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Relationship between Laboratory Germination and Biometric Parameters of *Betula jarmolenkoana* Golosk. Aglets

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Abstract: This study evaluates the relationship between laboratory germination and biometric parameters of aglets of the critically endangered birch tree species *Betula jarmolenkoana* Golosk (Yarmolenko birch). The Yarmolenko birch is a very rare, narrowly endemic species, growing at an altitude of 1,900-2,100 m above sea level and only in the basins of three rivers (Kakpak, Bayynkol, and Tekes) in the Almaty region of Kazakhstan. Therefore, research is currently needed to increase the stability of birch forests and determine the optimal ways to preserve them. The study aimed to establish the nature of the relationship between laboratory germination and biometric parameters of birch aglets. To conduct surveys on the Yarmolenko birch forests, six sampling areas were selected, and five trees of close age (VI-VII age classes) were selected and marked in each sampling area. At the end of summer (August), after the seeds had reached physiological maturity (yellowing of the aglet core), 100 pieces of aglets were collected from trees at a height of 2.0 to 2.5 m and weighed on electronic scales. The data obtained were processed using methods of variational statistics, and the average values, coefficient of variability, and standard error of the average value were calculated. Student's t-test was used to compare features between the areas. The relationship between biometric parameters and seed germination was identified and statistically substantiated. According to three-year observations, in some areas of the forest, especially in areas with young and medium-aged plants, the morphometric parameters of aglets were not the same and did not repeat in different years. This was due to the weather conditions of the year of aglet formation and the growth and development of seeds.

Keywords: Yarmolenko Birch (*Betula jarmolenkoana* Golosk), Forest Growing Conditions, Sampling Areas, Soil, Laboratory Analysis, Seed Germination

Introduction

In Kazakhstan, covering an area of 2.7 million km^2, about 15% of the territory is mountainous landscapes (Bykov *et al*., 1987; Sehring, 2012; UNDP, 2022), representing a large reserve for agricultural, industrial, and recreational development.

Mountain forests of Kazakhstan, due to the variety of habitat conditions inherent in mountain landscapes, are distinguished by a large abundance of forest-forming species and a significant number of forest types. The nature of these forests has a wide ecological range and phytogeographic scope, from the Altai mountain taiga to the mountain savanna (rare-coniferous) pistachio trees and pear trees of the Southern Karatau. This territory hosts more than 30 forest-forming species, including seven coniferous species (Baizakov and Tilenov, 2013).

The mountain habitats are shelters (refugiums) where forests have preserved their characteristics and are the keepers of several relict and rare species. Mountain habitats are especially favorable for speciation processes, which is expressed in the polymorphism of several species, including tree species. As a result, many tree and shrub species and other components of mountain forests,

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such as spruce, apple, apricot, hawthorn, juniper, almond, etc. have acquired significant value as a gene pool.

Every year the role of the forest in soil protection, protection against mudslides, and especially water regulation in mountain ecosystems become more and more important. While the value of forests in soil protection and protection against mudslides is manifested in their locations, the hydrological role of forests is performed in the vast adjacent territory.

Along with the water-regulating role, which is performed by all forest plantations growing within the forest basins, located along the banks and in floodplains of rivers and streams, they perform an additional, very important protective and accumulative role. They protect the intertidal shores from destruction, accumulate sandy alluvium in floodplains and protect the steep slopes of valleys from erosion and landslides, thereby preventing the filling of erosion products and siltation of reservoirs, water basins, riverbeds, and channels. These forests also contribute to the transformation of surface runoff from the above-located treeless areas into intra-soil runoff (Bityukov, 2007; Pobedinskii, 2013).

One of the most important components of the mountain flora is the forests of the Yarmolenko birch (*Betula jarmolenkoana* Golosk.). The Yarmolenko birch (*Betula jarmolenkoana* Golosk.) is a representative of the birch family (*Betulaceae*), ecologically isolated in the conditions of the continental climate of the highlands, such as *Betula tianschanica* Rupr., *Betula turkestanica* Litv., *Betula alatavica* Musheg. and *Betula talassica* P. Pol., native to Kazakhstan. There are 15 wild and nine introduced birch species on the territory of Kazakhstan (Mushegyan, 1962). Several wild-growing species are rare and are listed in the red book (list of endangered species) of Kazakhstan. Among these species, is a very rare, narrowly endemic species called *Betula jarmolenkoana* Golosk. deserves special attention. It grows at an altitude of 1900-2100 m above sea level and only in the basins of three rivers (Kakpak, Bayynkol, Tekes) of the Almaty region, among shrubby thickets (Dzhangaliev *et al*., 2003; Eastwood *et al*., 2009).

Due to the proximity of its distribution area to populated areas, the Yarmolenko birch is negatively affected by anthropogenic factors, namely, the use of forests for recreational purposes, wood logging, and cattle grazing. Therefore, today, to solve these problems, there is a need to carry out research aimed at increasing the stability of birch forests and determining the optimal ways to preserve them.

The study aimed to establish the nature of the relationship between laboratory germination and biometric parameters of birch aglets. The study consists of five sections, namely the introduction, materials and methods, results, discussion, and conclusion.

Materials and Methods

The object of the study was the freshly harvested aglets and seeds of *Betula jarmolenkoana* Golosk. growing on the territory of the Narynkol forestry municipal state institution of the Almaty region (Fig. 1).

In the course of the study, maps of forest plantations of the municipal state institution were studied and routes were planned. The conditions for the plant growth were described based on the routes and the taxational characteristics of birch trees were observed. For this purpose, a total of six sampling areas were selected in the three conditional groups of forest types (sea buckthorn-sedge birch forest-trial plots No. 1 and 5, caragana-sedge birch forest-trial plots No. 2, 4, and 6, and juniper-caragana birch forest-trial plot No. 3). The following data were noted: The route number, its direction, the date of sampling area selection and its coordinates. There should have been at least 150 registered birch specimens in each sampling area. Besides that, we described the following in each sampling area: The forest type, geographical location, relief, surrounding area, and grass cover. The system of plant taxonomy was given according to the Engler system. Continuous recounts were carried out in the sampling areas and the height, diameter, and projective cover of the crown of each tree were measured.

For a complete understanding and description of forest conditions, a survey of soil horizons was carried out. The power of genetic horizons, humidity, color, structure, consistency, mechanical composition, presence of roots, effervescence from 10% HCl, inclusions, neoplasms, and transition to the next horizon was determined. In the most typical soil sections, soil samples weighing no more than 0.5 kg each were taken and analyzed to determine the chemical composition of the aqueous extract.

Based on the results of the analysis of water extraction, the degree and chemistry of soil salinity were established. Special attention was paid to soda, chloride, and sodium salinization. The mechanical composition, agro-hydrological properties of soils, and mobile nutrients in the soils of this region were determined by reference books. The degree of salinity of soils and the qualitative composition of soils were determined based on the analysis of the aqueous extract.

Soil conditions and hydrological regime were studied as follows: In the most typical places or typical soil groups, soil sections were made, morphological horizons of soils were described and soil samples were taken for laboratory analysis. According to the results of the morphological description of soil horizons and the chemical composition of soils, the composition and salinity of soils were determined and the highest moisture capacity of soils was described.

Fig. 1: Map-diagram of the location of the study; Note: Narynkol forestry municipal state institution, bayynkol forest district

Six sampling areas were chosen for surveys on the Yarmolenko birch forests. According to the descriptions of (Yablokov, 1962), five trees of close age (VI-VII age classes) of each sampling area were selected and marked. When studying the reproductive sphere of birch morphotypes, attention was paid to the parameters of female aglets, seeds, and nuts. At the end of summer (August), after the seeds had reached physiological maturity (yellowing of the aglet cores), at a height of 2.0 to 2.5 m on the west side of the numbered trees, 100 aglets were collected and their length, width, and weight were measured. Then the aglets were dried in a well-ventilated room for 2-3 days, placed in wooden boxes covered with paper, and left for storage at a temperature of 0-5°C (Vetchinnikova, 2004).

The mass of 1,000 seeds in different sampling areas was determined following State Standard 13056.4-67 (SSUSSR, 1968), while the laboratory germination of seeds was determined according to State Standard 13857-95 (SSR, 1996). Samples for germination were randomly selected from the total mass of collected seeds in the sampling areas. Seed germination was carried out using the apparatus and in the glass of Professor V.D. Ogievsky for seed germination in the light by 100 seeds for each sampling area in three-fold repetition. The technical and absolute germination and the germination energy were determined according to State Standard 13056-97 (SSR, 1998). The sprouted seeds were counted on the 5^{th}, 7^{th}, 10^{th}, and 15^{th} days. The laboratory seed germination was calculated as the arithmetic mean of the germination results and expressed as a percentage.

The obtained data were processed using methods of variational statistics (Eremina *et al*., 2002), and the average values, the coefficient of variability, and the standard error of the average value were calculated. To compare the characteristics of the aglets collected in different sampling areas, Student's t-test was used.

Results

The morphological description of soils is given according to the soil section which was laid on meadow-swamp soils. The data are presented in Table 1.

The results of laboratory analysis of the chemical composition of these soils are presented in Table 2.

Table 2 that these soils are slightly alkaline from the surface (pH-7.49) and medium alkaline in the 48-58 cm horizon (pH-8.21), not saline. The salt content of the dense residue is 0.165-0.259%.

When studying the generative sphere, attention should be paid to the female aglets of the silver birch, since the seeds necessary to obtain planting material are formed inside them. The length of the aglets varies in different areas of the birch from 17.452 to 26.462 mm and the variability of this parameter ranges from 6.51 to 10.36% (Table 3). The average data for different areas show that the maximum variability is observed in the second area (10.36%) and the minimum variability is observed in the fifth area (6.51%). According to the average data, the length of the fruiting birch aglets of the third area differs sharply from other forms.

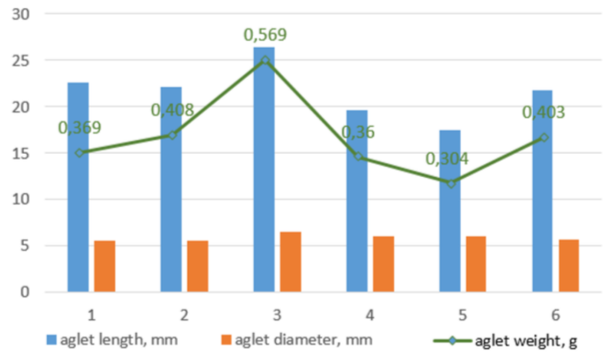

Fig. 2: Comparison of statistical size parameters of the *Betula jarmolenkoana* Golosk. Aglets

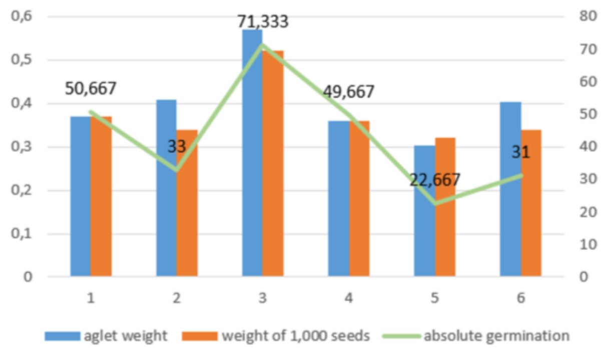

Fig. 3: Comparison of the dependence between the weight of aglets and seeds and germination in *Betula jarmolenkoana* Golosk

The thickness of the aglets in different areas ranges from 5.595 to 6.571 mm and the variability ranges from 5.22 to 11.89%. The average values of variability in the thickness of the aglets between areas 1-4 are close but areas 5 and 6 have the least variability. Thus, according to this parameter, the aglets collected from the third area are distinguished and the diamond-shaped-fractured one is close to the smooth-bark one, as its intermediate form.

According to the average values in different birch areas, the differences between all the areas are significant, which indicates the existence of genetically fixed features between birch areas in terms of the formation of fruiting aglets.

According to the average data of the areas (Fig. 2), it can be noted that the 3rd area is characterized by the highest values for all three parameters: The length of the aglets (26.462 mm) is 34.05% higher than that of the 5th area; the thickness of the aglets (6.571 mm) is 8.42% more than that of the 5th area and the weight of the aglets (0.569 g) is 46.6% higher than that of the 5th area. The biometric parameters of aglets in the second and sixth areas occupy an intermediate position and are close to each other in terms of the weight of the aglets (0.408, 0.403 g) and differ from the 5th area by 25.5 and 24.6%, respectively. The lowest biometric parameters were noted in the 5th area in terms of the length of the aglets (17.452 mm) and the weight of the aglets (0.304 g).

The laboratory study of seed germination (Table 4) shows that the seeds collected at the 3rd exceed the 5th and the 1st areas in all parameters. The mass of 1,000 seeds is 0.52 g, which is 30.8 and 28.8% more than in the 5th and 1st areas, respectively. Seeds collected in the 2nd and 6th areas are characterized by the same parameter values (0.34 and 0.34 g, respectively). The lightest seeds were found in the 5th area (0.032 g) and the heaviest ones in the 3rd area (0.52 g). Areas 1 and 4 are characterized by similar parameter values (0.37 and 0.36 g, respectively).

Figure 3 shows that the 3rd area is characterized by the highest values for all parameters with the absolute germination (71.333%) 68.2 and 29.0% higher than that of the 5th and 1st areas, respectively; germination energy (67.667%) equaling 69.5 and 32.5% higher than that of the 5th and 1st areas, respectively. Seeds collected in the 1st and 4th areas occupy an intermediate position in absolute germination (50.667 and 49.667%, respectively) and germination energy (45.667 and 44.667%, respectively), showing similar parameter values. The lowest values of absolute germination (22.667%) and germination energy (20.667%) were noted in the 5th area: 26.9 and 24.4% less than in the 6th area.

Table 1: Morphological description of soils

0-6 6 cm	Moist, brown and loose, mainly consisting of forest litter, permeated with plant roots, with no inclusions or new formations and a sharp transition
6-12 6 cm	Moist, gray, sandy, and gravelly with a large number of roots, no inclusions or new formations, and a sharp transition
12-47 35 cm	Moist, yellowish-gray with a straw-colored shade, loamy, dense, lumpy, and chunky, with no inclusions, new formations are marked as rusty spots of iron oxides
47-60 13 cm	Moist, light gray with a pale straw-colored shade, loamy, dense
60-68 8 cm	Moist, gray, sandy, and gravelly with a small number of roots, with no inclusions or new formations and a sharp transition
68-97 29 cm	High humidity, dark gray, with a mosaic straw-colored shade, loamy, dense, permeated with a small number of roots
97 cm and mor	Sand-gravel layer with a small number of roots, with no inclusions or new formations. Groundwater is present

Table 2: Results of laboratory analysis of water extraction of soils under Yarmolenko birch forest stands

		mg-eq per 100 g of soil and% to dry soil							
		HCO_3-		Cl^-		SO_4^{2-}		CO_3^{2-}	
Horizon, cm	pH	mg-eq per 100 g of soil	% to dry soil	mg-eq per 100 g of soil	% to dry soil	mg-eq per 100 g of soil	% to dry soil	mg-eq per 100 g of soil	% to dry soil
0-6	7.49	0.63	0.038	0.52	0.018	0.115	0.006	-	-
6-12	7.97	0.25	0.015	0.34	0.012	0.080	0.004	-	-
25-35	8.17	0.25	0.015	0.34	0.012	0.160	0.008	-	-
48-58	8.21	0.30	0.018	0.24	0.008	0.110	0.005	-	-
58-68	7.75	0.33	0.020	0.36	0.013	0.090	0.004	-	-
79-89	7.68	0.23	0.014	0.24	0.008	0.105	0.005	-	-

Table 3: Biometric parameters of *Betula jarmolenkoana* Golosk. Aglets

	Aglet length, mm		Aglet thickness, mm		Aglet weight, g	
Sampling area no.	$X \pm m_x$	Cv, %	$X \pm m_x$	Cv, %	$X \pm m_x$	Cv, %
1	22.629±0.228	10.10	5.595±0.058	10.37	0.369±0.007	19.47
2	22.113±0.324	10.36	5.623±0.084	10.58	0.408±0.013	23.05
3	26.462±0.350	9.91	6.571±0.098	11.21	0.569±0.013	17.45
4	19.680±0.225	8.10	6.054±0.102	11.89	0.360±0.010	20.74
5	17.452±0.161	6.51	6.018±0.044	5.22	0.304±0.005	11.90
6	21.760±0.318	10.84	5.716±0.065	8.49	0.403±0.011	20.46

Note: X-mean value; m_x-standard error of the mean value; Cv-coefficient of variation (%)

Table 4: Seed quality of *Betula jarmolenkoana* Golosk

Sampling area no.	Absolute germination, %	Germination energy, %	Weight of 1,000 seeds, g
1	50.667±0.981	45.667±0.720	0.37
2	33.000±1.247	32.667±2.373	0.34
3	71.333±0.272	67.667±0.272	0.52
4	49.667±1.186	44.667±1.089	0.36
5	22.667±1.655	20.667±1.515	0.32
6	31.000±0.816	27.333±0.720	0.34

Discussion

One of the important decisions in increasing the stability of forest stands is the study of the morphological and physiological state of aglets and the sowing quality of seeds. Many properties and features of trees (crown and trunk shape, growth dynamics, resistance to diseases and pests, etc.), are determined by heredity, reflected in the genetic code of seeds. Therefore, during artificial reforestation, the initial forest cultural material for obtaining high-priority birch plantations is seed material that ensures the cultivation of high-quality forest stands in the shortest possible time.

Thus, in our research, the biometric indicators of generative organs (length, width, and mass of catkins), the weight of 1,000 seeds, absolute germination, and germination energy were determined in laboratory conditions.

The juniper-caragana birch forest had better performance than the sea-buckthorn-sedge and caragana-sedge birch forests. I also had better indicators of the weight of 1,000 seeds (30.8%), absolute seed germination (68.2%), and germination energy 69.5.

The conducted studies allowed us to conclude that one of the factors that significantly worsens the germination of Yarmolenko birch seeds is the low biometric indicators of catkins and the weight of 1,000 seeds. However, the quality and size of birch seeds are more dependent on the weather conditions of the year of catkin formation and seed growth and development (Volova *et al*., 2020). Therefore, it is necessary to further study the influence of factors on the biometric indicators of the generative sphere of the Yarmolenko birch.

In our study, the forest stand consists of Yarmolenko birch. The trees are usually low, from 4-6 to 8-13 m in height, mostly with a curved trunk having a diameter of 12-38 cm. The diameter of some separate trees reaches up to 53 cm. The closeness of the upper tier does not exceed 0.5-0.6. Stunted trees stand 2-3 m apart. In the undergrowth there are 15 species of shrubs, among which there are especially many willows (*Salix caesia* Vill., *S. tenuijulis* Ledeb., *S. wilhel-msiana* M. V., *S. niedzwieckii* Gorz), honeysuckle (*Lonicera albertii* Rgl., *L. tatarica* L., *L. stenantha* Pojark., *L. hispida* Pall.), rosehip (*Rosa* *dscharkenti* Chrshan.), barberry (*Berberis heteropoda* Schrenk) karagana (*Caragana aurantiaca* Koehne), sea buckthorn (*Hippophae rhamnoides* L.), Myricaria (*Myricaria squamosa* Desv.) and juniper (*Juniperus sabina* L.) (Mushegyan, 1962; Goloskokov, 1972). The closeness of the undergrowth is 0.5 to 0.8. The grass cover is diverse. The soils are meadow-boggy; often with high (up to 40 cm) hummocks formed by various types of alpine sedges: Carex melanantha S. A. M., S. orbicularis Boott, S. philocrena V. Krecz., S. stenocarpa Turcz. ex Bess (Goloskokov, 1972).

One of the effective methods of growing highly productive and stable forest stands is the use of genetically valuable seeds harvested at permanent forest seed facilities. There are two main methods in the selection and varietal seed production of birch: The first is the selection of valuable forms in plantings and their intended use in industrial development and reforestation and the second one is the production of new varieties by modern breeding and genetic methods.

Considering these methods, birch breeding is effective for the two most important economic characteristics, namely, the speed of growth and the decorative value of the wood. For these purposes, seeds from elite and normal trees of valuable birch forms and appropriate agrotechnical techniques for growing their planting material are used. The main techniques are the following: A high level of preservation of seedlings, sorting of seedlings and young plants by the tree height and separate cultivation of fast-and slow-growing plants to reduce mutual competition between them, cultivating slow-growing seedlings in the transplant section to standard sizes to increase the yield in artificial stands of birch with a decorative wavy texture of wood, create target crops aimed at reproducing the valuable gene pool and improve the quality of the created plantings of the species.

Birch is resistant to adverse climatic conditions. It tolerates low temperatures and frosts well (Zobel and Singh, 1997). Another valuable property of birch, noted by many authors, is a relatively low requirement for soil fertility and moisture (Vetchinnikova, 2004). Due to its frost resistance and generally undemanding character to environmental conditions, birch forms forests in the forest-tundra subzone where other tree species can no longer grow (Kullman, 2001; Vetchinnikova, 2004). Kullman notes in his work that with the warming of the climate in the 20th century, the ranges of birch and coniferous species such as spruce and pine increase with the advance into the tundra zone (Kullman, 2001).

The most expedient kind of sowing is the summer sowing with freshly harvested seeds. The advantage of this sowing is that by the autumn of next year all seedlings will have reached standard sizes (up to 50 cm), while in autumn and spring crops by that time most of the seedlings would be left for another year to grow. The care of summer crops lasts for a year and a half and other varieties, it lasts for 2 years. For summer crops, seeds of fresh harvest are used, from which, as it is established, the most resilient plants grow. When using such crops, there is no need to store seeds and the work is carried out with more workforce available than in spring and autumn.

Conclusion

The study of morphometric parameters of the generative sphere and a laboratory study of the germination of birch seeds within different areas showed the following. According to the size and weight of the aglets and the weight of 1,000 seeds, there are fairly clear differences between the areas. In most cases, the birch trees from the 3rd area have the advantage in terms of the size of generative organs (aglets).

The laboratory study of seed germination showed that the juniper-caragana birch forest is characterized by the highest values for all parameters: The absolute germination there is 68.2 and 29.0% higher than that of the 5th and 1st areas, respectively; and the germination energy is 69.5 and 32.5% higher than that of the 5th and 1st areas, respectively. Seeds collected in the 1st and 4th areas occupy an intermediate position in absolute germination (50.667 and 49.667%, respectively) and germination energy (45.667 and 44.667%, respectively), showing similar parameter values. The lowest values of absolute germination (22.667%) and germination energy (20.667%) were noted in the 5th area: 26.9 and 24.4% less than in the 6th area.

However, the quality and biometric indicators of birch seeds are largely determined by the weather conditions of the year of the formation of aglets and the growth and development of seeds. The results of the study showed that when collecting seeds for growing high-quality and resistant to adverse factors planting materials from *Betula jarmolenkoana* Golosk. It is necessary to pay attention to the biometric parameters of aglets since aglets and seeds with high morphometric data showed the best germination.

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Author’s Contributions

All authors equally contributed to this study.

Ethics

This article is original and contains unpublished material. The corresponding author confirms that all of the other authors have read and approved the manuscript and that no ethical issues are involved.

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