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BIOLOGICAL PREPARATION EFFECTS ON THE PHYSIOLOGICAL GROWTH OF *PINUS SYLVESTRIS* L. SEEDLINGS AT THE CHERNOZEM SOIL IN NORTHERN KAZAKHSTAN

A. KURMANGOZHINOV[1*], B. OSSERKHAN[1*], B. MUSSAEVA[1], A. OSPANGALIYEV[1], B. KAPAR[1], and A. NAUANOVA[2]

[1]Department of Forest Resources and Forestry, Faculty of Forestry, Wildlife and Environment, S. Seifullin Kazakh AgroTechnical Research University, Astana, Kazakhstan
[2]Department of Agriculture and Plant Growing, Faculty of Agronomy, S. Seifullin Kazakh AgroTechnical Research University, Astana, Kazakhstan
*Corresponding authors' emails: kurmangozhinov@inbox.ru
Email addresses of co-authors: bekbolatosserkhan@mail.ru, binazirmussaeva@mail.ru, askhat.ospangaliyev@mail.ru, bekturkapar@mail.ru, ainashnauanova@mail.ru

SUMMARY

Pinus sylvestris L. is a widely used tree in landscaping, and therefore, its high-quality planting material is most relevant in Kazakhstan. The recent study evaluated the effects of the various biological preparations on the physiological growth of the *P. sylvestris* L. seedlings in the ordinary chernozem of Northern Kazakhstan. The study used several methods for evaluation, i.e., sowing and planting, measurements, data compilation, formulation, and analysis, and recommended computer software. In 2022, sowing 20 kg seeds of *P. sylvestris* ensued on a 0.4 ha area. For the agrochemical assessment of the experimental site, soil samples collected underwent a chemical composition analysis. The morphological parameters of the upper and lower parts of the seedlings also reached identification. Concerning the indicators of agrochemical assessment of the soil after using biological preparations, i.e., Agrarka (1.5%) and Agro-MIX (10%), the sum of macronutrients and exchangeable calcium and magnesium was high. The results also showed that the average number of seedlings incurred enhancements using the Agro-MIX (10%). Therefore, Agrarka and Agro-MIX can be helpful in forest nurseries as effective growth stimulators in growing planting material for tree and shrub species.

Keywords: *Pinus sylvestris* L., seedlings, biological preparations, soil chemical composition, Agrarka and Agro-MIX, agrochemical assessment, growth traits

Key findings: The growth stimulators, viz., Agrarka and Agro-MIX can be helpful for effective management of planting materials in the forest nurseries for tree and shrub species.

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INTRODUCTION

In the present era, the use of growth stimulants is one of the promising areas in growing and managing the planting material, widespread in numerous countries (Kirienko and Goncharova, 2016; Kwak *et al*., 2016). Various organic (Ustinova, 2016) and inorganic (Caradonia *et al*., 2019) fertilizers and growth stimulants have a worldwide use (Chrysargyris *et al*., 2021) to hasten seed germination and seedling growth.

Physiologically active substances and regulators used for promoting plant growth and development are vital in agricultural practices. These biological preparations enhance plants' resistance to various stresses caused by several biotic and abiotic factors. These preparations also improve the water regime, increase the plant's resistance to low temperatures and are environmentally safe (Aladina *et al*., 2006).

In recent years, various growth regulators have become identified with a multifaceted focus on crop plants. Growth regulators' wide application helps improve the cultivation of several crops. These stimulators encourage the growth and development of crop plants and enhance their stability and productivity (Rezvyakova, 2016). However, the complete mechanisms and features of their influence on crop plants have reached adequate studies.

The success of artificial reforestation can be identifiable by the quality of planting materials and its association with several important factors, including soil fertility and susceptibility of the coniferous seedlings to complex diseases (Yessimbek *et al*., 2022; Akhmetov *et al*., 2023; Ospangaliyev *et al*., 2023). In solving these problems, biologically active substances can play a vital role in accelerating seed germination and also improving the growth and development of the planting material of the main forest-forming species, and reducing the influence of adverse environmental factors on the seedlings (Prokazin *et al*., 2015).

The intensive technologies used for growing coniferous seedlings include applying various chemicals for seeds and plant treatment. According to their target characteristics, divide these chemicals into fertilizers, pesticides, and growth stimulants. The latter group received increasing attention as new environmentally friendly preparations are progressing that find practical positions in the agriculture and forestry sectors. During pre-sowing treatment, the biological preparations become applicable to increase the germination energy of seeds, stimulate plant growth, and protect the plants from various diseases at the initial stage of growing in the field (Kirienko and Goncharova, 2016; Makenova *et al*., 2023).

The intensification of development on the synthesis and introduction of growth stimulants link with the use of safer technologies for the environment, the available resources, rational use of industrial waste, and economic activities (Khurshkainen and Kuchin, 2011; Zakharenko, 2015). Unlike traditionally used mineral fertilizers and pesticides, these substances most often incur synthesis from organic matter of natural origin. Therefore, these biological preparations have safe environmental considerations, and increasing their volumes can be feasible to protect crop plants from possible adverse environmental factors. Recently, acquired biological preparations based on woody greenery of coniferous species have appeared (Pankiv *et al*., 2009; Egorova, 2016).

There are a few growth regulators for softwood planting material in nurseries (Pentelkina *et al*., 2009). The growth stimulants developed for crops (Epin and Zircon) have recommendations for growing seedlings of coniferous species (Kirienko and Goncharova, 2016). However, coniferous tree species may differ in reaction to compounds developed for conventional agriculture from the prime and industrial crops. Besides, in nurseries, the cultivation of planting material for coniferous species takes several years, and accordingly, plants experience seasonal variations in weather and edaphic factors.

One should also consider that coniferous tree species, including *Pinus sylvestris* L., are highly mycotrophic (Sarsekova *et al*., 2021). By the end of the first year of life, seedlings of these species have ectotrophic mycorrhizae on their roots. On the root system of seedlings, the formation of mycorrhiza is one of the influential factors contributing to improving the quality of nutrition of coniferous plants and increasing their adaptability during replanting (Sarsekova *et al*., 2021). Recently, the research progressed on various technologies that will allow for obtaining standard planting material with a high level of mycorrhizal root system formation (Burtsev, 2014; Baryshnikov and Kopytkov, 2015). In this regard, the study on the effects of growth stimulants on mycorrhiza formation on the root system of coniferous seedlings and the possibility of their use for growing planting material in a nursery is relevant.

P. sylvestris L. is a widely use tree in landscaping in Kazakhstan. It is one of the species most planted in the form of forest crops in the Northern, Northeastern, and Eastern Kazakhstan regions (Sarsekova *et al*., 2022). Therefore, research on obtaining high-quality planting material (seedlings) in Kazakhstan is relevant. Various biological preparations' used for better soil fertilization of *P. sylvestris* L. seedlings in forest crops and landscaping is effective. *P. sylvestris* seedlings have shown 82.9%–86.7% survival indicators when applied with biological preparations (Sautkina and Kuznetsova, 2021). A study by Reshetnkova and Zarechniv (2020) showed that applying microbiological fertilizer impacted seedling growth and habitus. In another study, the effects of stimulants on seed germination and the growth of *P. sylvestris* L. seedlings were also evident in Northern Kazakhstan (Kabanova *et al*., 2019). The latest study aimed to evaluate the effects of various biological preparations on the physiological growth of *P. sylvestris* L. seedlings in the ordinary chernozem of Northern Kazakhstan.

MATERIALS AND METHODS

Place and period of the study

The study commenced in 2021–2022 at the forest nursery of the Severny Region Branch of the Republican Forest Selection and Seed Center in Shchuchinsk City, District Burabay, Akmola region, Kazakhstan. Soil analysis transpired in the Soil Laboratory, S. Seifullin Kazakh State Agrotechnical University (KSAU), Astana, Kazakhstan.

Seeds sowing

In 2022, the seed sowing began in the second half of May. Data collection and processing included physiological, phenological, biochemical, and soil methods throughout the year's growing season. In 2022, sowing 20 kg of *P. sylvestris* L. seeds covered a 0.4 ha area. Seedling planting was in a linear-row strip, with the pine seeds sowing in a linear-row strip (N:52.951859, E:70.272170). The seedlings, planted in a five-row strip, consisted of 14 strips. Sowing ordinary pine seeds used a mechanized Belarus 82 tractor and an Egedal seeder. The seedlings sustained division into trial areas for testing and monitoring purposes. Nine experimental and three control plots developed had a size of 1 $m^2 \times 1$ m^2 in three-fold repetition. Each plot received watering two times a week according to the established norm for the biological preparation.

Storing of the seed material under snow for three months was by stratification. Before sowing, treatment applications protected the seeds from various diseases and pests. The seedlings grown from seeds sown in the open ground acquired treatment throughout the season with the specified norms of biological preparations by dividing into trial areas.

Treatment with biological preparations and agrotechnical care

Soil watering with growth-stimulating substances ensued twice a week after sowing the seeds. All the seeds remained in a snow heap for 2.5 months, then received treatment with stimulants and dried before planting. Each established variant was in a four-fold repetition, with at least 250 seedlings considered for the repetition. The crop care consisted of weeding, loosening the soil, and small-drip irrigation. In annual seedlings, the height measurement from the ground surface to the apical bud utilized a ruler with an accuracy of 0.1 cm.

The following biological preparations applied to the seedlings in three-fold repetition included:

a) Agro-MIX in doses of 2%, 6%, and 10%,
b) Agrarka in doses of 0.5%, 1.5%, and 2.5%,
c) Epin in doses of 0.1%, 0.2%, and 0.3%, and
d) Control (watering only).

Soil analysis

The soils of the study sites consist of ordinary chernozem. Soil samples' collection was according to genetic horizons, at a depth of 0–10 and 10–15 cm in three repetitions. The following analyses proceeded. Determination of the physical properties of soils (soil density, density of the solid phase of the soil using the pycnometric method, porosity using calculations, and soil moisture using the thermostatic-weight method) and determination of the granulometric composition of soils using the N.A. Kachinsky method (the pipette method).

Determining physicochemical properties (pH H_2O) employed the potentiometric method, the sum of absorbed bases used the trigonometric method, the humus applied the I.V. Tyurin method, carbonates' content engaged the gasometric method, analysis of water extract dry residue, the composition of anions (CO32-, HCO3-, SI-, SO42-), cations (Ca2+, Md+, Na+, K+), and mobile forms of phosphorus used B.P. Machigin method, and exchange potassium was on a flame photometer.

In the experimental plots of chestnut soils, taking samples with a soil drill used the solid column method (10–100 cm) to determine soil moisture, 10–40 cm to determine the density, the density of the solid phase of the soil, and the aggregate composition of the soil, and in layers 0–20 and 20–40 cm to determine the amount of absorbed bases, humus, and nitrogen, phosphorus, and potassium (NPK).

Morphometric traits of the seedlings

The stem and needle length also comprised the measured features of perennial pine tree seedlings, which belonged in the list of physiological indicators of growth and development in determining the standardization of coniferous seedlings. These indicators exhibited a correlation with the degree of mycotrophy of coniferous seedlings.

Determining the age of the seedlings followed the technique of retrospective analysis on the traces of the places of the buds on the stem. Analyzing shoots metamerically determined the ontogenesis phase of seedlings during the year, i.e., once a year, establishing three zones on the shoot: sterile cataphiles, brachiblasts, and auxiblasts (in older seedlings). Accordingly, counting the number of metamers determined the age of the seedling. The first year's counting was from the hypocotyl zone.

Data analysis

Collecting data from the test fields occurred every week during the season, with calculations and computer-based analyses carried out with observations and measurements. Statistical data processing runs through publicly available software packages Microsoft Excel 2010 and STATISTICA 13.

RESULTS AND DISCUSSION

Soil analysis and biological preparations

The analysis results of the physicochemical characteristics are available in Table 1. Significant ($P \leq 0.05$) difference and reduction in soil pH attained recording for the soil samples treated with different combinations of biological preparations compared with the control variant (Table 2). The lowest soil pH (7.95) resulted in the samples treated with Agro-MIX 2%, followed by the seedlings treated with Agro-MIX 6% and Agro-MIX 10% (8.11:8.10) (Mamikhin *et al*., 2023). However, the differences in soil pH between the control variant and Agrarka 1.5% were nonsignificant.

Table 1. Physicochemical properties (mean value ± standard deviation) of the soil.

Soil properties	Unit of measurement	Results
Sand	(%)	62.75±1.22
Sludge		30.06±0.58
Clay		7.19±0.79
Humus		4.81±0.29
Soil texture	-	Medium loamy, sludge/fine sand
Density	(g/cm^{-3})	2.07±0.18
pH	-	8.19±0.01
Organic carbon	(%)	2.79±0.17
Total N		0.14±0.01
NH_4^+ - N		259.14±27.5
NH_3^- - N		4.23±0.23
mobile P	(mg/kg^{-1} of soil)	46.91±1.16
mobile K		600.5±26.0
Cation exchange capacity	(cmol$^{(+)}$/kg^{-1} of soil)	81.5±0.18
Absorbed bases	mmol/kg^{-1}	27.13±0.39
Ca		2.8±0.3
Mg		0.45±0.1
Na		

Table 2. Effect of various biological preparations on soil pH, the content of nitrate nitrogen, mobile phosphorus, potassium, and sulfur, and humus content in the soil.

Treatments	pH	NH_3^- - N (mg/kg^{-1})	Mobile P (mg/kg^{-1})	Mobile K (mg/kg^{-1})	Mobile S (mg/kg^{-1})	Humus (%)
Agro-MIX 2%	7.95±0.07	4.47±0.78	46.63±5.93	642.79±24.65	3.06±1.86	5.41±0.14
Agro-MIX 6%	8.11±0.04	3.70±0.18	54.64±0.98	623.29±20.22	1.25±0.04	5.01±0.19
Agro-MIX 10%	8.10±0.03	6.53±0.19	73.27±5.51	695.61±16.76	8.31±1.14	4.83±0.19
Agrarka 0.5%	8.16±0.09	3.97±0.69	53.31±1.81	628.25±8.60	2.89±2.45	4.95±0.11
Agrarka 1.5%	8.19±0.03	3.07±0.27	63.27±4.12	643.22±11.96	1.27±0.02	4.84±0.25
Agrarka 2.5%	8.20±0.02	3.83±0.49	82.30±1.21	730.98±14.92	1.17±0.05	5.16±0.14
Epin 0.1%	8.20±0.02	3.63±0.46	43.46±2.24	605.21±13.27	-	5.23±0.17
Epin 0.2%	8.28±0.04	4.70±0.5	46.35±2.24	590.53±4.28	1.97±0.80	4.91±0.31
Epin 0.3%	8.33±0.13	3.97±0.75	44.90±2.87	592.19±26.53	1.93±0.44	4.62±0.12
Control	8.19±0.01	4.90±1.24	46.91±1.16	600.50±26.03	-	4.81±0.1

A significant ($P < 0.05$) difference and an increase were evident in the nitrate nitrogen content of the soil samples treated with various biological preparations compared with the control variant. However, the maximum nitrate nitrogen content (6.953 mg·kg^{-1} of soil) appeared in soils treated with Agro-MIX 10%. Besides, the highest content of mobile phosphorus and nitrogen was visible in the variants with Agro-MIX 10% (73.27:695.61), and Agrarka 2.5% (82.3:730.98), and the minimum values for the said elements emerged in variants with Epin and the control variant (Fan *et al*., 2023). Furthermore, significant ($P < 0.05$) increases were prominent in the mobile sulfur and humus content of soil samples treated with various combinations of biological preparations compared with the control group. In the Agro-MIX 10% variant, mobile sulfur content reached 8.31, while non-mobile sulfur manifested in the Epin (0.1%) and control variants. Conversely, the lowest humus content was evident in the Epin (0.3%) and control groups.

Germination traits of *P. sylvestris* L.

Based on study results, the purity of *P. sylvestris* seeds was 92%, germination was

91% in laboratory conditions, the germination energy was 43.25%, and the 1000-seed weight was 29.8 g. In field conditions, the results showed that seed germination and germination energy depended upon the various biological preparations used (Table 3).

The highest results of *P. sylvestris* seed germination came from seeds treated with Agrarka 2.5% (91.2%), which was 13.7% more than the control variant (Fillingim *et al*., 2023). Almost the same result emerged in the preparation with Agrarka 1.5% (90.7%). The seeds treated with Agro-MIX 6%, Agro-MIX 10%, Epin 0.3%, and Agro-MIX 2% showed germination of 89.2%, 87.9%, 85.5%, and 83.3%, respectively, and these values were higher than the control indicators, by 11.7%, 10.4%, 8.0%, and 5.8%, respectively. The experimental variants with Epin 0.2%, Agrarka 0.5%, and Epin 0.1% scored even lower germination % than the control indicators, by 1.4%, 3.8%, and 8.7%, respectively. These findings suggest that careful selection and application of biological preparations can significantly enhance the early growth and vitality of *P. sylvestris*, potentially benefiting forest regeneration and ecosystem health. Further research could explore specific mechanisms these preparations influence seed germination and energy, offering valuable insights into forest management and conservation practices.

On germination energy, the maximum value was also evident in the *P. sylvestris* seeds treated with Agrarka 2.5% (67.8%), which was 13.7% higher than the control value for the said trait. Almost all the biological preparations beneficially impacted the germination energy of the seeds in experimental units, except the variants treated with Agrarka 0.5% and Epin 0.1%. Thus, the preparations made with Agrarka 2.5%, Agrarka 1.5%, Agro-MIX 2%, Agro-MIX 6%, Agro-MIX 10%, and Epin 0.3% showed the utmost positive effects on the *P. sylvestris* seed germination percentage and germination energy (Zhang *et al*., 2023). This positive impact on germination energy was a common trend across most biological preparations, underscoring their effectiveness in promoting the early growth stages of *P. sylvestris* seeds.

The positive impact of root fertilization on the aboveground growth of *P. sylvestris* seedlings in the summer of 2022 is a promising result, which suggests that this treatment can enhance plant development. This finding aligns with the broader understanding of the importance of nutrient availability for plant growth and productivity (Hischier *et al*., 2023). However, it is crucial to note that despite the positive effects on aboveground growth, the average germination rate of the seedlings in the field was 82.39% ± 2.5%, with a coefficient of variation of 9.55%. While this germination rate was relatively high, the variation indicates some degree of inconsistency in germination success among the individual seedlings.

Table 3. Dynamics of *P. sylvestris L.* seed germination after treatment with solutions of different biological preparations.

Date of the planned counting of seedlings (days)	Experiment variants, the number of germinated seeds									
	Control	Agro-MIX 2%	Agro-MIX 6%	Agro-MIX 10%	Agrarka 0.5%	Agrarka 1.5%	Agrarka 2.5%	Epin 0.1%	Epin 0.2%	Epin 0.3%
Day 5	7.2	8.7	9.4	7.0	6.8	8.5	9.0	6.5	7.1	8.2
Day 7	54.1	60.5	66.0	56.2	50.5	62.9	67.8	51.3	59.4	63.7
Day 10	60.9	82.3	86.5	62.0	64.3	86.6	88.3	64.0	69.7	70.8
Day 15	77.5	83.3	89.2	87.9	73.7	90.7	91.2	68.8	76.1	85.5
Germination energy (%)	54.1	60.5	66.0	56.2	50.5	62.9	67.8	51.3	59.4	63.7
Germination (%)	77.5	83.3	89.2	87.9	73.7	90.7	91.2	68.8	76.1	85.5
Not sprouted seeds (%)	22.5	16.7	10.8	12.1	26.3	9.3	8.8	31.2	23.9	14.5

Table 4. Variation statistics of *P. sylvestris L.* seedlings' variability by length of shoots and roots.

Study variants	Quantity (%)	N (pcs)	M±m (cm)	Average square measurement (σ)	Variation coefficient	Asymmetry	Excess kurtosis
Shoots' length							
Agro-MIX	0.5	7	3.75±0.45	0.901	16.50%	0.702	-0.812
Agro-MIX	1.5	9	2.75±0.53	0.750	8.824%	-0.707	-1.500
Agro-MIX	2.5	8	3.21±0.55	1.444	41.12%	-0.384	-0.925
Agrarka	2.0	5	3.0±0.79	1.118	13.55%	-1.500	0.250
Agrarka	6.0	7	3.25±0.40	0.804	17.40%	0.595	-0.641
Agrarka	10.0	6	3.25±0.34	0.677	16.31%	0.486	-0.656
Epin	0.1	7	3.17±0.53	0.920	16.67%	1.080	0.500
Epin	0.2	7	3.5±0.50	0.866	12.24%	1.358	0.234
Epin	0.3	9	2.63±0.59	1.174	21.55%	-1.341	1.055
Control	-	15	3.37±0.69	1.382	18.49%	0.777	0.274
Roots' length							
Agro-MIX	0.5	7	7.67±0.99	2.419	29.14%	-0.053	-0.479
Agro-MIX	1.5	9	8.71±0.55	1.444	14.42%	0.566	-0.535
Agro-MIX	2.5	8	9.08±1.03	2.518	23.49%	0.086	-1.552
Agrarka	2.0	5	8.1±1.03	2.302	28.42%	1.111	-0.192
Agrarka	6.0	7	8.4±1.19	2.656	25.73%	0.700	0.102
Agrarka	10.0	6	10.6±1.05	2.348	19.98%	0.374	-1.249
Epin	0.1	7	7.7±1.71	3.813	38.26%	-0.051	-1.606
Epin	0.2	7	7.3±0.68	1.515	15.44%	-0.121	-1.399
Epin	0.3	9	7.36±0.91	2.374	28.55%	0.523	-0.193
Control	-	15	8.4±0.75	2.112	18.05%	0.659	-0.465

Biological preparations' impact on the morphological traits

The results on the effects of different biological preparations, i.e., Agro-MIX, Agrarka, and Epin, had a stimulating effect on the growth process of the *P. sylvestris* seedlings (Table 4). According to the results of the seedlings' length (Shaikh *et al*., 2023), the highest arithmetic mean of 3.75 ± 0.45 appeared in the variant treated with Agro-MIX 0.5%, and the minimal arithmetic mean (2.63 ± 0.59) registered in the variant with Epin (0.3%). In the variant with Epin (0.1%), the observed standard deviation was σ = 3.813.

Like other biologically active compounds, the growth regulators also need careful handling (Kalin *et al*., 2023; Makenova *et al*., 2023; Smirnova *et al*., 2024). The overdose of these biological compounds is also dangerous and may not obtain the expected effects but even opposite results. Most biologically active substances in low and minimal concentrations act as growth stimulants, increase immunity, and activate fruiting (Nasiyev and Dukeyeva, 2023; Nokusheva *et al*., 2023). Quantile analysis of the *P. sylvestris* seedling height was the difference between the maximum and minimum values.

The analysis of the dispersion of the length of shoots and roots of the *P. sylvestris* seedlings appears in Table 5. The Fischer-Snedecor criterion showed 0.6745 for the length of the shoots and 1.1891 for the root length; however, it did not prove the influence of the factors. The differences' analysis in the average by factors was justified (Duresso *et al*., 2023). The length of the chief root in the seedlings was valid using the Bartlett criterion, a fixed difference through the $LSD_{0.05}$ at the rate of Agrarka 10%.

Biological preparations' effect on *P. sylvestris* seedling biomass

The variation statistics about the variability of the *P. sylvestris* seedlings for the shoots and roots weight are in Table 6. The dry biomass of the seedlings generally corresponded to their linear parameters. Concerning the weight of seedlings, the maximum average was notable

Table 5. Analysis of variance of the shoot and root lengths of *P. sylvestris* L. seedlings.

Variance	Set of squares	Variation fraction	Category of freedom	Middle square	F criterion
Shoots' length					
Total	31.622	1.0000	79	0.4003	
	2.523	0.0798	9	0.2804	0.675
	29.098	0.9202	70	0.4157	
Roots' length					
Total	367.922	1.0000	79	4.6578	
Variants	48.789	0.1326	9	5.4209	1.189
Factors	319.133	0.8674	70	4.5590	

Table 6. Variation statistics of *P. sylvestris L.* seedlings' variability by dry biomass of shoots and roots.

Study variants	Quantity (%)	N (pcs)	M±m (mg)	Average square measurement (σ)	Variation coefficient	Asymmetry	Excess kurtosis
Shoots' dry biomass							
Agro-MIX	0.5	7	0.051±0.009	0.023	44.80%	0.905	-0.389
Agro-MIX	1.5	9	0.019±0.003	0.008	40.22%	0.641	-1.075
Agro-MIX	2.5	8	0.055±0.011	0.032	57.54%	-0.037	-1.221
Agrarka	2.0	5	0.079±0.012	0.026	32.54%	0.927	-0.545
Agrarka	6.0	7	0.047±0.004	0.012	25.26%	0.465	-1.239
Agrarka	10.0	6	0.047±0.004	0.009	19.43%	-0.472	-1.111
Epin	0.1	7	0.056±0.007	0.017	30.71%	0.019,	-1.583
Epin	0.2	7	0.042±0.005	0.013	31.32%	1.428	0.908
Epin	0.3	9	0.034±0.005	0.014	41.11%	0.041	-1.041
Control	-	15	0.057±0.005	0.020	35.52%	0.191	-1.013
Roots' dry biomass							
Agro-MIX	0.5	7	0.020±0.004	0.010	49.15%	1.488	0.813
Agro-MIX	1.5	9	0.034±0.005	0.015	45.57%	0.646	0.289
Agro-MIX	2.5	8	0.029±0.003	0.008	28.75%	0.858	-0.122
Agrarka	2.0	5	0.027±0.003	0.007	24.75%	-0.847	-0.577
Agrarka	6.0	7	0.060±0.032	0.084	139.9%	1.499	0.673
Agrarka	10.0	6	0.058±0.036	0.089	155.0%	1.748	1.124
Epin	0.1	7	0.018±0.004	0.010	56.17%	0.976	-0.010
Epin	0.2	7	0.014±0.001	0.003	19.99%	-0.458	-0.880
Epin	0.3	9	0.013±0.002	0.005	37.92%	0.598	-0.645
Control	-	15	0.027±0.003	0.011	41.57%	0.440	-0.562

in the experimental variant treated with Agrarka 2.0% (0.079 ± 0.012 mg) and in the control variants (0.057 ± 0.005 mg). The *P. sylvestris* seedling shoot weight in variants treated with the biological preparations, i.e., Agro-MIX (0.5%, 1.5%, and 2.5%), Agrarka (6.0% and 10.0%), and Epin (0.1%, 0.2%, and 0.3%) was lower than the same seedlings in the control variant. According to the *P. sylvestris* seedling roots, the maximum weight was prominent in the variants treated with Agrarka 6.0% and 10.0% (Salungyu *et al*., 2020).

CONCLUSIONS

In the agrochemical assessment of the experimental soil, the variables were pH (8.19 ± 0.01), organic carbon (2.79 ± 0.17), total nitrogen (0.14 ± 0.01), available phosphorus (46.91 ± 1.16), and exchange cations (81.5 ± 0.18). The *P. sylvestris* seed germination rate was 82.39% ± 2.5% in the field. The average maximum length of the seedling shoots and roots emerged in the variants treated with Agrarka 10% and Agro-MIX 2.5%. The combined use of Agro-MIX 10% and Agrarka

2.5% accelerated the growth of *P. sylvestris* seedlings and is recognizably the best among all biological preparations. The seedlings' biomass gained positive effects from Agrarka with all concentrations. Agrarka and Agro-MIX can benefit forest nurseries as effective growth stimulators by growing planting material for tree and shrub species.

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