Reproduction of a living collection of dendrological garden plants for urban landscaping

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Abstract. Experimental data for 2017-2020 are presented. The influence of microbiological preparations produced in the biological laboratory of the Federal State Institution "Omsk Reference Center of Rosselkhoznadzor" on the reproduction of introduced tree species growing on the territory of the natural monument of regional significance "Regional Dendrological Garden named after G.I. Gense" is analyzed. Reproduction of tree species was carried out using lignified (winter) cuttings in open ground conditions. Microbiological preparations were used based on *Pseudomonas aureofaciens* (Elena), *Azotobacter vinelandii* (Azolene), *Trichoderma viride* (Trichodermin) and *Exophiala Nigrum* (Black yeast). Their positive effect on rooting, development of the root system, an increase in the diameter of the root neck and growth in annual, biennial, three-year and four-year seedlings was established. The best preparations that influence the formation of more vigorous seedlings with the most developed root system are Black yeast and Trichodermin. The tree species that was more responsive to the use of the studied microbiological preparations was the spherical willow (*Salix fragilis*).

1. Introduction

Almost all cities have environmental problems, one of the ways to solve it is landscaping. Green spaces play a crucial role in the formation of a comfortable and favorable environmental situation in the city. Squares, parks, urban forests perform the most important functions associated with the release of oxygen and phytoncides, air ionization, dust deposition, noise absorption and at the same time have a positive effect on the emotional state of the population, increase the prestige of places of residence [1, 2].

Currently, the green fund of the Omsk region occupies 47.6% of the total area of 14114 thousand hectares. In order to maintain and develop public facilities (parks, squares, boulevards), the administration of the city of Omsk has developed a concept for the development of the territory according to the "Garden City" model for the period 2014 - 2025. Reproduction of perennial tree and shrub plantations requires a large amount of high-quality planting material adapted to the climatic conditions of Western Siberia. In this regard, the cultivation of *Myricaria alopecuroides, Tamarix gracilis, Salix fragilis*, rarely used tree and shrub species in urban landscaping, is relevant. The introduction of these species increases the biodiversity and ecosystem services of urban green spaces.

To obtain high-quality planting material, it is possible to use synthetic and natural growth regulators. Natural ones are natural growth regulators, and their artificial counterparts have found the greatest practical value. However, in the light of the overall greening of agriculture and forestry, it is...
preferable to use natural growth substances, and currently there is an active search for substances for the rooting of woody plants [3].

Microbiological preparations are based on live cultures and their metabolic products, which provide a growth-stimulating effect and protection against pathogens. These are phytohormones, enzymes, antibiotics, siderophores and other biologically active substances. Many biofertilizers improve plant nutrition. These biofertilizers are proposed to be considered as a subcategory of biostimulants that increase the efficiency of nutrient use and open up new pathways for the absorption of nutrients by plants [4]. The basis of the Azolene preparation is *Azotobacter vinelandii*, a nitrogen-fixing microorganism that plays an important role in the productivity of plants, improving their mineral nutrition [5,6]. *Pseudomonas aureofaciens*, being the basis of Elena's biological product, produces secondary metabolites of 2,4-diacetylphloroglucinol, which provide biocontrol properties and resistance of the host plant to attacks of true pathogens. *Pseudomonas* bacteria drive out other pathogens with siderophores, giving the plant a competitive advantage for iron capture [7]. Trichodermin is a complex preparation of protection, stimulation of plant growth, fertilization and soil formation. Its active ingredients are produced most of all by the germinating spores of the fungi *Trichoderma sp.* These are primarily antibiotics with a pronounced fungicidal effect, which inhibit the development of many pathogens and inhibit their reproductive capacity. The use of these microscopic fungi has given positive results in various agricultural crops due to their high antagonistic ability [7–9]. The use of yeast as plant growth promoting agents is underutilized. Currently, work is underway to search for rhizosphere yeast with the properties of stimulating the growth of agricultural plants. The isolated isolates show phytoproductive properties such as solubility of nutrients, synthesis of active biomolecules, and production of cell wall degrading enzymes. Their use increased the weight and number of roots on agricultural crops [10–12].

Since 2017, on the basis of the regional dendrological garden named after G.I. Hense, work has been underway to improve the technology of propagation of introduced tree species using microbiological preparations. Research is aimed at determining the influence of biological products on the development of stronger and more vigorous seedlings with a more developed root system [13].

2. Materials and methods of research
The objects of study were samples of tree and shrub species growing on the territory of the arboretum: *Myricaria alopecuroides, Tamarix gracilis, Salix fragile*. Lignified (winter) cuttings were harvested in February, tied in bunches and kept at rest until spring in snow piles. In June 2017, 2018, 2019, 2020 they were planted in a pre-prepared soil for rooting and treated with biological products. The observations were carried out on 365 cuttings in triplicate. In each subsequent year, the preparation of the terrestrial part of the plants was carried out.

The effect of microbiological preparations during the reproduction of tree and shrub species was assessed by an increase in the percentage of rooting, an increase in height, diameter of the root neck, and the length of the root system compared to the control without the use of preparations. The processing of the research results was carried out using analysis of variance. The research was carried out using the equipment of the center for collective use of Omsk State Agrarian University "Additive Technologies and Materials Processing".

3. Results and Discussion
The results of the stimulating effect of biological growth regulators on the root formation of cuttings are shown in Table 1. Studies have shown that the highest average percentage of rooting was observed with the use of Elena 74.5% in willow, 88.2% - in myrikaria with Black Yeast and 51.5% - in tamarix under the influence of Azolen (Fig. 1).

Higher efficiency of rooting was observed in myrikaria, where the percentage of rooting in the experiments ranged from 71.2 to 88.2%. Treatment of cuttings with the Black Yeast preparation increased rooting by 25.5% compared to the control. In willow, root formation increased by 12%
under the influence of Elena; in tamarix, the increase in comparison with the control was by 10.5% under the influence of the biological product Azolene.

The greatest average growth in brittle willow is observed under the influence of the preparation Trichodermin 38.0 cm in the first year of cultivation and 66.3; 45.9; 44.3 cm in the second, third and fourth years. A similar better effect of Trichodermin was observed on the growth of one-year, two-year, three-year and four-year myrikaria seedlings: 27.8; 59.3; 36.0; 35.8 cm. In the first year of growing tamarix seedlings, a greater increase was observed under the influence of Trichodermin - 15.5 cm, while the best growth in two-year, three-year and four-year seedlings was in the experiment using the Black Yeast preparation (Table 2).

Table 1. The effect of preparation on the percentage of rooting cuttings

| Tree species name | Preparation   | Rooting percentage | Average percentage rooting |
|-------------------|---------------|--------------------|---------------------------|
|                   | 2017 | 2018 | 2019 | 2020 |                  |
| Spherical Willow  | Control | 56   | 68   | 65   | 61 | 62.5 |
|                   | Elena   | 75   | 76   | 72   | 75 | 74.5 |
|                   | Azolene | 61   | 75   | 69   | 65 | 67.5 |
|                   | Black yeast | 63  | 76   | 69   | 63 | 67.7 |
|                   | Trichodermin | 68  | 76   | 70   | 69 | 70.7 |
| Mirikaria          | Control | 66   | 61   | 59   | 65 | 62.7 |
|                   | Elena   | 88   | 79   | 76   | 82 | 81.2 |
|                   | Azolene | 74   | 71   | 69   | 71 | 71.2 |
|                   | Black yeast | 95  | 89   | 84   | 85 | 88.2 |
|                   | Trichodermin | 83  | 86   | 79   | 79 | 81.7 |
| Tamarix            | Control | 41   | 39   | 43   | 41 | 41.0 |
|                   | Elena   | 46   | 45   | 47   | 45 | 45.7 |
|                   | Azolene | 51   | 52   | 51   | 52 | 51.5 |
|                   | Black yeast | 51  | 49   | 50   | 55 | 51.2 |
|                   | Trichodermin | 48  | 46   | 49   | 48 | 47.7 |

Figure 1. The average rooting lignified cuttings; LSD_{0.05} = 3.1
In seedlings of the first year of cultivation, the average increase in the control variant was 25.5; 21.1; 18.8 cm, respectively: spherical willow, myrikaria, tamarix - in the second: 26.2; 28.9; 20.9 cm - in the third: 22.7; 21.1; 19.8 - in the fourth: 25.4; 25.4; 18.9. Under the influence of preparations the gain increased significantly relative to control in all four years of observation (Fig. 2, 3, 4, 5).

Table 2. The effect of preparations on the growth of seedlings

| Tree species | Name/Preparation | Growth in seedlings, 1 year of cultivation | Average growth, cm | Growth in seedlings, 2 years of cultivation | Average growth, cm | Growth in seedlings, 3 years of cultivation | Average growth, cm | Growth in seedlings, 4 years of cultivation | Average growth, cm |
|--------------|------------------|-----------------------------------------|-------------------|-----------------------------------------|-------------------|-----------------------------------------|-------------------|-----------------------------------------|-------------------|
| Spherical Willow | Control | 25.3 | 25.0 | 26.2 | 25.7 | 25.5 | 25.3 | 25.8 | 27.6 | 26.2 | 23.6 | 21.8 | 22.7 | 25.4 |
|               | Elena | 30.1 | 30.0 | 29.7 | 28.9 | 29.7 | 30.1 | 30.6 | 31.8 | 30.8 | 30.5 | 31.2 | 30.8 | 30.2 |
|               | Azolen | 36.0 | 36.2 | 36.1 | 36.3 | 36.1 | 42.9 | 43.2 | 41.9 | 42.7 | 39.8 | 40.5 | 40.1 | 35.4 |
|               | Black yeast | 36.1 | 36.7 | 37.9 | 36.5 | 36.8 | 57.3 | 56.5 | 51.8 | 55.2 | 40.6 | 41.5 | 41.0 | 42.6 |
|               | Trichodermin | 38.6 | 38.1 | 38.4 | 37.1 | 38.0 | 69.4 | 65.5 | 64.0 | 66.3 | 45.5 | 46.3 | 45.9 | 44.3 |
| Mirikaria | Control | 21.1 | 21.0 | 20.9 | 21.6 | 21.1 | 28.9 | 28.3 | 29.1 | 28.9 | 22.1 | 20.1 | 21.1 | 25.4 |
|               | Elena | 23.3 | 23.1 | 23.6 | 23.8 | 23.4 | 31.3 | 31.6 | 31.7 | 31.5 | 25.4 | 26.0 | 25.7 | 28.1 |
|               | Azolen | 23.1 | 22.7 | 23.2 | 23.5 | 23.1 | 32.8 | 32.5 | 32.3 | 32.5 | 26.6 | 26.5 | 26.3 | 28.5 |
|               | Black yeast | 27.3 | 26.7 | 27.1 | 26.8 | 27.0 | 50.2 | 43.9 | 42.8 | 45.6 | 30.1 | 29.9 | 30.0 | 32.3 |
|               | Trichodermin | 28.1 | 27.7 | 27.8 | 27.5 | 27.8 | 66.3 | 55.6 | 53.1 | 59.3 | 35.6 | 36.4 | 36.0 | 35.8 |
| Tamarix | Control | 18.9 | 19.3 | 18.8 | 18.2 | 18.8 | 19.1 | 21.6 | 22.1 | 20.9 | 20.1 | 19.6 | 19.8 | 18.9 |
|               | Elena | 21.1 | 22.2 | 21.6 | 21.3 | 21.5 | 27.3 | 26.6 | 26.9 | 26.9 | 24.2 | 22.1 | 23.1 | 22.8 |
|               | Azolen | 21.4 | 22.7 | 22.4 | 22.1 | 22.1 | 26.3 | 25.3 | 26.4 | 26.0 | 22.5 | 23.6 | 23.0 | 23.2 |
|               | Black yeast | 23.3 | 24.3 | 23.7 | 23.8 | 23.8 | 29.9 | 28.6 | 28.9 | 29.1 | 29.0 | 28.4 | 28.7 | 28.1 |
|               | Trichodermin | 25.5 | 25.8 | 25.7 | 24.9 | 25.5 | 27.8 | 27.4 | 27.7 | 27.6 | 29.1 | 26.8 | 27.9 | 27.2 |

Figure 2. The average growth of annual seedlings; LSD$_{0.05}$ = 2.4

Figure 3. The average growth of two year seedlings; LSD$_{0.05}$ = 2.3

Figure 4. The average increase in three year seedlings; LSD$_{0.05}$ = 2.8

Figure 5. The average gain in four year seedlings; LSD$_{0.05}$ = 3.1

The average diameter of the root collar in seedlings of the first year of cultivation in the control was: 5.2; 5.2; 5.3 mm, respectively, for spherical willow, myrikaria, tamarix; in the second: 6.5; 5.7;
5.6; in the third: 9.4; 6.6; 5.7 and in the fourth year of cultivation: 15.2; 7.3; 6.1. Under the influence of preparations, the diameter significantly increased relative to the control (Table 3).

The greatest increase in the root neck in willow was observed under the influence of the preparation Trichodermin: 5.7; 10.6; 18.0; 26.7 mm over all four years of observation. A similar effect of the preparation was recorded in Tamariks: 5.7; 6.6; 6.9; 7.5 mm, respectively, for one-year, two-year, three-year and four-year-old seedlings. In Mirikaria, the best preparation affecting the increase in the diameter of the root neck was Black yeast: 5.6; 6.6; 8.8; 9.1 mm (Fig. 6, 7, 8, 9).

The formation of the root neck in all the studied tree species for all four years of observation was more intensive under the influence of the preparations Black Yeast and Trichodermin. The difference in the effect of these drugs on the increase in the root collar was within the margin of error.

The same preparations had a more noticeable stimulating effect on the growth and development of the root system of seedlings (Table 4).

Compared to the control, a more developed root system develops in willow under the influence of Trichodermin, an increase of 8.3 cm - in the second, 14.3 cm - in the third and 14.0 cm - in the fourth year of cultivation. A similar effect of the preparation was recorded in tamarix: 2.7; 7.7; 5.3 cm in the second, third and fourth years of observation. The development of the root system in myrikaria was more intense under the influence of the Black Yeast preparation. Compared with the control variant, the preparation influenced an increase in the average length of the root system by 9.9 cm in seedlings of the second year of cultivation, 4.3 cm - in the third and 3.8 cm - in the fourth year (Fig. 10, 11, 12).

Table 3. The effect of preparations on the diameter of the root neck

| Tree species | Diameter of the root neck in seedlings, 1 year of cultivation | Average diameter, mm | Diameter of the root neck in seedlings, 2 years of cultivation | Average diameter, mm | Diameter of the root neck in seedlings, 3 years of cultivation | Average diameter, mm | Diameter of the root neck in seedlings, 4 years of cultivation | Average diameter, mm |
|--------------|-------------------------------------------------------------|----------------------|-------------------------------------------------------------|----------------------|-------------------------------------------------------------|----------------------|-------------------------------------------------------------|----------------------|
| Spherical Willow |                                             | 2017  | 2018  | 2019  | 2020 | 2018  | 2019  | 2020 | 2019  | 2020 | 2018  | 2019  | 2020 | 2018  | 2019  | 2020 |
| Control       |                                             | 5.1   | 5.4   | 5.2   | 5.2  | 5.2   | 6.5   | 6.6   | 6.3  | 6.5   | 9.4  | 9.4   | 9.4  | 15.2 |
| Elena         |                                             | 5.3   | 5.6   | 5.3   | 5.4  | 5.4   | 7.5   | 7.3   | 7.4  | 7.4   | 9.6  | 10.0  | 9.8  | 25.0 |
| Azolen        |                                             | 5.4   | 5.6   | 5.4   | 5.3  | 5.4   | 7.4   | 7.3   | 7.2  | 7.3   | 10.4 | 10.3  | 10.6 | 25.5 |
| Black yeast   |                                             | 5.5   | 5.7   | 5.4   | 5.6  | 5.5   | 10.5  | 10.3  | 10.5 | 10.4  | 18.5 | 16.6  | 17.5 | 26.2 |
| Trichodermin  |                                             | 5.5   | 5.7   | 5.6   | 5.8  | 5.7   | 10.6  | 10.4  | 10.7 | 10.6  | 18.8 | 17.3  | 18.0 | 26.7 |
| Mirikaria     |                                             | 5.3   | 5.2   | 5.2   | 5.3  | 5.2   | 5.6   | 5.7   | 5.7  | 5.7   | 6.7  | 6.6   | 6.6  | 7.3  |
| Control       |                                             | 5.5   | 5.6   | 5.6   | 5.5  | 5.5   | 5.9   | 5.9   | 6.0  | 5.9   | 7.6  | 7.4   | 7.5  | 7.9  |
| Elena         |                                             | 5.5   | 5.6   | 5.6   | 5.5  | 5.5   | 5.8   | 5.9   | 5.9  | 5.9   | 7.2  | 7.2   | 7.2  | 7.6  |
| Azolen        |                                             | 5.6   | 5.7   | 5.5   | 5.6  | 5.6   | 6.6   | 6.5   | 6.7  | 6.6   | 8.7  | 8.9   | 8.8  | 9.1  |
| Black yeast   |                                             | 5.6   | 5.7   | 5.6   | 5.6  | 5.6   | 6.5   | 6.3   | 6.4  | 6.4   | 8.3  | 8.5   | 8.4  | 8.7  |
| Trichodermin  |                                             | 5.5   | 5.7   | 5.5   | 5.6  | 5.6   | 6.3   | 6.5   | 6.4  | 6.4   | 7.0  | 6.9   | 6.9  | 7.5  |
| Tamarix       |                                             | 5.3   | 5.4   | 5.1   | 5.4  | 5.3   | 5.4   | 5.6   | 5.8  | 5.6   | 5.8  | 5.7   | 5.7  | 6.1  |
| Control       |                                             | 5.4   | 5.7   | 5.5   | 5.5  | 5.5   | 5.6   | 5.8   | 6.4  | 5.9   | 6.3  | 6.2   | 6.2  | 6.8  |
| Elena         |                                             | 5.5   | 5.6   | 5.7   | 5.6  | 5.6   | 5.6   | 6.1   | 6.2  | 6.0   | 6.1  | 6.3   | 6.2  | 6.6  |
| Azolen        |                                             | 5.7   | 5.8   | 6.0   | 5.6  | 5.8   | 5.6   | 6.1   | 6.6  | 6.1   | 6.5  | 6.4   | 6.4  | 7.1  |
| Black yeast   |                                             | 5.5   | 5.7   | 5.8   | 5.6  | 5.7   | 6.3   | 6.5   | 6.9  | 6.6   | 7.0  | 6.9   | 6.9  | 7.5  |
Figure 6. The average diameter of the root neck in annual seedlings; LSD$_{0.05}$ = 0.24

Figure 7. The average diameter of the root neck in two year old seedling; LSD$_{0.05}$ = 0.31

Figure 8. The average diameter of the root neck in three year old seedling; LSD$_{0.05}$ = 0.35

Figure 9. The average diameter of the root neck in four year old seedling; LSD$_{0.05}$ = 0.54

The formation of the root neck in all the studied tree species for all four years of observation was more intensive under the influence of the preparations Black Yeast and Trichodermin. The difference in the effect of these drugs on the increase in the root collar was within the margin of error.

The same preparations had a more noticeable stimulating effect on the growth and development of the root system of seedlings (Table 4).

Compared to the control, a more developed root system develops in willow under the influence of Trichodermin, an increase of 8.3 cm in the second, 14.3 cm in the third and 14.0 cm in the fourth year of cultivation. A similar effect of the preparation was recorded in tamarix: 2.7; 7.7; 5.3 cm in the second, third and fourth years of observation. The development of the root system in myrikaria was more intense under the influence of the Black Yeast preparation. Compared with the control variant, the preparation influenced an increase in the average length of the root system by 9.9 cm in seedlings of the second year of cultivation, 4.3 cm - in the third and 3.8 cm - in the fourth year (Fig. 10, 11, 12).
Table 4. The influence of preparations on the development of the root system

| Tree species | Preparation | Root system of seedlings, 2 years of cultivation | Root system of seedlings, 3 years of cultivation | Root system of seedlings, 4 years of cultivation |
|--------------|-------------|-----------------------------------------------|-----------------------------------------------|-----------------------------------------------|
|              |             | Average length, cm | Average length, cm | Average length, cm |
|              | 2018 | 2019 | 2020 | 2019 | 2020 | 2020 | 2019 | 2020 | 2020 | 2019 | 2020 | 2020 |
| Spherical Willow | Control | 16.9 | 17.0 | 17.1 | 17.0 | 28.7 | 28.1 | 28.4 | 34.2 |
|                 | Elena | 17.6 | 18.1 | 18.2 | 18.0 | 29.6 | 29.7 | 29.6 | 35.3 |
|                 | Azolen | 20.9 | 20.6 | 20.4 | 21.9 | 30.3 | 30.9 | 30.6 | 36.2 |
|                 | Black yeast | 25.3 | 24.9 | 24.2 | 24.8 | 42.5 | 41.9 | 42.2 | 47.6 |
|                 | Trichodermin | 25.8 | 25.5 | 24.6 | 25.3 | 42.9 | 42.5 | 42.7 | 48.2 |
| Mirikaria | Control | 8.0 | 8.1 | 8.3 | 8.1 | 13.5 | 14.1 | 13.8 | 17.8 |
|                 | Elena | 10.1 | 10.0 | 10.4 | 10.2 | 16.9 | 17.1 | 17.0 | 21.0 |
|                 | Azolen | 11.3 | 11.1 | 11.3 | 11.2 | 17.4 | 17.5 | 17.4 | 21.4 |
|                 | Black yeast | 12.0 | 11.7 | 11.9 | 11.9 | 18.0 | 18.2 | 18.1 | 22.7 |
|                 | Trichodermin | 11.2 | 11.4 | 11.4 | 11.3 | 17.6 | 17.8 | 17.7 | 21.6 |
| Tamarix | Control | 5.9 | 6.0 | 6.3 | 6.0 | 8.1 | 8.3 | 8.2 | 15.3 |
|                 | Elena | 10.2 | 9.7 | 9.5 | 9.8 | 12.2 | 11.6 | 11.9 | 18.2 |
|                 | Azolen | 9.6 | 9.1 | 8.9 | 9.2 | 12.1 | 11.0 | 11.5 | 17.8 |
|                 | Black yeast | 6.3 | 7.5 | 7.4 | 7.1 | 14.5 | 13.6 | 14.0 | 20.0 |
|                 | Trichodermin | 9.0 | 8.6 | 8.4 | 8.7 | 16.7 | 15.1 | 15.9 | 20.6 |

Figure 10. The average length of the root system in two year old seedlings; LSD_{0.05} = 2.9

Figure 11. The average length of the root system in three year old seedlings; LSD_{0.05} = 3.3

Figure 12. The average length of the root system in four year old seedlings; LSD_{0.05} = 3.5
4. Conclusion

According to the results of growing tree species, the best preparations that affect the formation of taller seedlings with the most developed root system of plants are Black Yeast and Trichodermin. The multidimensional mechanism of action of the preparation Trichodermin includes the suppression of the development of phytopathogens by direct parasitism, competition for the substrate, the release of enzymes, antibiotics (glyoxin, viridin, trichodermin, etc.), which reduces the spread of pathogens and inhibits their reproductive ability. The Black Yeast preparation is produced on the basis of a live culture of yeast-like microorganisms *Exophiala Nigrum*, which produces enzymes and hormones that increase the general resistance of plants and inhibit the development of pathogenic microflora. The yeast culture liquid contains nutrients: nitrogen, phosphorus, potassium, which optimize the processes of providing plants with mineral nutrition. This is consistent with the data obtained by other researchers, showing the prospects for the use of biofertilizers based on *Azotobacter sp.* to manage soil and plant health [4]. In the past few years, great progress has been made in studying the composition of rhizosphere microbiomes and their dynamics, rhizosphere populations of *Pseudomonas sp.*, *Trichoderma sp.* are being studied, and their beneficial properties for plants are recorded. The idea of microorganisms applied to plants that perform a dual function as a biocontrol agent and a biostimulator is confirmed [3,7,8]. Our newly obtained data are consistent with those previously published [12].

The tree species in our experiments was more responsive to the use of the studied microbiological preparations, the spherical willow (*Salix fragilis*). However, to expand the range used in urban landscaping and increase the decorativeness of park compositions, it is recommended to use not only spherical willow (*Salix fragilis*), but also foxtail myricaria (*Myricaria lopeucopters*), and graceful tamarix (*Tamarix gracilis*) as tree species that can grow well and develop in the conditions of Western Siberia.

References

[1] Wang C, Turner V K, Wentz E A, Zhao Q, Myint S W 2021 Optimization of residential green space for environmental sustainability and property appreciation in metropolitan Phoenix, *Arizona Science of the Total Environment* 763 144605
[2] Kosenchuk O, Shumakova O, Zinich A, Shelkovnikov S, Poltarykhin A 2019 The development of agriculture in agricultural areas of Siberia: Multifunctional character, environmental aspects *Journal of Environmental Management and Tourism* 10(5) 991-1001
[3] da Silvaa J A T, Pacholczakb A, Ilczuk A 2018 Smoke tree (*Cotinus coggygria* Scop.) propagation and biotechnology: A mini-review *South African J. of Botany* 114 232-240
[4] du Jardin P 2015 Plant biostimulants: Definition, concept, main categories and regulation *Scientia Horticulturae* 196 3-14
[5] Sumbul A, Ansari R A, Rizvi R, Mahmood I 2020 Azotobacter: A potential bio-fertilizer for soil and plant health management *Saudi J. of Biological Sciences* 27 3634-3640
[6] Jacoby R, Peukert M, Succurro A, Koprivova A, Kopriva S 2017 The Role of Soil Microorganisms in Plant Mineral Nutrition—Current Knowledge and Future Directions *Front Plant Science* 8 1617
[7] Barayshchuk G V 2009 Bioecological basis for the use of safe protection of tree plantations in the Omsk Irtysh Region (Omsk: OmSAU)
[8] Patkowska E, Mielniczuk E, Jamiołkowska A, Skwaryło-Bednarz B and Błazewicz-Wozniak M 2020 The Influence of Trichoderma harzianum Rifai T-22 and Other Biostimulants on Rhizosphere Beneficial Microorganisms of Carrot *Agronomy* 10 1637
[9] Konappa N, Krishnamurthy S, Arakere U C, Chowdappa S and Ramachandrappa N S 2020 Efficacy of indigenous plant growth-promoting rhizobacteria and Trichoderma strains in eliciting resistance against bacterial wilt in a tomato *Egyptian J. of Biological Pest Control* 30 106
[10] MillanI A F-S, Farran I, Larraya L, Ancin M, Arregui L M, Veramendi J 2020 Plant growth-promoting traits of yeasts isolated from Spanish vineyards: benefits for seedling development Microbiological Research 237 126480

[11] Khanokon A, Rose M T, Kecskés M, Pereg M, Nguyen H T, Kennedy R I 2012 Plant growth promoting characteristics of soil yeast (Candida tropicalis HY) and its effectiveness for promoting rice growth Applied Soil Ecology 61 295-299

[12] Sarabi M, Cazares S, González-Rodríguez A, Mora F, Carreón-Abud Y, Larsen J 2018 Plant growth promotion traits of rhizosphere yeasts and their response to soil characteristics and crop cycle in maize agroecosystems Rhizosphere 6 67-73

[13] Gorb E A and Barayshchuk G V 2019 Evaluation of microbiological preparations effect on introduced species of trees The Fifth Technological Order: Prospects for the Development and Modernization of the Russian Agro-Industrial Sector pp 119-123 (Atlantis Press)