Creation of planting material for small-leaved linden in the Omsk region

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Abstract. Small-leaved linden occupies the most important place among tree species, being a valuable plant due to its ability to yield nectar. Expanding the growth area of small-leaved linden will allow the local population to increase the production volume of linden honey, which has long been considered the best one. Currently, there is no artificial reforestation of this tree species in the Omsk region, since this tree species is grown in very small quantities in the forest nurseries of the main Forestry Department of the Omsk region, mainly for the purpose of urban planting of greenery. Small-leaved linden has a high decorative value and is therefore used as a park tree for urban planting of greenery in Omsk and for improvement of recreational areas. Many issues of artificial reproduction of small-leaved linden in the conditions of the Omsk region remain unexplored. In places of natural growth, only propagation with young growing trees is of practical value. Seed propagation technology has not been developed for the conditions of the Omsk region. The issue complexity lies in the fact that small-leaved linden has a period of long and deep physiological seed dormancy. The article considers experimental data on the propagation of small-leaved linden by seeds, analyzes parameters of growth and development of seedlings. The heterogeneity of planting material (seedlings) grown from seeds of local origin has been determined. The use of environmentally friendly products to protect and stimulate the growth of seedlings has produced positive results. Preparations Black yeast and Azolen increased the height of seedlings and the diameter of the root neck, and preparations Trichodermin and Elena contributed to the formation of a more powerful root system.

1. Introduction
At the present stage of forestry development, the main objectives of forestry are to increase the productivity and resistance of forests to adverse factors, as well as to strengthen their protective and recreational functions. Successful solution of these problems involves widespread use of promising forest-forming species in artificial reforestation that most corresponds to these principles.

In the Omsk region, small-leaved linden is one of these tree species. On the territory of the Omsk Irtysh Land, small-leaved linden grows naturally only to a limited extent; plantings are located in Bolsheukovsky, Ust-Ishim, and Tevrizsky districts. Omsk foresters determined the area occupied by the linden tree; it occupies only 1.5 thousand hectares [1]. City district forestry of the Omsk forest district in the Omsk region with a total area of 15.1 hectares grows more than 5 thousand seedlings of small-leaved linden for planting of greenery and community improvement in the Omsk region. Forest crops involving linden trees are practically not created due to the lack of recommendations for growing planting material and creating forest crops, as well as objective difficulties in growing this
Developing the technology for creating planting material includes using microbiological preparations with protective and stimulating plant growth effects. The success of the use of microorganisms as the basis of biopreparations is justified by the works by H. Burges [2; 3]. Environmental friendliness of microbiological preparations is associated with their selectivity, rapid destruction of metabolites and microorganism-producers preservation in the environment as its natural components. Used preparations are made with microorganisms: Trichodermin is based on soil fungus Trihoderma viride (strain Omskiy); Black yeast – based on living culture of yeast-like microorganisms Exophiala Nigrum; Azolen – based on the strain Azotobacter vinelandii; Elena – based on strains of Pseudomonas aureofaciens.

The research is relevant because it is aimed at increasing the share of small-leaved linden in forests of the Omsk region, increasing the decorative value of recreational areas, city parks and squares, increasing the volume of linden honey production and developing small businesses.

2. Statement of the problem
Growing high-quality planting material is the main and most important stage in creation of artificial plantings. The peculiarity of growing small-leaved linden is the period of long and deep physiological seed dormancy, which results in the completion of intra-seed growth of the embryo. Problematic issues involve determining optimal timing of harvesting and seeding of seeds, methods of pre-sowing preparation, development of technological methods for growing small-leaved linden planting material with open and closed root systems. Correct selection and determining the growing period, determining the optimal mode of pre-sowing seed treatment directly affects the efficiency of growing small-leaved linden planting material, which, in turn, will make it possible to create highly productive plantings [4, 5]. To improve the technology of growing planting material, mineral fertilizers are used [6–8] and microbiological preparations that contribute to the production of seedlings that are taller and more resistant to adverse environmental factors. We have been studying the effect of bacterial and fungal preparations on the rooting process of green and woody seedlings and the yield of high-quality planting material for more than ten years [9, 10]. The feasibility of using microbiological agents originally developed and implemented in agriculture is obvious. [11, 12]. Omsk scientists have convincingly shown the effectiveness of use of microorganisms and complex fertilizers to increase the competitiveness of agricultural production [13, 14].

3. Materials and methods
The objects of the study were small-leaved linden seedlings grown from seeds collected in the dendrological park of Omsk State Agrarian University. Stratified seeds were sown in the spring of 2013, to a depth of 1.5-2 cm, mulched with sand and peat, but did not spring up. Young seedlings were obtained in the spring of 2014 and needed shading, that was provided with the help of shields. The seedlings were of different quality according to biometric parameters. Thus, they were divided into three groups by height: short, medium-sized and tall. There was observation over 300 seedlings (three replications for each group). Starting from 2018, environmentally safe preparations were added when watering containers with seedlings to protect against phytopathogens and stimulate plant growth in the consumption rates recommended by the manufacturer: Omsk Reference Center of Rosselkhoznadzor.

Microbiological preparations effect on the propagation of small-leaved linden was assessed according to increasing growth in height, root neck diameter, length and width of the root system compared to the control without use of preparations. Study results were processed using analysis of variance. Further study in this area is planned conjointly with the Resource Sharing Center "Agricultural and Technological research".

4. Results and discussion
Growing small-leaved linden is difficult due to low soil seeds germination. In 2013, there was zero
germination of seeds, which sprouted a year later with 47% of the number of seeds sown. One-year-old seedlings were grown with shading shields. Due to the observed differences in the quality of growth parameters, they were divided into groups by height: short, medium-sized and tall and replanted to the nursery. In 2016, two-year-old seedlings were measured by height in groups: short (4-10 cm), medium-sized (11-16 cm) and tall seedlings (17-23.5 cm). In the spring of 2017, measurements were made of height and diameter of the root neck of three-year-old seedlings of small-leaved linden (Fig. 1).

Figure 1. Diagram of distribution of three-year-old seedlings by height (LSD$_{0.05}$ = 3.2), diameter of root neck (LSD$_{0.05}$ = 0.15)

Measurements of the length and width of the root system showed that a statistically significant increase in root growth occurred only in the group of tall seedlings (Fig. 2).

Figure 2. Diagram of distribution of three-year-old seedlings by length and width of the root system (LSD$_{0.05}$ = 2.52)

Statistical processing of data for three years confirmed the feasibility of dividing seedlings into groups (tall, medium-sized and short) and different quality of the seed material used, grown from seeds collected in the dendrological park of Omsk State Agrarian University. Obtained data gave reason to conclude that due to the heterogeneity of seedlings grown from seeds of local origin, a group of tall ones should be selected to create planting material.

In 2017, plants from the nursery were replanted into containers to create planting material with a closed root system. This technology of growing seedlings in containers, pots, cell packs was used because it forms a compact root system, seedlings become more resistant to adverse climatic factors and maintain a high degree of survival after replanting into the open ground during the entire vegetational season.
From a group of tall seedlings, a group was formed to study stimulating and protective effects of microbiological preparations that were used in 2018 and 2019. In 2019, measurements were made of height, diameter of the root neck, length and width of the root system in small-leaved linden seedlings for the fifth year of cultivation with the use of preparations.

The results showed that the use of preparations had a positive effect on the growth and development of small-leaved linden seedlings. The best result was recorded for the variant of experiment with using the preparation Black yeast, where the increase in the average height of seedlings was 77% compared to the control one. A significant increase in the height of seedlings compared to the control was observed in all variants of the experiment, but the effectiveness of the use of Azolen and Elena preparations did not differ statistically (Fig. 3).

![Figure 3. Average height of five-year-old seedlings (LSD<sub>05</sub> = 2.39)](image)

Positive results on the use of microbiological preparations were obtained when studying their effect on the diameter of the root neck. The largest average diameter of the root neck is observed when using Black yeast preparation – 12.6 mm (average diameter of the root neck is 45% larger than the control). After using Azolen preparation the value of average diameter of the root neck did not differ statistically from the value obtained after using Black yeast preparation (Fig. 4).

![Figure 4. Average diameter of the root neck of five-year-old seedlings (LSD<sub>05</sub> = 0.86)](image)

The most developed root system was formed under the influence of Elena preparation. The metabolites of bacterium *Pseudomonas aureofaciens* (antibiotics, enzymes, siderophores, hormones) in the container showed high efficiency compared to the control for development of a more powerful root system (Fig. 5).
The effect of Azolen and Trichodermin preparations were not statistically distinguishable. The microbiological fertilizer Azolen increases soil fertility due to the nitrogen-fixing ability of *Azotobacter vinelandii* producing strain. Fungi of the genus *Trichoderma*, which are the basis of Trichodermin preparation, suppress the development of phytopathogens by direct parasitism, secrete enzymes and antibiotics, which reduces the spread of pathogens. These microorganisms are able to reproduce in the soil environment, which increases the effect of their use for plants with a closed root system.

5. Conclusion

According to the results of growing the planting material of small-leaved linden, the best preparations that affect the formation of taller and stronger seedlings are Black yeast and Azolen. The producing strains of these preparations ensure their effectiveness. So, Black yeast preparation is produced in the preparative form “culture liquid”, it contains nitrogen, phosphorus, potassium, live culture of yeast *Exophiala Nigrum*. Living yeast cells form symbiotic associations with plants and grow on the dying cells of the plant root zone, using them as a substrate. During growth, they secrete oxygenase enzymes, hormones auxin and cytokinins, as well as humic acids.

Containing *Azotobacter vinelandii* as a producer strain, Azolen is able to convert atmospheric nitrogen into a form suitable for plant nutrition and thereby increase soil fertility. The mechanisms of action of both preparations are aimed at optimizing the seedlings nutrition. The results obtained are consistent with the conclusions of other researchers, who claim that mineral fertilizers use in the norm N$_{60}$P$_{60}$K$_{60}$ guarantees 100% production of standard seedlings of common ash in the first year of cultivation [7]. The positive effect of mineral nutrition is established while growing seedlings of pine [8]. Full fertilizer N$_{90}$P$_{60}$K$_{30}$ and a variant with an increased dose of nitrogen N$_{60}$P$_{30}$ provide good growth of two-year-old seedlings of small-leaved linden and their high yield of 160-240 thousand units/ha [6].

Elena and Trichodermin preparations had a significant stimulating effect on the growth of root system. The main mechanism of action of these preparations on plants is antibiosis. The known antibiotics produced by bacteria of genus *Pseudomonas* are pyoluteorin, pyrrolnitrin, oomycin, phenazine-1-carboxylic acid and 2,4-Diacetylphloroglucinol that suppress soil-inhabiting pathogens [12]. Soil fungus *Trichoderma viride*, being the basis of Trichodermin preparation, also produces more than ten antibiotics and protects from phytopathogens, due to its ability to self-produce in the soil environment.
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