286 nm reach the Earth's surface, while shorter ones are absorbed by the ozone layer. These data correspond to the physical concepts of the 286 nm limit for solar radiation penetration through the ozone layer. Based on the universal UVR8-dependent mechanism of UV-B reception in plants, we conclude that plants have potential as indicators for assessing the penetration of the shortest solar UV-B wavelengths through the ozone layer.

Keywords: UV-B, 286 nm, *Sphagnum*, growing season, growth inhibition

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1. Introduction

Natural fluctuations in solar radiation are one of the obligate components of ambient UV (ultraviolet). Near the earth's surface, they are practically invisible due to masking by stronger factors (state of the ozone layer, seasonality, time of day, cloudiness, etc.), but in open space they are clearly represented at different wavelengths.

The specificity of such fluctuations at different wavelengths can be used in botanical detection of the passage of these wavelengths through the ozone layer. It follows from the negative UV-B dependence of plant growth [1] that wavelengths partially transmitted by the ozone layer, as opposed to fully absorbed ones, should leave a specific signature in the form of inhibition of shoot growth. For a long time, solar satellites have been recording in detail the natural fluctuations of solar UV at different wavelengths in open space, so the hypothesis can be tested by studying the response of daily plant growth to the radiation intensity at individual wavelengths [2].

2. Methods and Equipment

The model object was the widespread peat moss *Sphagnum riparium* Ångstr. (Sphagnaceae, Bryophyta) with circumpolar distribution in Europe, Asia, and North America. The study site was a minerotrophic herb-sphagnum mire area with an absolute dominance of *S.riparum*, located in Karelia (Russia, 61°51'14" N; 34°10'51" E; 50 m above sea level). In the period from 2015 to 2018, detailed growth monitoring was carried out in a series of sample plotsusing natural markers of growth – geotropic curvatures of the stem [3]. The main monitoring parameters are shown in Table 1, and details are described in our previous papers [2, 4]. Each year, sample plots were madein new undisturbed areas of the Sphagnum carpet. The monitoring process consisted in sequential measurement of the increment of sampled shoots relative to those measured previously. Thus, patterns of daily shoot growth were obtained for each sample plot, and on their basis, patterns of daily shoot growth were obtained for the entire mire area. The latter were used for the analysis. Here, we analyzed data collected after June 1 to avoid the effect of spring flooding of the Sphagnum mat, which could limit the supply of short wavelengths to plants. The data source on solar UV at selected wavelengths in open space was the freely available daily spectral data of the SOLSTICE instrument (SOLar STellar Irradiance Comparison Experiment; 115–310 nm, values in W nm^{-1} m^{-2}) from the SORCE (SOlar Radiation Climate Experiment) solar space satellite http://lasp.colorado.edu/lisird/data/sorce_ssi_l3/. The focus range was 200–310 nm, which includes a significant portion of the UV–C and UV–B spectra. Thus, the selected interval contains both partially transmitted and fully absorbed by the ozone layer UV wavelengths. The preliminary preparation of the data consisted of removing trends from the patterns of daily growth and UV. The second order polynomial seasonal trend was subtracted from the daily growth patterns. A 30-day moving average was subtracted from UV-patterns, which reflects the current trend of solar activity. The effect of individual UV wavelengths on Sphagnum growth was analyzed using Pearson's correlation coefficient.

3. Results and Discussion

According to the growth response of *S.riparium*, two contrasting intervals were demarcated within the investigated range of 200–310 nm (Figure 1). In the first interval, 200–285 nm, no inhibitory effect of wavelengths on the daily increment of Sphagnum was found ($-0.074 \leq r \leq +0.004$; $0.084 \leq P \leq 0.934$; $n = 539$). In the second interval, 286-310

Table 1: Main parameters of *Sphagnum riparium* growth monitoring

	2015	2016	2017	2018	2015–2018
Period of observations, days	127	131	142	139	539
Number of sample plots	4	11	13	6	4–13
Number of shoots measured	9092	24217	40598	22761	96668
Total number of daily growth rates	443	1110	1364	830	3747
Mean sample size, shoots	94	60	55	53	66
Mean interval between sampling events, days	5.2	2.8	2.0	2.1	3.0

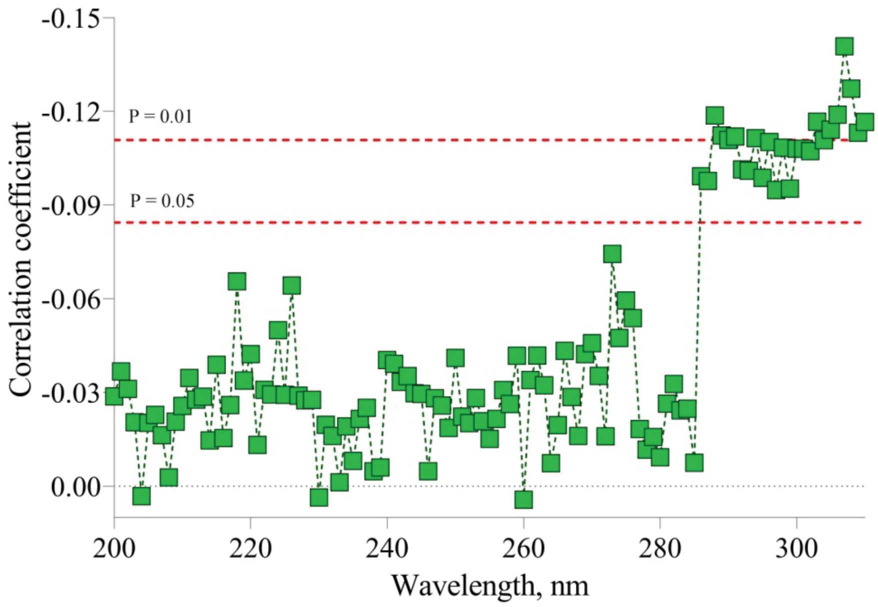

Figure 1: Correlation between the daily growth rates of *S.riparium* and the corresponding UV intensities for the 200–310 nmrange with 1 nm step.

nm, a significant inhibitory effect of all wavelengths was recorded (–0.141 ≤ r ≤ – 0.095; 0.001 ≤ P ≤ 0.028; n = 539). Thus, the analysis revealed biological signatures of ≥286 nm ambient UV wavelengths, but did not find signatures of <286 nm wavelengths.

Thus, the results support the hypothesis about the presence of UV–B wavelength signature in the growth of plants. Moreover, such a signature is found throughout the 286-310 nm spectrum i.e., from the short wavelength limit of the atmosphere to the upper limit of the SOLSTICE instrument. The existence of a universal UV-B photoreceptor UVR8 (UV-B resistance locus 8 protein) in plants, with maximum sensitivity to 280-300 nm convincesus that many plants may contain a similar signature.

It has now been established that plants can record some ancient solar events, as well as the history of the UV-climate and ozone layer. However, until now, plants have not been considered as detectors of the transmission of solar UV-B wavelengths through the ozone layer, although this may have important applied applications. It is believed that under ecologically relevant conditions, solar UV-B near the short wavelength limit of the atmosphere is relatively safe, since it reaches the earth's surface in trace amounts and is practically undetectable by physical instruments. However, the data obtained here indicate that this trace radiation can have a significant biological effect on the natural growth of plants, and therefore may pose an underestimated threat to wildlife. It is necessary to verify the results using different plant species, but in the future our idea can be applied in the reconstruction of the ozone layer capacity for solar UV-B over the past decades.

4. Funding

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5. Conflict of Interest

The author declares no conflicts of interest related to this paper.

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