Adaptability of *Pinus sylvestris* L. to various environmental conditions

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Abstract. Comparative anatomical studies conducted in provenance trial plantations and natural pine forests to study the anatomy of the needles and identify anatomical variability have helped to obtain the data on the formation peculiarities of vegetative shoot organs, on the variability and persistence of structural features, ways of adaptive evolution. Studies of Scots pine provenance trial plantations from the zone of deciduous forests, southern forest-steppe and dry steppe have made it possible to note that morphological and anatomical structure of the needles changes to local ecotypes. Thus, structural adaptation of assimilation apparatus to new growing conditions occurs. It determines the productivity and stability of tree stands, the duration and intensity of growth of all plant organs in general.

1. Introduction

*Pinus sylvestris* L. is a very plastic species with wide ecological amplitude of soil and climatic growing conditions. Pine is common in Siberia and Europe. Pine forests reach Laplandia in the north, and they are found in China and Mongolia in the south. This species is widely distributed in Eurasia. Its distribution area is noted in Spain and Great Britain eastward to the Ardan and the Amur rivers in Siberia. Scots pine forms populations on sandy, sandy loam, and peat soils. It is rarely found on clayed soils.

High degree of adaptability of this species should be noted studying the distribution area of Scots pine. It is possible to explain such a physiological feature through studying the anatomical and morphological structure of the needles in more detail, its features at the level of the cell structure. According to the results of long-term research by various authors, it should be noted that pine needles are characterized by a high degree of sensitivity, which helps to rebuild the structure of needle cells of each level quite easily. It helps to change indicators and signs depending on the growing conditions and other physiological features of the species.

It is noted that anatomical and morphological features of the needle structure determine, on a whole, the productivity and stability of the stands, the duration and intensity of growth of all organs of the plant. This physiological pattern is very sensitive to the growth of Scots pine in provenance trial plantations. Authors, studying provenance trial plantation, have noted that the sizes of needles (width, length) are constant signs. They retain their individual adaptiveness due to evolutionary adaptation while transferring ecotypes from natural forests to new conditions.
1.1. Aim of the study
The purpose of this work is to study anatomical and morphological features of the structure of Pinus sylvestris L. needles both in different and in identical growing conditions, but of different origin, in order to establish the influence of genetic and environmental factors on the adaptive abilities.

2. Methods and Materials
The object of research was Scots pine (Pinus sylvestris L.), growing in the Bryansk region (Karachevsky district forestry), Voronezh (Khrenovskoe forest area), Volgograd (Archedinsky district forestry) and provenance trial plantations in the Voronezh forestry (Bryansk, Voronezh, and Volgograd origin), and aged 45-60 years. Growing conditions of the studied objects are characterized by various climatic indicators (Table 1).

The material for the study was collected in the summer period of 2008 and 2014. Trial plots (natural habitat) of 0.25 hectares were laid, in which model trees (10 specimens) were selected. Needles of the second year were taken from each model tree in the amount of 350 pieces.

The needles were cut and the middle part of the cross-section was placed in glycerin. The following indicators were measured to study the influence of genetic and environmental factors on the anatomical and morphological structure of needles: length, width, thickness of needles, dimensions of epidermis, hypodermis, folded mesophyll, number of resin passages, cell diameters. Studies of the cellular structure of various levels of needles were carried out with a Biolam microscope at magnification of 20×8. All the measurements were processed using Stadia program.

Table 1. Characteristic of climatic growing conditions of research objects.

| №  | Indicator                              | The Bryansk region (Karachevsky district forestry) | The Voronezh region (Khrenovskoe forest area) | The Volgograd region (Archedinsky district forestry) |
|----|---------------------------------------|---------------------------------------------------|------------------------------------------------|-----------------------------------------------------|
| 1  | Natural and climatic zone             | Deciduous forests                                 | Southern forest-steppe                          | Dry steppe                                          |
| 2  | Average annual temperature, °C        | +4.5                                              | +6.9                                            | +6.9                                                |
| 3  | Annual precipitation, mm              | 750                                               | 486                                             | 200                                                 |
| 4  | Hydro-thermal coefficient (HTC)       | 1.6 (excessive moistening)                         | 0.9                                             | 0.6                                                 |
| 5  | Vegetation period, days               | 185                                               | 200                                             | 206                                                 |

3. Results and discussion
Structural characteristics of external protective tissues of needles, structure and dimensions of mesophyll, resin canals are the most important signs of adaptive ability characterizing the degree of adaptability, stability and growth in the new growing conditions.

The results of our research indicate that anatomical and morphological structure of pine needles, growing in the Bryansk region (zone of deciduous forests) is characterized by higher indicators in comparison with Voronezh and Volgograd representatives. It can be stated that sufficient moistening and a relatively warm climate contribute to the development of needles of larger sizes: in the zone of deciduous forests of the Bryansk region the thickness is 647.8 μm on average, the average width of the needles is 1380.0 μm.

The thickness of the mesophilic part of the needles is 169.4 μm. The size of epithelial tissues is also characterized by higher rates: epidermis thickness is 18.6 μm and hypodermis thickness is 7.7 μm.

Favorable growing conditions also affect the formation of resin canals. The resin canals in the needles from the Bryansk region are round in shape, evenly spread around the perimeter in the mesophilic part of the needles, touching hypodermis by one side (Figure 1).
The number of resin canals in the needles in the Bryansk region is about 12 pieces (vary from 7 to 16 pieces); the average diameter is equal to 108.1 μm.

Anatomical and morphological parameters of pine needles, growing in the Voronezh and Volgograd regions, are characterized by lower indicators, apparently as a consequence of changes in climatic conditions.

So the needles thickness in Khrenovskoy pine forest of the Voronezh Region is 537.7 μm, width - 1173 μm. Needle thickness in the dry steppe of the Volgograd region is 520 μm, and the width is 1112.0 μm on average.

The thickness of needle mesophyll is 152.2 μm in the Voronezh region (southern forest-steppe) and 144.7 μm - in the Volgograd region (dry steppe).

The sizes of surface tissues, which play an important protective role, have increased in the Voronezh and Volgograd regions. So the thickness of epidermis is 19.1 μm, the thickness of hypodermis is 7.8 μm in the Voronezh region. In the Volgograd region the thickness of epidermis is 21.6 μm the thickness of the hypodermis is 8.6 μm.

The resin canals in the needles from the Voronezh region are not large (Figure 2). The average diameter is 105.6 μm. They are located close to the hypodermis. The number of resin canals in the conditions of the southern forest-steppe was 9.6 pieces on average, ranging from 6 to 12 pieces.

The resin canals in the needles from the Volgograd region are medium-sized, oval in shape, slightly flattened on the side of the epithelial tissues (figure 3). The average diameter is 90.8 μm. They are located very close to the hypodermis. The number of resin canals in the conditions of the southern forest-steppe is 8.6 pieces on average, ranging from 6 to 12 pieces. 8 and 10 pieces are often found.

A completely different picture can be seen in the anatomical structure of the pine needles of Scots pine tree growing in the same conditions of the Voronezh district forestry (A2), but of different origin (Bryansk ecotype, Voronezh ecotype and Volgograd ecotype). Sharp difference in the morphological and anatomical structure of needles, observed in natural pine forests of different growing conditions, is diminishing. The needle structure in its characteristics and indicators is similar to the local representatives. However, analyzing the data, it can be noted that genetic factors influence the size and indicators of needle structure which are explained by the origin of the species. There is regularity in reduction of needle size in the same sequence as in natural forests. The needles of Bryansk origin are characterized by the largest size. The needles of Volgograd origin are characterized by the smallest size.

Figures 1-3 show the microstructure of Scots pine needles in different growing conditions.

Figure 1. Cross-section of Pinus sylvestris L needles in the conditions of deciduous forests.
Figure 2. Cross-section of *Pinus sylvestris* L needles in the conditions of southern forest-steppe (provenance trial plantations of Volgograd origin) 1 – epidermis, 2 - hypodermis, 3 - folded mesophyll, 4 - endodermis, 5 - resin canal, 6 - vascular bundles.

Figure 3. Cross-section of *Pinus sylvestris* L needles in the conditions of dry steppe.

The obtained results of measuring the diameters of cells of different tissues indicate the influence of environmental factors on the cell sizes of epithelial and transfusion tissues, tracheids of vascular bundles, resin canals.

So in more favorable growing conditions (zone of deciduous forests) mesophyll cells are larger (218.3 μm). The average diameter of the mesophyll cells is 212.2 μm and 139.1 μm, respectively in conditions, where insufficient moistening is noted (the Voronezh region, southern forest-steppe, HTC of 0.9; the Volgograd region, dry steppe, HTC of 0.6).

The same reduction regularity in the cell sizes of the tissues of assimilation apparatus can be traced in external protective tissues, vascular bundle and fibers surrounding the resin canals (during deterioration of growing conditions).

When considering the structure of the pine needles, growing in the conditions of dry steppe, it should be noted that resin canals are surrounded by round-shaped epithelial cells, tightly pressed to each other.

The structure of mesophilic tissue, as a rule, is represented by a large cell surface facing the intercellular spaces. The structure of the mesophilic tissue in the needles of Scots pine is rebuilt depending on the growing conditions. Thus, the folded tissue of the needle mesophyll is looser and is located on both sides in xerophytic conditions. There is a decrease in cell size within 35% and formation of small-cell mesophyll structure when going into the conditions of insufficient moisture (dry steppe).

The data on the cell diameter of Scots pine needle tissue in provenance trial plantations also indicate anatomical and structural rearrangement up to indices of local representatives. However, there is some slight difference due to the regularity of geographical origin. The table shows that the regularity in the diameter of cells of various tissues, which is seen between the specimens of different
growing conditions, is noted in provenance trials of the same growing conditions. This regularity indicates the genetic influence on morphological and anatomical structure of needles.

4. Conclusion
The results of the work has showed that the structure of assimilative tissue, growth rate and development of leaf plate reflect the influence of past and modern conditions of existence. It was noted that (at the time of the research) Scots pine needles, growing in different forest vegetation zones (zone of deciduous forests, southern forest-steppe, dry steppe) is characterized by different structural and anatomical indicators and characteristics. The needles are longer and wider, tougher and more resilient, dense to the touch in deciduous forests. It is thinner, shorter and narrower in the dry steppe zone. The study of anatomical structure of the needles has showed that thickness of assimilative and conductive tissues in the dry steppe is less in comparison with the zone of deciduous forests. Such indicators as thickness of the folded mesophyll, diameter of vascular bundles, diameter of resin canals have the largest values in the zone of deciduous forests. These parameters gradually decrease in dry steppe. The number of resin canals also decreases under adverse conditions. But the most important aspect is the increase in the thickness of external protective tissues of the leaf in arid conditions.

Thus, the thickness of external protective tissues plays the main role in the species adaptation to the new growing conditions. The size of external protective tissues of needles increases with the introduction of Scots pine into more extreme environmental conditions (the zone of dry steppe). The size of the assimilative tissues plays a significant role in the adaptation of the species to new growing conditions. It changes depending on the growing environment conditions. It is maximal under the more favorable conditions. Assimilative tissue decreases when the plant is introduced into the dry steppe. It is also noted that the sizes of other tissues also change in order to ensure the stability and good growth of Scots pine in the dry steppe: diameter of vascular bundles increases with the introduction into the dry steppe. There is a decrease in the diameter of cells in all the needle tissues during the movement of Scots pine from west to east (small cell tissues are formed in more unfavorable conditions).

Studies of Scots pine, which grows in provenance trial plantations of the Voronezh region (Bryansk ecotype, Voronezh ecotype, Volgograd ecotype), have made it possible to note that morphological and anatomical structure of the needles is rearranged. They become similar to local ecotypes. However, significant differences have been noted due to the origin of ecotypes, which indicates the influence of genetic factors on the morphological and anatomical structure of needles, which is responsible for the adaptive ability to new growing conditions.

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