Influence of growth stimulants on the cultivation of annual Mongolian oak (Quercus Mongolian Fisch. ex Ledeb.) seedlings

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Abstract. Growth stimulants are substances that provide the growth and development of plants. The aim of this study was to assess the effect of growth stimulants Albit, Energen and Epin-Extra on the cultivation of annual seedlings of Mongolian oak (Quercus mongolica Fisch. ex Ledeb.) in a forest nursery of Primorye Territory. These stimulants were used as a pre-sowing seed treatment in various concentrations of solutions. Control – seeds which have not been treated with preparations. At the end of the growing season, the parameters of seedlings were determined: height, diameter of the root neck, length of the root system, number of leaf blades, leaf surface area and dry mass. It was revealed that the growth stimulator Albit had a more positive effect on the height of seedlings, and Epin-Extra was more effective on the diameter of the root neck. The total dry mass was influenced by Energen. The rest of the parameters were within the control group, or their decrease was observed. In the future, it is planned to study the effect of these stimulants on the subsequent growth of oak seedlings.

1 Introduction

Oak is one of the most important woody covered plants of the Russian Far East. It occupies an area of about 3.5 million ha [1], where in Territory its distribution area is 983.8 thousand ha [2].

In the Far East, oak grows mainly in Primorye, Khabarovsk Territories, Amur and Sakhalin Regions, and the Jewish Autonomous Region [2].

In Primorye and Khabarovsk Territories, Amur Region (Zeya Reserve), as well as the eastern coast of Nikolai Bay in Nikolayevsky District of Khabarovsk Territory grows Mongolian oak [2]. It is an important component of mixed forests of the Russian Far East [3]. In the southern areas, it is observed at a height 700-800 m and sometimes up to 1 km into the mountains. Under favourable growing conditions, the Mongolian oak can reach a height of 30 m. In mountainous and northern coastal areas, its height rarely exceeds 10-12 metres. The trunks of young oaks have smooth bark with a "mirror-like" surface, while the trunks of old specimens have thick bark covered with cracks. The leaves of Mongolian oak

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are deep lobed, oblong [2]. They have similarities to the leaves of European oak, but larger in size (30×17). This fact is connected with the process of hybridisation. Thus, analyses of genome evolution showed that Mongolian oak has a close resemblance to Q. robur, and they have a common ancestor that was 11.8 million years ago [4]. However, due to Pakhomov’s research, the Mongolian oak wood is not only as good as that of the petiole oak, but also superior in mechanical properties. The acorns have almost sessile, ovoid shape, with hemisphere-shaped plescae, lightly covered with down. The length of acorns is 1.5 cm and the thickness is about 1.3 cm [2].

Oak is a tree species, that has a great economic importance [3]. It is noted that it has a good stability after fires [5].

Mongolian oak is ornamental. It is actively used in alleys, group plantings for protective forest belts, non-renewed woodlots, as well as restoration of abandoned territories [2]. It has a great national economic significance [3]. Oak is effectively used in the creation of protective forest plantations along railway tracks and motorways, as well as in the restoration of agricultural land. It is noted that it is better to use it to create an impervious structure due to the fact that it sheds its leaves not completely in winter, although it cannot be recommended for all cases. The forage base of oak forests includes a variety of plants, which favourably affects the diet of animals. For some animal species, this forage base is a priority. Acorns are used to make coffee; leaves are used in pickling. Oak wood is used in wagon building, shipbuilding, construction of underwater structures, agricultural machinery production, interior decoration of premises. Oak wood is used for barrels, parquet, furniture, planed and peeled veneer and glued plywood. After steaming, it bends well and has good strength, so it is used for crafts. Also, it can be used to produce acetic acid, carbon dioxide, cellulose, fodder yeast, carton, furfural, and charcoal, wine and wood alcohol. The resilient and strong trees are used to make hoops [2].

In recent decades, it is noted, that the distribution area and stock of Mongolian oak is decreased due to forest fires and illegal logging of timber [2,6]. It is necessary to accelerate its artificial restoration. It is possible with the use of growth stimulants at various stages of growing planting material.

Growth stimulants are substances of natural or synthetic origin that have been widely used in the cultivation of coniferous and deciduous planting material in recent decades. Among them: Benzyladenine, dihydroquercetin, PGRs, Ecopin, Epin-Extra (brassinosteroid), IAA, IBA, Kinetin, Gibberellic acid, Kelpak, Kornevin, OA, Ribav-Extra, Rizopone, Stimulax, Wuxal Ascofol, Zircon, Humate+7, Potassium humate “Sufler”, Biohumus, Agrostimul VE, Emistim-R, Gibberellin, Etamon, Verva-spruce, Melafen, Fumar, EridGrow, etc. [7‒26].

Growth stimulants increase germination energy, laboratory germination of seeds, length and weight of seedlings. They accelerate the growth and development of the above-ground part and the root system of plants; increase yield, survival and preservation.

In this regard, the use of such growth stimulants, which also include Albit, Energen and Epin-Extra is relevant. Albit contains the natural microbial polymer polydihydro-oxybutyric acid from soil bacteria Baccillus megaterium and Pseudomonas aurefaciens, growth stimulants, as well as immunity inducers, a balanced set of micro- and macroelements (NPK, Mg, S, Fe, Mn, Cu, Zn, Mo, Na, B, Co, Ni, Ca, I, Sc and Si) and terpenic acids. This drug has a pronounced growth-stimulating effect; it increases the supply of nutrients to plants, promotes the formation and growth of a powerful root system [27]. It has a positive effect on seed viability, the duration of the growing season and plant yield [28,29]. It stimulates the growth of seedlings, increases soil germination of seeds, seedling density, survival and resistance of plants to various diseases [30].
Energen — is made of potassium humate salts and trace elements, which enchances plant growth as well as other ranges of physiological functions [31]. The authors noted that Energen increases the leaf surface area, as well as plant yields [32‒35].

Epin-Extra is a synthetic analogue of a natural phytohormone. The active ingredient of the drug is epibrassinolide, which belongs to brassinosteroid, a natural hormone of plants. Its mechanism of action is the activation of plant's own phytohormones, natural hormones. Epibrassinolide activates biological processes in plants, literally saving them from diseases, old age, and stress. Studies have established that Epin-Extra increases the laboratory germination of seeds, morphometric indicators of seedlings, the productivity of plants, their preservation and survival. It has an antibacterial effect [15]. It has been noted that Epin-Extra is effective for germination and yield [36‒38]. A positive effect of this drug on the enlargement of the root system of plants and the leaf apparatus has been revealed [39,40].

This research is devoted to studying the effectiveness of the use of growth stimulants Albit, Energen and Epin-Extra on biometric indicators (height, diameter of the root neck, length of the root system, number of leaf blades, leaf surface area and dry weight) of annual Mongolian oak (*Quercus mongolica* Fisch. ex Ledeb.) seedlings, which is a promising tree species for growing in a forest nursery in the south of Primorye Territory.

### 2 Methods

Field studies were carried out in a forest nursery located on the territory of the GTS - a branch of the Federal Research Center for Biodiversity of the Far Eastern Branch of the Russian Academy of Sciences (43°41'37" N; 132°09'10" E), located 24 km from Ussuriysk, Russia. The soils here are mountainous and forested. The terrain is slightly undulating, with minimal slope. The climate in the research site is monsoonal. The temperature reaches 30-35° C in July-August. The distribution of precipitation is uneven. Their average amount is about 80% in the warm season and only 20% falls in winter. The largest number of them is in July-October (about 50-57%). The dynamics of changes in air humidity is unique. So, in summer, it reaches its maximum values (more than 80%); In April-May, it is the lowest, amounting to 50-70% [41].

The experiments were laid in 2023 in the sowing department of the nursery. The scheme of the experiment included variants of pre-sowing treatment of acorns with growth stimulants: I – control (without the use of stimulants); II – use of Albit; II – Energen; III – Epin-Extra. Treatment of the seed material was carried out in three repetitions in accordance with the instructions for the use of the studied preparations. Thus, the concentration of Albit was 2 drops / 50 ml, Energen – 15 drops / 50 ml, Epin-Extra – 2 drops / 100 ml of water. The soil of the experimental site is brown, podzolic, heavy loamy, with a gradual transition in the lower part of the gentle slope to meadow-brown. The humus content in the soil is low (2.83%), the exchange acidity is neutral (6.5 pH), the mobile phosphorus content is very high (20.5 mg/100 g of soil), and the potassium content is low (7.3 mg/100 g of soil). Soil preparation was carried out according to the black fallow system. Mongolian oak acorns were sown in the spring in the first decade of May. The sowing scheme was three-line, row, with a row spacing of 40 cm. The area of the experimental plots was 12 m².

At the end of the growing season (in early September), measurements of biometric indicators of seedlings were carried out. The height was determined with a ruler using the continuous counting method. Model samples were identified. From each variant of the experiment, 3 model seedlings were taken, from which the diameter of the root neck was measured using an electronic caliper (Carbon Fiber Composites Digital Caliper) with an accuracy of 0.1 mm (manufactured by Shenzhen Alisi Electronic Technology Co., Ltd., China). The length of the root system and the surface area of the leaves were determined.
using a ruler (Gamma, Russia). Dry weight was measured on an MW-II electronic scale with an accuracy of 0.01 g (manufactured by Cas Corp., Korea).

The parameters of height, diameter of the root neck, length of root system, number of leaf blades, leaf surface area and dry mass of above-ground part and root system did not differ significantly from the normal distribution, and the variances of the compared variants were homogeneous, so the significance of differences was assessed by a one-way analysis of variance (ANOVA).

3 Results

The increase in the height of Mongolian oak seedlings was significantly influenced by the pre-sowing treatment of acorns with the stimulant Albit. Thus, its average values were 7.6 cm, exceeding the control by 13.4%. The seedlings visually had a higher height of the above-ground part in comparison with other variants and under control. The differences with the control are significant: $t_{\text{act}} \geq t_{\text{tabl}}$. Epin-Extra had a weak effect, amounting to 6.8 cm (the excess to the control was 1.5%). Treatment of acorns with the stimulant Energen turned out to be ineffective. The average height was 5.9 cm (11.9% decrease compared to the control). This is clearly shown in the graphs (Table 1, Figure 1).

Table 1. Biometric parameters of Mongolian oak (Quercus mongolica Fisch. ex Ledeb.) seedlings treated with Albit, Energen, Epin-Extra and of the unprotected control

<table>
<thead>
<tr>
<th>Growth stimulator / Solution concentration, ml/l</th>
<th>Height, M±m, cm</th>
<th>Diameter of the root neck, cm</th>
<th>Length of roots, cm</th>
<th>Number of leaf blades, st.</th>
<th>Leaf surface area of 1 seedling, cm²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>6.7±0.1</td>
<td>0.4±0.1</td>
<td>11.9±3.8</td>
<td>4.7±0.7</td>
<td>113.4±13.7</td>
</tr>
<tr>
<td>Albit 2 drops / 50 ml</td>
<td>7.6±0.1*</td>
<td>0.9±0.7</td>
<td>11.8±2.9</td>
<td>4.0±1.5</td>
<td>88.7±21.6</td>
</tr>
<tr>
<td>Energen 15 drops / 50 ml</td>
<td>5.9±0.6</td>
<td>0.4±0.1</td>
<td>8.0±3.4</td>
<td>5.0±0.1</td>
<td>93.7±37.1</td>
</tr>
<tr>
<td>Epin-Extra 2 drops / 100 ml</td>
<td>6.8±0.5</td>
<td>1.8±0.1*</td>
<td>8.3±1.2</td>
<td>5.0±0.6</td>
<td>104.9±16.5</td>
</tr>
</tbody>
</table>

Note: * - differences with control are significant when $p < 0.05$

Fig. 1. Effect of growth stimulants on the height growth of annual Mongolian oak (Quercus mongolica Fisch. ex Ledeb.) seedlings
Treatment of acorns with stimulants Albit and Epin-Extra had a positive effect on the diameter of the root neck of Mongolian oak seedlings, amounting to 0.9 and 1.8 cm, respectively, exceeding the indicators of the control group by 125.0-350.0%. When use the growth stimulator Epin-Extra the differences with the control are significant: $t_{\text{fact}} \geq t_{\text{tabl}}$. The indicators of Energen were the same as in the control. Thus, the average diameter of the root neck was 0.4 cm (Table 1, Figure 2).

![Graph 1: Effect of growth stimulants on the diameter of root neck of annual Mongolian oak seedlings](image1)

**Fig. 2.** Effect of growth stimulants on the diameter of root neck of annual Mongolian oak (*Quercus mongolica* Fisch. ex Ledeb.) seedlings

Energen and Epin-Extra, in comparison with the control, did not have a positive effect on the length of the roots, where it was in the range of 8.0-8.3 cm. When acorns were treated with the stimulant Albit, its parameters were at the level of the control, amounting to 11.8 cm (Table 1, Figure 3).

![Graph 2: Effect of growth stimulants on the length of roots of annual Mongolian oak seedlings](image2)

**Fig. 3.** Effect of growth stimulants on the length of roots of annual Mongolian oak (*Quercus mongolica* Fisch. ex Ledeb.) seedlings

The number of leaf blades was slightly higher with the use of stimulants Energen and Epin-Extra. Thus, their average number was 5 pieces, exceeding the indicators at the control by 6.4%. However, the total leaf surface area of one seedling was higher in the control variants, amounting to 113.4 cm².

The stimulant Energen had a more active effect on the increase in the dry weight of Mongolian oak seedlings (Table 2).
Table 2. Dry weight of Mongolian oak (*Quercus mongolica* Fisch. ex Ledeb.) seedlings, treated with Albit, Energen, Epin-Extra, and of the unprotected control

<table>
<thead>
<tr>
<th>Growth stimulator / Solution concentration, ml/l</th>
<th>Trunk weight, g</th>
<th>Leaves weight, g</th>
<th>Root system weight, g</th>
<th>Total weight, g</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>0.15±0.02</td>
<td>0.59±0.14</td>
<td>0.85±0.16</td>
<td>1.59</td>
</tr>
<tr>
<td>Albit 2 drops / 50 ml</td>
<td>0.13±0.03</td>
<td>0.40±0.16</td>
<td>1.05±0.51</td>
<td>1.58</td>
</tr>
<tr>
<td>Energen 15 drops / 50 ml</td>
<td>0.15±0.01</td>
<td>0.52±0.03</td>
<td>2.60±1.04*</td>
<td>3.27</td>
</tr>
<tr>
<td>Epin-Extra 2 drops / 100 ml</td>
<td>0.19±0.09</td>
<td>0.45±0.07*</td>
<td>0.96±0.32</td>
<td>1.60</td>
</tr>
</tbody>
</table>

Thus, the total weight of seedlings was 3.27 g, exceeding the control by 105.7%. At the same time, the stimulant had the greatest effect on the mass of the root system. The differences with the control are significant: t_{fact} > t_{table}. With the use of Epin-Extra, there was a slight excess of the control (by 0.6%). The total weight is 1.60 g. The treatment option with Albit did not affect the increase in the total weight of oak seedlings. It was within the parameters of the control group.

4 Discussion

In the forest nursery of the GTS – a branch of the Federal Research Center for Biodiversity of the Far Eastern Branch of the Russian Academy of Sciences, work on the cultivation of seedlings of coniferous species using growth stimulants has been carried out for about 20 years. This research is devoted to the study of the effect of growth stimulants Albit, Energen and Epin-Extra on the cultivation of annual seedlings of Mongolian oak, a promising tree species of great economic importance in the Primorye Territory.

The literature reflects the experience of using these growth stimulants in the cultivation of agricultural crops. Thus I. R. Haniyeva, Yu. Abdulkhalikov, Y. Shogenov, etc. noted the positive effect of Albit on the duration of the growing season and the yield of sunflower [28]; Yu. Pleskachiov, S. Voronov, S. Kurbanov, etc. studied the effect of Albit on the yield and quality parameters of winter wheat [29]. The active influence of Albit on the structure of the crop, the density of seedlings, the number of surviving plants of winter triticale has been established by A. M. Zhukov, M. V. Anosova, I. A. Popov [30]. The positive effect of the stimulant Energen on the growth and development of black currant and tomato plants has been documented by T. M. Trifonova [32,33]. S. Yu. Sorokina, N. S. Sorokin, S. M. Sychev, etc. tested the stimulant Energen to increase soybean yields [34]. It is noted by V. T. Lobkov, V. P. Naumkin, N. A. Lopachev, etc. that Energen increases the yield of beans [35]. It has been established that Epin-Extra increases the germination and yield of tomatoes, as well as winter wheat [36,37]. A positive effect of this drug on the enlargement of the root system and leaf apparatus of barley has been noted [38]. It has also been found that Epin-Extra increases the weight, number of needles, as well as the activity of nitrogenase in leguminous plants [42]. The authors have established its active influence on the development of the root system, leaf apparatus and the appearance of the peduncle of orchid plants [39]. The positive effect of the drug on reducing the negative impact of stress factors in spring wheat, Ural onions and cabbage has been revealed [43]. Epin-Extra has a positive effect on the growth of corn seedlings [44].

Also, a small amount of research has been done on woody plants. Thus, the authors observed a positive effect of the stimulant Albit on the root formation of white cedar seedlings; increasing the length of the 2-year-old part of the axial shoot of Schrenk spruce
seeds; on accumulation of a pharmacological complex of bioflavonoids (dihydroquercetin, quercetin, and rutin) and organic silicon in young and developing leaves of amaranth plants [45–47]. The effect of the stimulant Epin-Extra on the viability of Siberian spruce (Picea obováta), prickly spruce Hoopsi (Picea pungens Hoopsii), western thuja Smaragd (Thuja occidentalis Smaragd), thuja western Brabant (Thuja occidentalis Brabant) has been studied [48]. We have also established the positive effect of Epin-Extra on germination energy, laboratory germination and sprouts length of Khingham fir seeds (Abies nephrolepis (Trautv.) Maxim.) [15].

In this study, we analyzed the effect of the growth stimulants Albit, Energen and Epin-Extra on morphometric parameters (height, diameter of the root neck, root length, number of leaf blades, leaf surface area and dry weight) of Mongolian oak seedlings. These preparations were used as a pre-sowing treatment of oak acorns in solution concentrations in accordance with the manufacturer's instructions. In our experiments, it was found that the stimulant Albit had a more active effect on the increase in the height of oak seedlings and on the diameter of the root neck – Epin-Extra. At the same time, the indicators of root length, number of leaf blades and leaf surface area were within the control group, or their decrease was observed in relation to the control. The growth of the dry mass of seedlings was actively influenced by the stimulant Energen.

In experiments conducted earlier by other authors with these stimulants in the same concentrations with pedunculate oak (Quercus robur L.), Epin-Extra had a more positive effect on all linear parameters. The action of Energen and Albit turned out to be less effective [49].

The positive effect of Albit on the increase in the height of oak seedlings in our experiments is probably associated with its polydihydro-oxybutyric acid, as well as macro and microelements, in particular, purified active substances from soil bacteria Bacillus megaterium and Pseudomonas aureofaciens, which in natural conditions live on the roots of plants, stimulate their growth, protect the plant from diseases and adverse environmental conditions [30]. The active effect of Epin-Extra on the diameter of the root neck is due to the action of epibrassinolide, a natural hormone of plants, which increases their morphometric indicators. The positive effect of the stimulant Energen on the dry mass of the root system is due to potassium humate salts, which actively participate in cellular and physiological processes in plants, such as osmotic adjustment, enzyme functioning, cation-anion balance, detoxification of ROS and protein synthesis in plants, increasing their volume indicators [31]. The preparations probably did not have a positive effect on the length of roots and other parameters due to unfavorable climatic conditions (a large amount of precipitation at the beginning of the growing season during the experiments), as well as the long seed dormancy of Mongolian oak acorns, which led to a later emergence of seedlings.

5 Conclusions

Growth stimulants are substances of natural or synthetic origin that are widely used in the cultivation of planting material of coniferous and deciduous species. It was revealed that the growth stimulator Albit had a more positive effect on the height of oak trunks, and Epin-Extra was more effective on the diameter of the root neck. The total dry mass was influenced by Energen. The rest of the parameters (root length, number of leaf blades, and total leaf surface area) were within the control group.

In the future, it is planned to study the effect of these stimulants on the subsequent growth of oak seedlings.
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