Productivity of *Polytrichum juniperinum* Hedw. in forest ecosystem of Tatarstan

N R Shafigullina and E N Karzhavkina

Institute of Environmental Sciences, Kazan Federal University, Kremlevskaya str., 18, 420008, Russia

E-mail: nadiashfigullina@gmail.com

Abstract. The values of linear and phytomass increments for the period May - October 2016 in forests of Tatarstan (central part of European Russia) are studied. The average values of increments for *Polytrichum juniperinum* Hedw. are provided. The relation between habitat characteristics and the productivity of *Polytrichum juniperinum* is discussed.

1. Introduction

It is possible to assess the role of productivity of mosses in conserving biodiversity and contributing to the productivity of the vegetative cover of the Republic of Tatarstan. Despite the apparent importance of the moss communities in the vegetation cover of forest ecosystems, they have not yet been sufficiently studied. The evaluation of forest production does not consider the contributions of the annual production of ground cover. However, it is the ground cover, including moss-lichen, which makes a significant contribution to the annual production of forest and forest-steppe ecosystems [1]. The study of moss growth is important for assessing the state of ecosystems in which bryophytes constitute a significant proportion of the components of the total biomass [2, 3]. In these regions, the amount of annual increments was measured to identify annual production. Such ecosystems include sphagnum bogs, forest complexes of Siberia, as well as tundra and northern coniferous taiga forests [4, 5, 6].

However, at present, the values of linear increments are not known for most of the mosses [7]. This situation is largely due to the fact that the boundaries between annual increments in many mosses are not visually determined and painstaking work is required to obtain the necessary data.

Growth is one of the indicators of productivity, but it has two components: biomass increment and linear increment (including branches). As Schwinnie [8] pointed out, unequal growth rates within one species can be the result of the influence of environmental and other factors that are not dependent on productivity. An interesting phenomenon, an increase in biomass and elongation, respectively, can occur at different times. Rincón and Grime [9] have very clearly shown that the linear increase and increase in the biomass of *Brachythecium rutabulum*, *Thuidium tamariscinum* and *Lophocolea bidentata* can be practically inverse. When the production of dry matter decreased, there was an increase in length, which led to negative biomass production [10]. Some authors [9, 11] concluded that measuring the elongation of the stem can only lead to an inaccurate picture of true productivity. In fact, biomass accumulation and linear growth are events that are not related to each other, and biomass is a better indicator of productivity than linear growth [12].
2. Materials and methods

*Polytrichum juniperinum* Hedw. is a large plant, and it grows in loose or dense turf, essentially in open habitats: on wastelands, after cutting of timber or burning, in sparse forests and forest belts, on various types of soil outcrops, both natural and man-made, in stony habitats, sometimes on fallen trees, and at the base of trunks.

To study the linear growth and growth of mosses by mass in spring (April 2016), test sites were laid in the territory of Narat-Astinsky Bor (Muslimovsky district, Republic of Tatarstan) and the national park "Nizhnyaya Kama" (Yelabuga district, Republic of Tatarstan).

The sites were chosen with different types of illumination, microrelief and substrate. Sites were in full light, in the opening between trees (penumbra), and under the trees (shadow). The substrata were chosen in a variety of ways: forest soil, stumps, and upturned roots on fallen trees. The microrelief was divided into 4 types: a flat area, a small slope, a slope, and a micro depression. To determine the dynamics of growth and the values of linear increments, the dressing method was used. To identify the mosses, decorative ribbons used for decoration of flower bouquets were split into thin long strips, and the strapping was attached at a distance of 1 cm from the tip of the shoot. In the fall (October 2016), the stalks of the banded shoots were harvested, cut at the dressing site, and collected in envelopes for further processing in the laboratory. The increments, without 1 cm, were measured and recorded and weighed on high-precision scales.

Correlation analysis was performed with the Pearson correlation coefficient. The values of increments were displayed using the ordihull function of the statistical programming environment R 3.2.2 [13]. Statistical data processing was conducted using vegan packages [14] of statistical analysis environment R. A correlation analysis of linear growth and biomass increment was carried out. Graphs of box plot with a spread of growth values with average values were constructed.

3. Results and discussion

In total 117 shoots of *Polytrichum juniperinum* were treated. The increase was measured in autumn during the growing season in April-October. Since *Polytrichum juniperinum* was found in the form of loose and small turf, we marked 12-15 shoots from which an average of 10 pieces were found. The lengths of linear increase vary from 4 to 22 mm (figure 1). There is a wide range of the magnitudes of the increment. The average increment is 12.52 mm. The increase in biomass varies from 2.6 to 19.1 mg. The average increment is 8.21 mg. The differences between the increments of *Polytrichum* samples grown in various forest areas (Nizhnyaya Kama and Narat-Astinsky Bor) are not observed.
Based on our data, the increase in biomass and linear increment react differently to the environmental factors of habitats. The Pearson correlation coefficient between linear growth and biomass increment was 0.676 (95% confidence interval 0.564-0.764, p-value <2.2e-16). Since *Polytrichum juniperinum* possesses monopodial growth and does not have lateral branches, the larger the linear increase, the greater the biomass increment.

3.1. Light

*Polytrichum juniperinum* is a heliophyte, and its growth in fully illuminated areas is higher than openings between trees and under the trees (figure 2).

Reduction of light content also affects the growth of biomass and linear growth. Reducing linear growth in penumbra and shadow is statistically significant (the level of significance in the penumbra is 0.0001, in the shadow = 0.004), in contrast to the increase in biomass.
3.2. Substrate

In the forest massifs studied by us, *Polytrichum* occupied such substrates as forest soil, dry stumps, and upturned roots on fallen trees (figure 3).

![Figure 3. Effect of substrate on growth of *Polytrichum juniperinum*. 1– forest soil; 2 – stumps; 3 – upturned roots on fallen trees.](image)

*Polytrichum juniperinum* prefers mostly well-drained sandy soils and dry habitats. The dry stump as a substrate has a negative effect on the increment of biomass -1, and the upturned roots is positive +1.5 relative to the forest soil, but these values are not reliable. Linear gain sensitively reacts to the substrate. The largest linear increase is observed on the upturned roots. If we take the values of linear increment in the forest soil for 0, then the gain on the upturned roots will be +7.3 which is statistically significant.

3.3. Microrelief

Microrelief affects the distribution of heat, moisture and light in the microhabitat. *Polytrichum* is found on four types of microrelief: a flat area, a small slope, a slope and a micro depression (figure 4). A small slope and slope negatively affect the biomass of moss, but this is not statistically significant (0.7 and 0.9) with respect to the flat area. The longest moss shoots were observed in a decrease of +8 relative to the flat area (significance level 5.50e-05). Also long shoots characterize the samples collected by a small slope +3.9 and slope +3 (significance level 0.02 and 0.37). Thus, the greatest increase is observed in microdepression.
Figure 4. Influence of the microrelief on growth of Polytrichum juniperinum. 1 – a flat area, 2 – a small slope; 3 – a slope; 4 – microdepression.

4. Conclusions
Polytrichum juniperinum prefers microdepression, open lighted areas and upturned roots as a substrate. Growth on the slope adversely affects the biomass of moss. Reduction of light content also affects the growth of biomass and linear growth. There were no significant differences between the growth rates in various forest areas.

Acknowledgements
We thank Nelli Chizhikova for help in statistical data processing.

References
[1] Goncharova I A and Benkov A V 2015 Sibirskiy lesnoy zhurnal 6 54–61
[2] Yermolayeva O V and Shmakova N Y 2016 Uchenye zapiski Petrozavodskogo gosudarstvennogo universiteta, obshchaya biologiya 8 (161) 40–45
[3] Kostina M V, Safronova G A and Agapov P A 2013 Arctoa 22 15–22
[4] Kostina M V and Safronova G A 2012 Botanicheskiy zhurnal (Moskva KMK) p 88-100
[5] Grabovik S I and Nazarova L E 2013 Arctoa 22 23–26
[6] Ermolaeva O V, Shmakova N Y and Lukyanova L M Arctoa 22 7–14.
[7] Kostina M V, Safronova G A and Barabanshchikova N S 2016 Bull. MOIP 121 (1) 53–64
[8] Schwinning S 1993 Bull. Ecol. Soc. Amer. Program and Abstracts 78th Ann. ESA Meeting 74(2) 432
[9] Rincón E and Grime J P 1989 J. Ecol. 77 447–455
[10] Glime J M 2012 Bryophyte Ecology (Electronic Book Vol 1)
[11] Stark L R and McLetchie D N, Mishler B D 2001 Plant Ecol. 157 183–196
[12] Stark L R 2002 Bryologist 105 204-218
[13] R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria.
[14] Oksanen J et al. 2012. vegan: Community Ecology Package. R package version 2.0