Structural features of the main forest producers at the initial stages of ontogenesis

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Abstract. Based on the analysis and generalization of the research results, the authors draw conclusions about the adaptive reactions of dark coniferous species of Siberian spruce (Picea obovata Ledeb.) and Siberian fir (Abies sibirica Ledeb.) during the forest formation process in the province of dark coniferous forests of the Southern Urals. Structural features are manifested in the modification of the xylorhizome, the duration of growth, the nature of rooting, and are a display of the mechanisms of morphological adaptation to ecologico-coenotic conditions and to the influence of soil-ecological components of the substrate. The authors researched anatomical and morphological changes in xylotomic formations from juvenile to the beginning of the immature period of the adaptation process, leading to the viability of woody plants in contrasting natural conditions. Since the structural and functional organization of vegetative shoots, renewal is modified in the process of adaptation. It is shown that up to the moment of development of the trunk, differences in the lignified rhizome are more significant, based on anatomical sections, as well as the level of formation of plant tissues and the nature of age-related changes. The rates of formation of certain anatomical elements of wood as a whole are not the same for each species and depend on age-related changes, ecological plasticity, environmental conditions and many other internal and external factors.

1. Introduction
The main forest producers of the dark coniferous forests of the Southern Urals grow in the Republic of Bashkortostan and are confined to the central part of the Southern Urals (the territory of the South Urals Nature Reserve). Nevertheless, so far, dark coniferous forests have been studied fragmentarily. The natural and climatic conditions of this area, favorable for the growth of numerous plant species, differ sharply in ecological properties and belong to the representatives of the nemoral and boreal flora. Here lies the southern border of the natural distribution of forests formed by Picea obovata Ledeb. and Abies sibirica Ledeb. [1].

The aim of the research is to study structural and functional features and adaptive responses of the main forest producers of the Southern Urals undergrowth category in contrasting forest conditions of natural character.

The object of the research is juvenile and immature undergrowth plants of Siberian spruce (Picea obovata Ledeb.) and Siberian fir (Abies sibirica Ledeb.). The age of trees is 8 - 25 years. Let us note that in the study of ontogeny, scientists use standard methods for determining the age of pre-generative plants (undergrowth) of dark coniferous species of woody plants. The age of the aerial part, traditionally determined by counting whorls on the stem or the average annual growth or annual rings.
in a cross section. However, as studies show, the use of standard methods for determining the age of undergrowth leads to significant errors. The fact is that in the process of growth, trees sometimes form not one ring per year, but more, or not a single one; it all depends on soil and climatic characteristics [2].

_Picea obovata_ Ledeb. is the main ediﬁer of forest communities in the province of broad-leaved-dark coniferous forests of the Southern Urals and dominates in the main layer of most stands of indigenous and conditionally indigenous types of forests, in the subordinate layer of which the participation of spruce in the stand composition is small. Spruce is represented by single trees in mixed forest types, both in the main and in the subordinate tier of stands [1].

_Abies sibirica_ Ledeb. acts as a coedifier of spruce in most of the studied stands of native and conditionally native types of forests. In some cases, at certain stages of the regenerative-age dynamics, fir can prevail in the composition of the main layer of stands of conditionally native forest types. At the same time, fir dominates in the subordinate layer of most stands of native, conditionally native and separate mixed types of forests [1].

We carried out laying of trial plots and sampling in the stands in accordance with the generally accepted approaches to studying the characteristics of the growth of spruce and fir at the initial stages of ontogenesis [3]. Fixation of plant material and preparation of permanent microtome preparations of underground organs of woody plants was carried out according to [4-7]. We made wood cuts on a freezing sled microtome in the transverse plane. Cross-sections cut through the core and included all tree rings in diameter. The preparations were examined on an Axioplan 2 Imaging reflected-light microscope (Carl Zeiss, Germany) at various lens magniﬁcation. We photographed on an MC 80 DX automatic camera (Carl Zeiss, Germany). We used the terminology proposed by A.A. Yatsenko-Khmelevsky and K. Esau when describing the anatomical structure.

2. Characteristics of the study area
The study area is the broad-leaved-dark coniferous forests of the Southern Urals. We carried out our research in the South Urals Natural Reserve. In its western part, the study area covers the northern slope of Yamantau ridge, the southwestern slope of Mount Arka and the valley of the Revet River in its middle reaches. The geographic coordinates are 54°10' - 54°15' n.l.; 57°40' - 57°50' el.

The relief is low-mountainous with a predominance of absolute heights of 400 - 600 m, some peaks exceed the mark of 900 m. The slopes of Yamantau ridge and Mount Arka are composed of quartzites; shales are common in the valley of Revet River. The climate of the region is moderately continental, in general, it is characterized by the following average long-term indicators: average annual air temperature - 1.20°C, average monthly temperatures in January - 15.8 °C and July + 17.0 °C, the duration of the frost-free period is 107 days, the growing season is 164 days, the average annual precipitation is 667 mm, the number of days per year with precipitation is on average 170, the duration of the period with snow cover is up to 180 days. The height of the snow cover reaches about 75 cm. Windblows are an integral element of the forest formation process. They periodically occur in small areas during squally winds. Soil type is gray mountain-forest loamy, periodically wet, shallow, humus content 4 - 5% [1; 8].

3. Results and Discussion
Mostly dark coniferous stands are indigenous to the broad-leaved dark coniferous forests of the Southern Urals. They have a complex spatial cenotic structure and are distinguished by a complex forest-forming process [1].

We should mention the resistance of spruce undergrowth to oppression by its tree layer in comparison with fir undergrowth. Fir, unlike spruce, mostly grows on mineralized soils with green moss cover. Most of the pre-generative plants of dark coniferous species form xylorizomas in the process of individual growth, on average 95%, in the province of the broad-leaved dark coniferous forests of the Southern Urals. The growth of an individual undergrowth with xylorhizome development is a very complex phenomenon [1; 5; 6]. In the first years of life in conifers, the basal
part of the stem gradually turns out to be underground, due to the bending of the hypocotyl and its burial in the forest litter. The adventitious roots begin to develop on the buried part of the stem. The adventitious roots are formed, as a rule, at the junctions of the apical growths of the previous and subsequent years. In the future, the stems of conifers, capable of rising almost entirely after lodging, bending at the very base, annually grow. The reason for this phenomenon is that coniferous nodes retain the ability to grow for a very long time, and as the stem is laid horizontally, the lower side begins to grow faster, the knot bends, and the entire overlying part of the trunk rises (figure 1). The ability of a species to take a certain position is due to the phenomenon of apogeotropism. It is practically impossible to trace the growth process of the aerial part during xylorhizome development, because the annual growths of the main axis add up to the increase in the size of the underground part of the stem [1].

![Figure 1. General view of xylorizome of Picea obobata Lebeb.](image)

The structural and functional organization of vegetative shoots of renewal changes in the process of adaptation to growing conditions. The peculiarities of the structural organization of the stem and root cortex are determined by the specifics of the habitat and the functional state of organs. Until the formation of the trunk, the differences in the rhizome are more significant, based on anatomical sections, as well as the level of tissue development and the nature of age-related modifications. Plant adaptation of *P. obovata* Ledeb. and *A. sibirica* Ledeb. occurs both at the level of the organ and the organism as a whole.

We analyzed the structure of wood during the growth and development of *P. obovata* Ledeb. and *A. sibirica* Ledeb.; and we can note that in the juvenile (embryonic) xylem of the undergrowth, features that are absent in the wood of the same adult plants are often observed. At the same time, some features characteristic of juvenile xylem subsequently disappear, while others, gradually transforming from ring to ring in the radial direction, reach their typical development only after a few years [9].

Differences in the structure of wood of annual layers deposited by cambium (starting from the first year) show that the definitive structure of the secondary xylem, which does not change further or changes within narrow limits in connection with the weather conditions of the year, is established over a long time [10; 11].

The nature of the formation of very narrow and false (anomalous) growth layers, often with an unclear boundary, is often observed. This is due to the frequency of cambium work during a short growing season, low temperature conditions, the presence of pessimal conditions, and the thinness of the soils. The boundary of the growth layers is expressed only by a simple narrowing of the radial
dimensions of a few layers of longitudinal elements, without thickening their walls [6; 12]. Thus, on cross sections of each species, all annual increments formed during the years of plant life were researched, taking into account all structural changes associated with their age.

The composition and size of the core rays change in the process of wood ontogenesis. The wood parenchyma is formed only by the cells of the parenchymal rays and the lining cells of the resin ducts. Parenchymal rays are simple, narrow. The root of the secondary structure looks like a stem outwardly. It is cylindrical along xylorizome - round in cross-section (figure 2).

Comparison of research materials and previously obtained results allows us to conclude that the transformations in the xylorhizome occurring in the process of phylogenesis are related to the type of idioadaptation and specialization (private progress). Adaptation of structural features in pre-generative plants of the main forest producers is aimed at enhancing protective and conductive functions (changing the shape from round to elliptical, developing a resinous system, etc.) [1; 5].

The specialization of the anatomical structures of xylorizomas in pre-generative plants of the main forest producers is manifested in annual increments - there are signs of evolutionary advancement of varying degrees (heterobatmia or heterochrony of characters). The data obtained indicate the adaptive role of xylorhizome in the natural regeneration and formation of forests with the participation of Siberian spruce and Siberian fir in the Southern Urals.

Figure 2. Cross section of a Siberian spruce xylorizome (Picea obovata Ledeb.): 13th year of life (stem) - aboveground part. a - periderm; b - phloem; c - parenchyma rays; d - cambium; e - late wood; f - early wood; g - resin passages; h - growth ring; j - the core

4. Conclusions
The following dynamic tendencies are clearly traced in broad-leaved-dark coniferous forests in the western part of the Southern Urals in the process of natural underground regeneration of Siberian spruce (Picea obovata Ledeb.) and Siberian fir (Abies sibirica Ledeb.) intact communities (native and conditionally native) of the broad-leaved subzone -dark coniferous species:

1. The anatomical structure of a xylorizome differs significantly from the structure of the trunk (for example, xylorizome has a well-defined core and a cambium without core rays with resin ducts).
2. Xylorizome is aimed at enhancing the protective and conductive functions of the undergrowth (change in shape from round to elliptical, development of the resinous system, etc.).

3. The formation of a xylorhizome in pre-generative plants of the main forest producers, as one of the methods of adaptation, contributes to the successful natural regeneration of forest communities in the Southern Urals.

4. The analysis of natural under-log regeneration shows that the positions of spruce in the province of deciduous-dark coniferous forests of the Southern Urals are more stable than those of fir.

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