Original article
УДК 631.531+631.8+635.92
DOI: 10.37482/0536-1036-2022-4-39-51

Growth of Schrenk's Spruce (*Picea schrenkiana*) Seedlings Related to the Pre-Sowing Stimulating Seed Treatment

Anna V. Kul'kova*[1], *Candidate of Agriculture; *ResearcherID: G-9517-2019,*
ORCID: https://orcid.org/0000-0001-5200-233X
Natalia N. Besschetnova*[1], *Doctor of Agriculture; *ResearcherID: H-1343-2019,*
ORCID: https://orcid.org/0000-0002-7140-8797
Vladimir P. Besschetnov*[1] ✉, *Doctor of Biology, Prof.; *ResearcherID: S-5889-2016,*
ORCID: https://orcid.org/0000-0001-5024-7464
Yerzhan Zh. Kentbaev*[2], *Doctor of Agriculture, Prof.; *ResearcherID: G-7677-2019,*
ORCID: https://orcid.org/0000-0002-3308-1287
Botagoz A. Kentbaeva*[2], *Doctor Biology, Prof.; *ResearcherID: G-8228-2019,*
ORCID: https://orcid.org/0000-0003-0969-9754
[1]Nizhny Novgorod State Agricultural Academy, prosp. Gagarina, 97, Nizhny Novgorod, 603107, Russian Federation; kulkova12@gmail.com, besschetnova1966@mail.ru, lesfak@bk.ru✉
[2]Kazakh National Research Agrarian University, prosp. Abaya, 8, Almaty, 050010, Republic of Kazakhstan; kentbayev@mail.ru, kentbayeva@mail.ru

Received on October 3, 2020 / Approved after reviewing on January 11, 2021 / Accepted on January 15, 2021

Abstract. The uniqueness of the biological properties and the occurrence in nature of the Schrenk's Spruce (*Picea schrenkiana* Fisch. & C.A. Mey.), its great forestry significance, and important eco-stabilizing functions of its stands in the Northern Tian Shan are of great interest to a wide range of researchers in many countries. However, many characteristics of this endemic species have been poorly studied so far, and information on the effectiveness of its introduction is extremely limited. We investigated the characteristics of growth and development of spruce seedlings in the conditions of the Nizhny Novgorod region. The seeds were harvested in natural plantations on the territory of the Almaty State Nature Reserve, which is located in the Central part of the Trans-Ili Alatau in South-Eastern Kazakhstan. They were sown in an open ground nursery under stimulating treatment with the following bioactive stimulants: siliplant, ferovit, ecofus, kornevin, heteroauxin, zircon, extrasol, epin, and albit. The soaking of all the seeds in water at the same exposure for 24 h served as control. The aftereffect of bioactive substances in the pre-sowing stimulating treatment of Shrenk's spruce seeds was found to activate the growth processes of the aboveground part of its seedlings during the introduction into the Nizhny Novgorod region. It was found that the biennial part of seedlings axial shoot had unequal length in different experimental options. The highest values were achieved in the variants with the use of the following stimulants: ferovit (5.95±±0.02 cm), heteroauxin (5.62±0.16 cm), ecofus (5.47±0.32 cm), and albit (5.49±0.015 cm). The generalized value was 5.08±0.07 cm. The growth characteristics of seedlings also respond to the stimulating effect. The best results in this case were shown by ferovit (2.25±0.023 cm) and heteroauxin (1.96±0.17 cm). The differences in the number of side shoots are less contrasting. However, we can also see the previously noted trends: ferovit (1.42±0.25 pcs); heteroauxin (1.34±0.19 pcs); and albit (1.31±0.19 pcs). We obtained the certificate of sufficient resource of natural conditions of the region for seed breeding of Schrenk's spruce in the open ground and the significant potential of its introduction to the Nizhny Novgorod region.

Keywords: Schrenk's spruce, introduction, seed propagation, growth stimulants, seedlings, morphometrics, analysis of variance, Nizhny Novgorod region

For citation: Kul'kova A.V., Besschetnova N.N., Besschetnov V.P., Kentbaev Y.Zh., Kentbaeva B.A. Growth of Schrenk's Spruce (*Picea schrenkiana*) Seedlings Related to the Pre-Sowing Stimulating Seed Treatment. *Lesnoy Zhurnal* = Russian Forestry Journal, 2022, no. 4, pp. 39–51. https://doi.org/10.37482/0536-1036-2022-4-39-51

Научная статья

Рост сеянцев ели Шренка (*Picea schrenkiana*) при предпосевной стимулирующей обработке семян

А.В. Кулькова*[1], *канд. с.-х. наук; ResearcherID: G-9517-2019, ORCID: https://orcid.org/0000-0001-5200-233X
Н.Н. Бессчетнова*[1], *д-р с.-х. наук; ResearcherID: H-1343-2019, ORCID: https://orcid.org/0000-0002-7140-8797
В.П. Бессчетнов*[1]✉, *д-р биол. наук, проф.; ResearcherID: S-5889-2016, ORCID: https://orcid.org/0000-0001-5024-7464
Е.Ж. Кентбаев*[2], *д-р с.-х. наук, проф.; ResearcherID: G-7677-2019, ORCID: https://orcid.org/0000-0002-3308-1287
Б.А. Кентбаева*[2], *д-р биол. наук, проф.; ResearcherID: G-8228-2019, ORCID: https://orcid.org/0000-0003-0969-9754
[1]Нижегородская государственная сельскохозяйственная академия, просп. Гагарина, д. 97, г. Нижний Новгород, Россия, 603107; kulkova12@gmail.com, besschetnova1966@mail.ru, lesfak@bk.ru✉
[2]Казахский национальный исследовательский аграрный университет, просп. Абая, д. 8, г. Алматы, Казахстан, 050010; kentbayev@mail.ru, kentbayeva@mail.ru

Поступила в редакцию 03.10.20 / Одобрена после рецензирования 11.01.21 / Принята к печати 15.01.21

Аннотация. Уникальность биологии и распространения ели Шренка (*Picea schrenkiana* Fisch. & C.A. Mey.), большое лесохозяйственное значение и важные эколого-стабилизирующие функции ее насаждений на Северном Тянь-Шане обуславливают неослабевающий интерес исследователей разных стран к этому эндемичному виду. Однако на сегодняшний день многие его характеристики изучены слабо, крайне ограничены сведения об эффективности интродукции. Нами исследованы особенности роста и развития сеянцев ели Шренка в условиях Нижегородской области. Семена были заготовлены в естественных насаждениях на территории Алматинского государственного природного заповедника, который расположен в центральной части Заилийского Алатау на юго-востоке Казахстана. Высевание семян производили в питомнике открытого грунта при стимулирующей обработке биоактивными препаратами: силиплантом, феровитом, экофусом, корневином, гетероауксином, цирконом, экстрасолом, эпином и альбитом. Контролем выступало намачивание семян в воде в единой для всех вариантов экспозиции 24 ч. Эффект применения биоактивных веществ при предпосевной стимулирующей обработке семян ели Шренка выразился в активизации ростовых процессов надземной части ее сеянцев при интродукции в Нижегородскую область. Установлена неодинаковая длина 2-летней части осевого побега сеянцев по вариантам опыта. Наибольшие значения достигнуты в вариантах применения феровита (5,95±0,02 см), гетероауксина (5,62±0,16 см), экофуса (5,47±0,32 см) и альбита (5,49±0,015 см). Среднее значение составило 5,08±0,07 см. Ростовые характеристики сеянцев также реагируют на стимулирующее воздействие. Лучшие результаты и в этом случае показали препараты феровит (2,25±0,023 см) и гетероауксин (1,96±0,17 см). Менее контрастны различия по количеству боковых побегов. Однако и здесь прослеживаются ранее отмеченные тенденции: феровит – 1,42±0,25 шт., гетероауксин – 1,34±0,19 шт., альбит – 1,31±0,19 шт. Получено свидетельство о достаточном ресурсе природных условий региона для семенного размножения ели Шренка в открытом грунте и о существенном потенциале ее интродукции в Нижегородскую область.

Ключевые слова: ель Шренка, интродукция, семенное размножение, стимуляторы роста, сеянцы, морфометрия, дисперсионный анализ, Нижегородская область

Для цитирования: Kul'kova A.V., Besschetnova N.N., Besschetnov V.P., Kentbaev Y.Zh., Kentbaeva B.A. Growth of Schrenk's Spruce (*Picea schrenkiana*) Seedlings Related to the Pre-Sowing Stimulating Seed Treatment // Изв. вузов. Лесн. журн. 2022. № 4. С. 39–51. https://doi.org/10.37482/0536-1036-2022-4-39-51

Introduction

Schrenk's spruce (*Picea schrenkiana* Fisch. & C.A. Mey.) is recognized as the main forest-forming species of the Northern Tian Shan [16, 47, 50] and, being an endemic species of the natural flora of this region, belongs to the dominant species of the forest cover [17, 25, 27, 48]. Having a large economic value [20, 21, 22, 29] and performing important eco-stabilizing functions [2, 18, 50], Schrenk's spruce is under constant scrutiny by researchers [1, 15, 19, 32, 33, 44]. Its occurrence in nature is described in detail [13, 25, 27, 51], the spatial and population structure of natural stands of this breed is well studied [4–6, 13], ecological reactions and biological features are described [16–18, 45, 46], data on karyology is accumulated [6, 15, 30, 43, 55]. The problems of Schrenk's spruce natural regeneration are considered in Kazakhstan and Kyrgyzstan [20, 32, 40]. The features of the Schrenk's spruce seedlings development [49] are studied and the relevance of creating its forest crops is shown [28, 34, 54] in the context of these problems. However, the taxonomy and systematic position, intraspecific variability and form diversity of this species remain debatable [4–6, 47, 48]. In the Russian Federation, the list of economically used spruce species is constantly updated, including non-regional species [10–12, 36, 37]. The Schrenk's spruce is the least studied among them. We introduced it into the Nizhny Novgorod region for the first time taking into account the formed theoretical concepts [3, 7, 8, 38, 39, 45].

The research aims at determining the prospects for the introduction of Schrenk's spruce into the Nizhny Novgorod region via evaluation of the growth processes of its seedlings against the background of stimulating treatment with bioactive compounds.

Research objects and methods

We studied two-year-old seedlings of Schrenk's spruce grown out of seeds harvested in the Almaty State Nature Reserve natural plantations. The reserve is located in the Central part of the Trans-Ili Alatau in the South-East of Kazakhstan (coordinates: 43° 06′ 00″ N 77° 19′ 00″ E). The high-altitude borders of the spruce forest belt are 1,600–2,800 m above sea level. Seedlings were grown in the open ground with artificial irrigation at the experimental site of the Faculty of Forestry of the Nizhny Novgorod State Agricultural Academy. Its geographical coordinates are 56° 19′ 43″ N 44° 00′ 07″ E, and the height above sea level is 136 m.

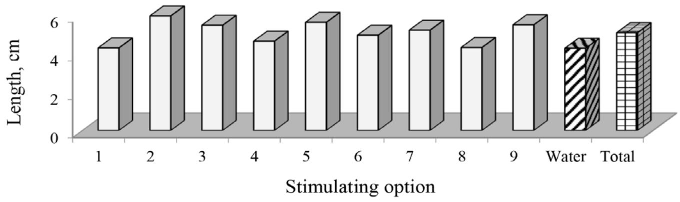
The methodological framework for developing operating procedures consisted of theoretical ideas on the basic requirements for the organization of an experiment (its typicality, suitability, expediency and reliability), the principles of the only logical difference and the randomized distribution of objects when they are included in the sample [23, 31, 41, 42, 52, 56]. That is why the differentiating influence of chronographic and environmental factors was levelled by simultaneous recording of all plants, including into the experiment scheme only single-aged seedlings growing in the same soil and climatic conditions, in the same agricultural background and in the same phenological state. The organizational and methodological scheme provided the construction of a one-factor variance complex and the performance of statistical analysis [14, 23, 26, 31, 41, 42, 52, 56].

Based on the fact that one of the key assessments of the plants introduction results is a set of their seed propagation indicators, we studied the morphometric parameters of the aboveground part and root systems of Schrenk's spruce seedlings in the conditions of their transfer to the Nizhny Novgorod region. At the same time, the stimulating effect of biologically active substances in pre-sowing seed treatment, which is described relative to an extensive list of tree species [24, 53], including spruce [9], was also considered. We tested the following preparations formed the test options: siliplant – 0.05 % (option 1); ferovit 0.15 % (option 2); ecofus – 0.3 % (option 3); kornevin – 0.01 % (option 4); heteroauxin – 0.02 % (option 5); zircon – 0.025 % (option 6); extrasol – 1.5 % (option 7); epin – 0.05 % (option 8); albite – 0.1 % (option 9). The soaking of all the seeds in water (Water option) at the same exposure for 24 h served as Control. The average value generalized for the entire data array is called Total. The length of the aerial part and roots were measured with a ruler with accuracy of 0.5 mm; diameter – with an electronic caliper (Digital Caliper SH20) to accuracy of 0.01 mm. The repetition of the experience is threefold. A total of 346 seedlings were biometrized.

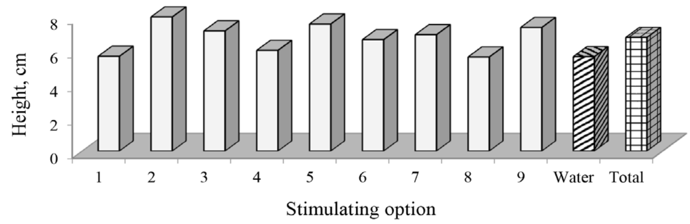
Results and discussion

The effectiveness of Schrenk's spruce seed propagation in the conditions of introduction was evaluated by the parameters of growth of seedlings sowed in the open ground and treated with stimulators (fig. 1–3). The length of the two-year part of the axial shoot of Schrenk's spruce seedlings was not the same according to the experimental options (fig. 1*a*). The highest values were achieved when the following stimulators were used: ferovit (option 2; 5.95±0.024 cm) and heteroauxin (option 5; 5.62±0.16 cm).

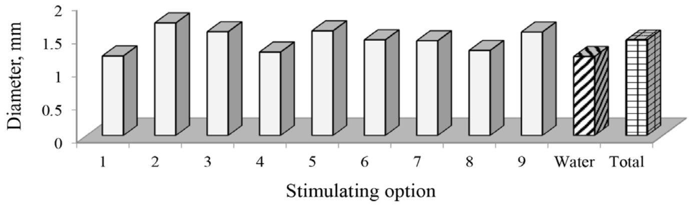
The estimates for ecofus (option 3) and albit (option 9) were slightly lower: 5.47±0.32 cm and 5.49±0.015 cm, respectively. Even weaker is the effect of siliplant (option 1) and epin (option 8) use: 4.29±0.17 and 4.31±17.30 cm, respectively. A similar situation is in the group of seeds soaked in water before the sowing (Control option): 4.27±0.14 cm. At the same time, the difference in estimates is clearly noticeable, and the largest of them exceeded the smallest by 1.68 cm or 1.39 times. Generalized value for the entire data array (Total option) was 5.08±0.07 cm. For the other parameters of the axial shoot of seedlings, the marked trends were generally preserved (fig. 1*b*, 1*c*).



a



b



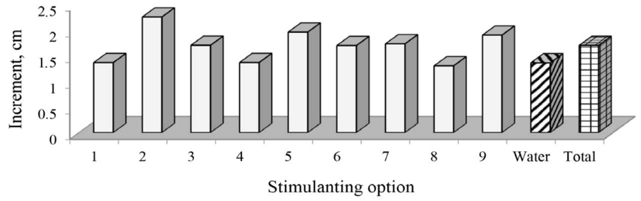
c

Fig. 1. Parameters of the axial shoot of Schrenk's spruce seedlings: *a* – length of the two-year part of the axial shoot; *b* – total height of the aboveground part; *c* – diameter of the root collar

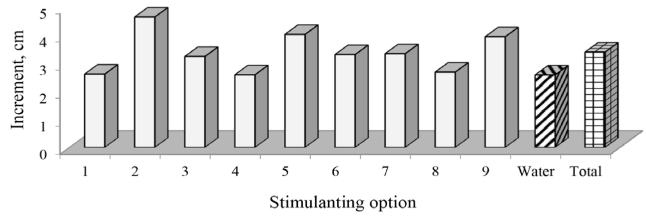
The increment characteristics of seedlings also showed heterogeneity in different options of the stimulating effect (fig. 2).

Like in the previous option, the highest current increment values were registered in the application with ferovit (option 2) and heteroauxin (option 5): 2.25±0.023 cm and 1.96±0.17 cm, respectively. They significantly exceeded the control value (1.36±0.09 cm) and the generalized average value (1.70±0.05 cm).

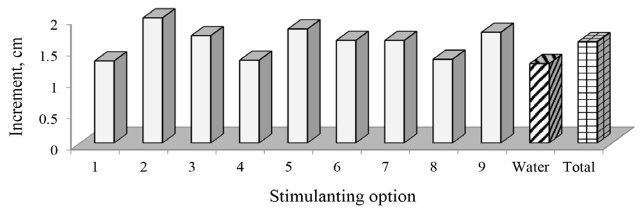
The use of albit (option 9) provoked a comparable increase (1.90±0.17 cm). Other stimulants showed less effectiveness in this regard, which can be attributed to the above-mentioned increment characteristics in general (fig. 2*b*, 2*c*). The general estimates of linear growth of the axial and lateral shoots at the time of measuring, as well as their average values (fig. 3*a*, 3*b*), retained the main trends established for the characteristics of the current increment (fig. 2). The differences in the number of lateral shoots in the aboveground part of the seedlings are less contrasting (fig. 3*c*), however, the previously noted ratios are also observed here. In particular, the use of ferovite (option 2), heteroauxin (option 5) and albite (option 9) was accompanied by high values, while siliplant (option 1) and epin (option 8) had the lowest values. They were close to the control values.



a



b

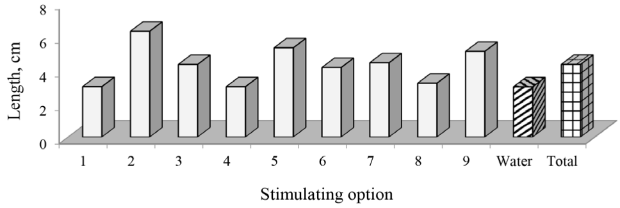


c

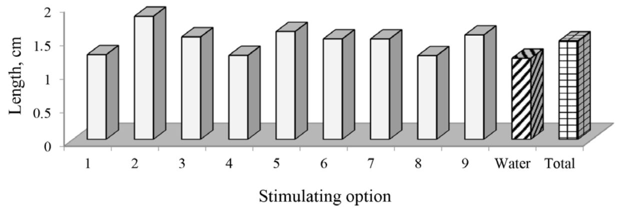
Fig. 2. Linear increment of Schrenk's spruce seedlings: *a* – current increment of the axial shoot; *b* – total current increment of shoots; *c* – average current increment of shoots

So it was found that the stimulating seed treatment of Schrenk's spruce seedlings by different stimulators provokes different changes in their growth and development features. The following features of growth and development were studied: feature 1 – height of two-year aboveground part of the seedlings without the last increment, cm; feature 2 – diameter of the root collar of seedlings, mm; feature 3 – current linear growth of the axial shoot in height, cm; feature 4 – total height of the aboveground part of seedlings including the last growth, cm; feature 5 – total current linear growth of shoots including axial shoots, cm; feature 6 – average current linear growth of shoots including axial shoots, cm; feature 7 – total linear shoot growth on all the whorls, cm; feature 8 – overall average linear growth of shoots including axial shoots, cm; feature 9 – total number of side shoots in all the seedling whorls, pcs. Their relative estimates expressed in terms of the coefficient of variation (C_V, %) are represented in table 1.

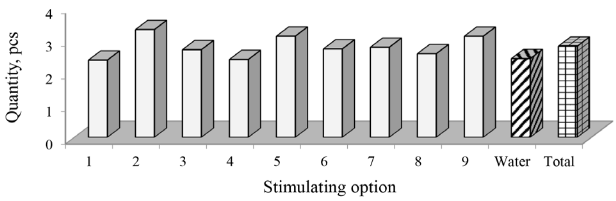
It is noticeable that the variability of linear parameters of the Schrenk's spruce seedlings axial shoot within the boundaries of the generalized data array (Total option) refers to the average (feature 1) and increased (features 2 and 4) level on the Mamaev's scale. The coefficients of variation were 23.94, 26.30 and 27.28 %, respectively. Other characteristics of seedlings are more variable, and their corresponding ratings are high, such as feature 6, feature 8, feature 9 (42.95, 39.71 and 44.03 %), and very high, such as feature 3, feature 5, feature 7 (58.81, 57.01 and 66.47 %) on the same scale.



a



b



c

Fig. 3. Total growth of Schrenk's spruce seedlings: *a* – total growth of shoots; *b* – total average growth of shoots; *c* – number of side shoots in the aboveground part

Table 1

Variability of characteristics of the aboveground part of Schrenk's spruce seedlings

Option	Feature								
	1	2	3	4	5	6	7	8	9
1	17.51	19.70	45.50	18.17	54.49	35.78	51.09	36.01	42.71
2	22.93	23.26	58.12	26.31	49.96	41.32	59.23	39.18	43.14
3	23.24	32.64	51.51	22.56	47.57	37.88	56.30	33.99	42.36
4	16.38	18.63	36.42	16.23	49.37	33.48	50.24	33.03	42.83
5	20.34	24.35	62.18	25.72	54.53	44.30	64.90	42.25	43.27
6	23.22	24.55	52.99	23.21	49.39	39.35	51.07	36.77	41.94
7	28.11	29.34	59.74	30.58	60.99	44.12	69.34	39.32	44.39
8	17.30	17.48	47.55	17.12	49.72	31.90	46.13	31.72	37.74
9	18.75	24.01	61.68	25.59	53.83	41.58	64.45	39.51	42.36
Water	17.22	16.64	35.93	16.78	53.06	29.97	55.48	30.32	48.92
Total	23.94	26.30	58.81	27.28	57.01	42.95	66.47	39.71	44.03

Absolute estimates of the variability of the analyzed indicators were characterized by ranges of limits, which were established at the stage of statistical analysis. In particular, the absolute maximum of the total height of the aboveground part (12.5 cm) exceeded the absolute minimum of the same indicator (3.7 cm) by 3.38 times. The range of root collar diameter limits was 2.21 mm (from 0.64 mm to 2.85 mm). The linear current growth of the axial shoot had a range of values from 0 to 4.5 cm, since it was not registered for individual seedlings. The total increment of shoots in the records for all seedling whorls had a spread of values from 0.3 to 16.8 cm, which formed a range of 16.5 cm and exceeded the limits by 56 times.

The effectiveness of the use of biologically active substances to stimulate the germination of Schrenk's spruce seeds (at the background of aftereffect) was evaluated by the one-way ANOVA (table 2).

Table 2

The effect of stimulants on the growth of Schrenk's spruce seedlings

Feature	F_{act}	Share of factor influence ($h^2 \pm s_h^2$)						Criteria for differences	
		by Plokhinsky's algorithm			by Snedecor's algorithm				
		h^2	$\pm s_h^2$	F_h^2	h^2	$\pm s_h^2$	F_h^2	LSD_{05}	D_{05}
1	10.44	0.2185	0.0209	10.436	0.2161	0.0210	10.293	0.517	0.820
2	8.30	0.1819	0.0219	8.302	0.1758	0.0221	7.965	0.165	0.262
3	3.64	0.0887	0.0244	3.635	0.0715	0.0249	2.874	0.458	0.727
4	10.26	0.2156	0.0210	10.264	0.2130	0.0211	10.105	0.786	1.248
5	5.20	0.1223	0.0235	5.200	0.1093	0.0239	4.582	0.869	1.379
6	5.46	0.1276	0.0234	5.462	0.1153	0.0237	4.867	0.312	0.495
7	6.04	0.1393	0.0231	6.041	0.1284	0.0233	5.499	1.282	2.034
8	4.25	0.1022	0.0240	4.251	0.0868	0.0245	3.546	0.265	0.421
9	2.53	0.0635	0.0251	2.533	0.0429	0.0256	1.673	0.572	0.908

Here we used the following statistical indicators: F_{act} – experimental value of Fisher test; F_{05} – table value of Fisher criterion for 5 % significance level (F_{05} = 1.91); F_{01} – table value of Fisher test at 1 % significance level (F_{01} = 2.48); h^2 – the proportion of influence of the organized factors; $\pm s_h^2$ – error share of influence of the organized factors; F_h^2 – the Fisher criterion in the assessment of the validity of the share of influence of the organized factors; LSD_{05} – least significant difference at 5 % level of significance; D_{05} – criterion of Tukey at 5 % significance level.

The one-way ANOVA confidently refutes the null hypothesis that there are no differences if different growth stimulants are used. The calculated values of the F-criterion were almost always greater than their acceptable table limits at the significance levels accepted in the article. This is true relative for almost all considered parameters of Schrenk's spruce seedlings. The only exception is the total number of side shoots in all seedling whorls (feature 9), where the significance of differences is estimated at 5 % significance and not at 1 % significance.

Estimates of growth stimulators impact on the development of spruce seedlings in calculations according the the Plokhinsky's algorithm are different for various parameters. The highest values of this indicator concerned the length of a two-year part of axial shoot of seedlings (feature 1) and the total height of the aerial part of seedlings from the last growth (feature 4). The estimates are quite reliable and were 21.85±2.09 % (F_h^2 = 10.44) and 21.56±2.10 % (F_h^2 = 10.26), respectively. The minimum impact was registered by the current linear growth of the axial shoot in height (feature 3) and by the total number of lateral shoots in all the seedling whorls (feature 9). In the first case, the estimates were reliable at the 5 and 1 % significance levels and amounted to 8.87±2.44 % (F_h^2 = 3.64). In the second case, they were reliable at 5 % and unreliable at 1 % significance level and reached the level of 6.35±2.51 % (F_h^2 = 2.53). Calculations using the Snedekor's algorithm showed mostly comparable results (table 2).

Significant difference estimates (LSD_{05} and D_{05}) allowed us to determine between which options of stimulating treatment the difference in average values corresponds to the level of significance. In particular, it was possible to determine which options of stimulating treatment significantly differed from soaking seeds in water for a particular feature of seedlings. Thus, the control value in the length of the two-year part of the axial shoot (feature 1) did not significantly differ with that received after the use of biologically active substances such as siliplant (option 1), kornevin (option 4), and epin (option 8). This is confirmed by the least significant difference (LSD_{05}) and the criterion of Tukey (D_{05}). This conclusion is also true for a range of other features: diameter of the seedling root collar (feature 2); current linear growth of the axial shoot in height (feature 3); total height of the aboveground part of seedlings with the last growth (feature 4). As for other features of the aboveground part, the situation is different. For example, for the total current linear growth of shoots, including axial shoots (feature 5), the control group did not show significant differences with 6 options of stimulating treatment, and only in three cases the aftereffect was confirmed by the criteria of significant differences: option 2 – ferovit; option 5 – heteroauxin; and option 9 – albit.

Conclusion

The aftereffect of bioactive substances in the pre-sowing stimulating treatment of Shrenk's spruce seeds is preserved. It is expressed in the activation of growth processes of the aboveground part of its seedlings during the introduction in the Nizhny Novgorod region.

The effectiveness of different bioactive substances is not the same for different growth indicators of the seedling aboveground part and has a specific level of manifestation. For some of them, a significant excess of tested indicator values in relation to the control was achieved, confirmed by the analysis of variance. The best results for most of the seedling characteristics were obtained by the use of ferovit, heteroauxin, and albit stimulators. The last circumstance necessitates making a differentiated approach to the selection of biostimulants used to expand the possibilities of the Schrenk's spruce introduction by seed material.

The registered level of growth and development of the aboveground part of Schrenk's spruce seedlings in the ground indicates a sufficient resource for seed reproduction in the region's natural conditions and a significant potential for its introduction in the Nizhny Novgorod region.

REFERENCES

1. Bakhtiyorov Z., Yu R., Yang M., Monoldorova A., Aminov J. Reconstructed Precipitation for the Eastern Tian Shan (China), based on *Picea shrenkiana* Tree-Ring Width. *Journal of Earth Science & Climatic Change*, 2017, vol. 8, iss. 12, art. 432. https://doi.org/10.4172/2157-7617.1000432

2. Baytulin I.O., Bykov B.A., Proskuryakov M.A., Roldugin I.I. On the Main Problems of Mountain Forestry in Kazakhstan. *Forests of Mountain Systems of Kazakhstan*. Alma-Ata, Nauka Kazakhskoy SSR Publ., 1987, pp. 3–11. (In Russ.).

3. Bazilevskaya N.A. *Theory and Methods of Plant Introduction*. Moscow, MSU Publ., 1964. 131 p. (In Russ.).

4. Berezin E.L. To the Taxonomy and Variety of the Schrenk Spruce. *Forest Genetics, Breeding and Seed Production: Collection of Academic Papers of the Meeting Held on December 12–15, 1967 in Petrozavodsk*. Petrozavodsk, Kareliya Publ., 1970, pp. 199–202. (In Russ.).

5. Berezin E.L. The Species Composition of Spruce Populations in the Forests of the Tian-Shan and Dzhungarian Ala-Tau Mts. *Botanicheskii Zhurnal*, 1970, vol. 55, no. 4, pp. 491–498. (In Russ.).

6. Berezin E.L., Budaragin V.A. Interpopulation Variability of Karyotypes of the Tian Shan and Dzungarian Alatau Spruce and Issues of Its Taxonomy. *Botanical Materials of the Herbarium of the Institute of Botany of the Kazakh SSR Academy of Sciences*. Alma-Ata, Nauka KazSSR Publ., 1982, iss. 12, pp. 60–67. (In Russ.).

7. Besschetnova M.V. Some Genetic Aspects of the Theory of Plant Introduction. *Bulletin of the Main Botanical Garden*, 1971, iss. 82, pp. 3–7. (In Russ.).

8. Besschetnova M.V. Adaptation Processes from the Standpoint of Plant Introduction. *Bulletin of the Main Botanical Garden*, 1983, iss. 128, pp. 3–6. (In Russ.).

9. Besschetnova N.N., Besschetnov V.P., Khramova O.Ju., Dorozhkina L.A. Stimulating Effect of EcoFus Preparation During Presowing Seeds Treatment of Norway Spruce. *Agrokhimicheskiy vestnik* = Agrochemical Herald, 2017, no. 2, pp. 41–44. (In Russ.).

10. Besschetnova N.N., Besschetnov V.P., Kulkova A.V., Mishukova I.V. Starch Content in Shoot Tissues of Different Spruce Species (*Picea* A. Dietr.) in Introduction. *Lesnoy Zhurnal* = Russian Forestry Journal, 2017, no. 4, pp. 57–68. (In Russ.). https://doi.org/10.17238/issn0536-1036.2017.4.57

11. Besschetnova N.N., Besschetnov V.P., Kul'kova A.V., Shirokov A.I. Correlation of Starch Content in Tissue of *Picea a.* Dietr. *Vestnik of Kazan State Agrarian University*, 2018, no. 2(49), pp. 19–22. (In Russ.). https://doi.org/10.12737/article_5b34ff5f201623.29401443

12. Besschenova N.N., Kul'kova A.V. The Content of Reserve Nutrients in the Cells of Annual Shoot Tissues of the Representatives of the Spruce (*Picea* L.) Genus in Nizhny Novgorod Region. *Lesnoy Zhurnal* = Russian Forestry Journal, 2019, no. 6, pp. 52–61. (In Russ.). https://doi.org/10.17238/issn0536-1036.2019.6.52

13. Bobrov E.G. *Forest-Forming Conifers of the USSR*. Leningrad, Nauka Publ., 1978. 188 p. (In Russ.).

14. Bondarenko A.S., Zhigunov A.V. *Statistical Processing of Forestry Research Materials*. Saint Petersburg, Polytechpress, 2016. 125 p. (In Russ.).

15. Budaragin V.A. Karyotypes of the Main Coniferous Species of Kazakhstan. *Proceedings of KazNIILKh*. Vol. 2. Protective Afforestation and Breeding Issues in Northern Kazakhstan. Alma-Ata, Kaynar Publ., 1980, pp. 116–122. (In Russ.).

16. Bykov B.A. *Spruce Forests of the Tian Shan, Their History, Features and Typology*. Alma-Ata, Akademiya nauk KazSSR Publ., 1950. 128 p. (In Russ.).

17. Bykov B.A. *Dominants of the Vegetation Cover of the Soviet Union*. In 3 Vol. Vol. 1. Alma-Ata, Akademiya nauk KazSSR Publ., 1960. 315 p. (In Russ.).

18. Bykov B.A. Spruce Forests of the Tian Shan. Alma-Ata, Nauka Kazakhskoy SSR Publ., 1985. 284 p. (In Russ.).

19. Chen F., Mambetov B., Maisupova B., Kelgenbayev N. Drought Variations in Almaty (Kazakhstan) Since AD 1785 Based on Spruce Tree Rings. *Stochastic Environmental Research and Risk Assessment*, 2017, vol. 31, iss. 8, pp. 2097–2105. https://doi.org/10.1007/s00477-016-1290-y

20. Cheshev L.S. *Cuttings and Renewal in Spruce Forests of the Issyk-Kul Region*. Frunze, Ilim Publ., 1974, pp. 8–26. (In Russ.).

21. Cheshev L.S. *Bioecological Basis of Final Felling in Spruce Forests of the Tian Shan*. Frunze, Ilim Publ., 1978. 78 p. (In Russ.).

22. Danilik V.N. Final Felling in Tian Shan Spruce Stands. *The System of Final Felling in the Mountain Forests of the Altai and Tian Shan: Proceedings of the Scientific and Production Conference Held in November 1957.* Alma-Ata, Kaynar Publ., 1959, pp. 20–23. (In Russ.).

23. Dean A., Voss D., Draguljić D. *Design and Analysis of Experiments*. Heidelberg, Springer Cham, 2017. 840 p. https://doi.org/10.1007/978-3-319-52250-0

24. De Atrip N., O'Reilly C. Germination Response of Alder and Birch Seeds to Applied Gibberellic Acid and Priming Treatments in Combination with Chilling. *Annals of Forest Science*, 2007, vol. 64, no. 4, pp. 385–394. https://doi.org/10.1051/forest:2007015

25. Debreczy Z., Rácz I. *Conifers Around the World*. In 2 Vol. Vol. 1. The International Dendrological Foundation. Ed. by K. Musial. DendroPress, 2012. 1089 p.

26. Dospekhov B.A. *Field Experiment Technique (With the Basics of Statistical Processing of Research Results)*. Moscow, Al'yans Publ., 2014. 351 p. (In Russ.).

27. Farjon A. *Picea schrenkiana*, Schrenk's Spruce. *The IUCN Red List of Threatened Species*. 2013. 6 p. https://doi.org/10.2305/IUCN.UK.2013-1.RLTS.T42336A2973645.en

28. Gan P.A Experience of Mountain Afforestation in the Belt of Spruce Forests of Kyrgyzstan. *Proceedings of the Meeting on the Problem of Restoration and Breeding of Spruce Forests*. Frunze, Akademiya nauk KirgSSR Publ., 1960, pp. 53–59. (In Russ.).

29. Gan P.A. *Introduction and Afforestation of Conifers in Kyrgyzstan*. Frunze, Ilim Publ., 1987. 147 p. (In Russ.).

30. Goryachkina O.V., Muratova E.N., Badaeva E.D. Karyological Studies of *Picea schrenkiana* (*Pinaceae*) from Kirghizia. *Botanicheskii Zhurnal*, 2018, no. 4, pp. 505–516. (In Russ.). https://doi.org/10.1134/S0006813618040063

31. Hinkelmann K., Kempthorne O. *Design and Analysis of Experiments: Introduction to Experimental Design*. Vol. 1. Hoboken, NJ, Wiley, 2008. 631 p. https://doi.org/10.1002/9780470191750

32. Isakov A.T., Buzykin A.I. Method for Assessing Natural Regeneration of Spruce Forests in the Issyk-Kul Region. *Conifers of the boreal zone*, 2012, vol. XXX, no. 3-4, pp. 214–219. (In Russ.).

33. Karpyuk T.V., Muratova E.N., Vladimirova O.S., Sedel'nikova T.S. Karyological Analysis of *Picea schrenkiana*. *Lesovedenie* = Russian Journal of Forest Science, 2009, no. 1, pp. 52–58. (In Russ.).

34. Kelgenbaev N.S., Besschetnov V.P., Mambetov B.T. Results of Reforestation in Medeo Hole After Disasters. *Vestnik of Kazan State Agrarian University*, 2016, no. 1(39), pp. 27–29. (In Russ.). https://doi.org/10.12737/19302

35. Kelgenbaev N.S., Mambetov B.T., Bukeikhanov A.N., Besschetnov V.P. Spruce Forests Distribution by Their Vital Resistance in the Mountain Forests of North Tyan-Shan. *Izvestia Orenburg State Agrarian University*, 2016, no. 2(58), part 2, pp. 137–140. (In Russ.).

36. Kulkova A.V., Besschetnova N.N., Besschetnov V.P. Multiparameter Evaluation of the Taxonomic Proximity of the Species of Spruce (*Picea a.* Dietr.) in the Pigment Composition

of Needles. *Vestnik of Volga State University of Technology Series “Forest: Ecology. Nature Management”*, 2018, no. 1(37), pp. 5–18. (In Russ.).

37. Kul’kova A.V., Besschetnova N.N., Besschetnov V.P. Multivariable Analysis in the Assessment of Spruce Species Specificity (*Picea*). *Lesnoy Zhurnal* = Russian Forestry Journal, 2018, no. 6, pp. 23–38. (In Russ.). https://doi.org/10.17238/issn0536-1036.2018.6.23

38. Lapin P.I., Kalutskiy K.K., Kalutskaya O.N. *Introduction of Forest Species*. Moscow, Lesnaya promyshlennost’ Publ., 1979. 224 p. (In Russ.).

39. Lapin P.I., Sidneva S.V. Assessment of the Prospects for the Introduction of Woody Plants Based on Visual Observation Data. *Experience in the Introduction of Woody Plants*. Moscow, Nauka Publ., 1973, pp. 7–67. (In Russ.).

40. Mambetov B.T., Kelgenbaev N.S., Maysupova B.D., Dosmanbetov D.A., Dukenov Zh.S. On the Evaluation Technique of Natural Regeneration of Schrenk’s Spruce (*Picea schrenkiana*) in Mountain Forests of the Northern Tien Shan. *Lesnoy Zhurnal* = Russian Forestry Journal, 2018, no. 4, pp. 63–69. (In Russ.). https://doi.org/10.17238/issn0536-1036.2018.4.63

41. Mason R.L., Gunst R.F., Hess J.L. *Statistical Design and Analysis of Experiments: With Applications to Engineering and Science*. Hoboken, NJ, Wiley, 2003. 752 p. https://doi.org/10.1002/0471458503

42. Mead R., Curnow R.N., Hasted A.M. *Statistical Methods in Agriculture and Experimental Biology.* New York, Chapman and Hall/CRC, 2002. 488 p. https://doi.org/10.1201/9780203738559

43. Muratova E.N., Sedel’nikova T.S., Goryachkina O.V., Pimenov A.V. Study of Coniferous Karyotypes by Classical and Molecular-Cytogenetic Methods. *Conservation of Forest Genetic Resources: Proceedings of the 6th International Conference*. Kokshetau, Mir pechati Publ., 2019, pp. 148–150. (In Russ.).

44. Panyushkina I.P., Chang C., Clemens A.W., Bykov N. First Tree-Ring Chronology from Andronovo Archaeological Timbers of Bronze Age in Central Asia. *Dendrochronologia*, 2010, vol. 28, iss. 1, pp. 13–21. https://doi.org/10.1016/j.dendro.2008.10.001

45. Plotnikova L.S. *Scientific Basis for the Introduction and Protection of Woody Flora of the USSR*. Moscow, Nauka Publ., 1988. 264 p. (In Russ.).

46. Proskuryakov M.A. On the Issue of Acclimatization of Schrenk’s Spruce on the Southern Slopes of the Tian Shan Mountains. *Vestnik sel’skokhozyaystvennoy nauki Kazakhstana*, 1965, no. 11, pp. 89–93. (In Russ.).

47. Proskuryakov M.A. Regularities of the Spatial Structure Formation of the Mountain Spruce Forest Stand of Tian Shan. *Lesovedenie* = Russian Journal of Forest Science, 1971, no. 6, pp. 3–10. (In Russ.).

48. Proskuryakov M.A. *Horizontal Structure of Mountain Dark Coniferous Forests*. Alma-Ata, Nauka KazSSR Publ., 1983. 215 p. (In Russ.).

49. Proskuryakov M.A., Khomullo O.N. Experimental Analysis of Differentiation of Schrenk’s Spruce Seedlings. *The Flora and Fauna of the Reserves of Kazakhstan: Proceedings of the Chief Administration of Reserves and Hunting Farms under the Council of Ministers of the Kazakh SSR*. Alma-Ata, Kaynar Publ., 1973, pp. 119–150. (In Russ.).

50. Roldugin I.I. *Spruce Forests of the Northern Tian Shan*. Alma-Ata, Nauka Kazakhskoy SSR Publ., 1989. 303 p. (In Russ.).

51. Rubtsov N.I. On the Geobotanical Zoning of the Tian Shan. *Bulletin of Moscow Society of Naturalists. Biological series*, 1956, vol. 56, pp. 86–94. (In Russ.).

52. Srinagesh K. *The Principles of Experimental Research*. Waltham, MA, Butterworth-Heinemann, 2005. 432 p.

53. Szczotka Z., Lewandowska U. Polyamines in Dormancy Breaking of Tree Seeds. *Annals of Forest Science*, 1989, vol. 46, no. Supplement, pp. 95s–97s. https://doi.org/10.1051/forest:19890518

54. Venglovskiy B.I., Lukashevich I.V., Isakov A. Creation of Forest Plantations of Tian Shan Spruce. *Rational Use and Conservation of Forest Resources: International Scientific Conference*. Bishkek, Ilim Publ., 2006, pp. 117–120. (In Russ.)

55. Vladimirova O.S., Karpjuk T.V., Muratova E.N. Chromosome Numbers of Some *Picea* Species (*Pinaceae*). *Botanicheskii Zhurnal*, 2003, vol. 88, no. 8, pp. 112–113. (In Russ.).

56. Zar J.H. *Biostatistical Analysis*. Edinburg Gate, Pearson New International edition, 2014. 756 p.

Конфликт интересов: Авторы заявляют об отсутствии конфликта интересов
Conflict of interest: The authors declare that there is no conflict of interest

Вклад авторов: Все авторы в равной доле участвовали в написании статьи
Authors' Contribution: All authors contributed equally to the writing of the article