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ОЙ СУДЛАЛ

Comparison of cone morphology, seed characteristics between natural and cultivated Scots pine /*Pinus sylvetris* L./ in Mongolia

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Abstract: The degradation of Mongolian forests, particularly Scots pine (*Pinus sylvestris* L.) stands, has raised urgent concerns for ecological stability and sustainable forest management. Seed quality is a decisive factor influencing afforestation success, yet little is known about how environmental and management conditions shape seed traits in natural versus cultivated populations. The aim of this study was to examine differences in seed characteristics of Scots pine (*Pinus sylvestris* L.) between natural forests in Dornod and Khentii provinces and cultivated stands at the Botanic Garden of the Mongolian Academy of Sciences in Ulaanbaatar, Eastern Khentii Mountains. Seeds exhibited significant variation in both size and coat color, the latter classified into three groups: black, brown, and light. Seed quality was assessed through 1000-seed weight, germination percentage, and germination rate. Results revealed substantial disparities among seed color groups. In natural populations, germination was highest in black seeds (83.7%), followed by brown (64.3%) and light-colored seeds (46.8%). In contrast, cultivated seeds displayed markedly lower germination: 37.1% in black, 8.6% in brown, and only 1% in light-colored seeds. Across all color groups, natural seeds outperformed cultivated seeds in germination capacity and vigor. However, 1000-seed weight was greater in the Botanic Garden samples, with black, brown, and light seeds averaging 7.2 g, 6.9 g, and 6.2 g, respectively, compared with lower weights in natural populations. These findings demonstrate that while cultivated seeds are heavier, natural forest seeds maintain superior physiological quality, emphasizing the ecological and genetic importance of natural seed sources for successful afforestation and reforestation programs in Mongolia.

Keywords: Cone shape, seed color, seed quality, seed germination, germination rate

Introduction

Mongolia's forests are located in a unique geographical zone, extending across a wide strip of approximately 1,800 km between 88°–120° east longitude. They occupy a transitional area between Eastern Siberia and the steppes and deserts of Central Asia, situated deep inland and far from the moderating influence of oceans (Dugarjav, 2006). As of 2020, the total forested area of Mongolia was estimated at 18.6 million hectares, representing 11.8% of the country's territory (Dashzeveg et al., 2011).

These forests are of immense ecological significance: they contribute to water resource formation, prevent soil erosion, preserve biodiversity, and regulate climatic balance. In addition, they play a vital role in supporting economic activities and social development. However, in recent decades, Mongolian forests have been severely degraded due to multiple factors, including overexploitation, wildfires, pest and disease outbreaks, unsustainable grazing practices, and poor management. According to a World Bank study (2002), Mongolia lost approximately 1.6 million hectares of forest between 1990 and 2000.

In response, the Government of Mongolia, led by the President, has launched the "Billion Trees" national movement, under which both government and private sector actors have intensified efforts to establish nurseries, expand reforestation, and implement forest restoration initiatives. Scots pine (*Pinus sylvestris* L.) accounts for 4.9% of the country's total forest cover (Dashzeveg et al., 2011). This species is particularly significant for its ecological functions in soil and water cycles, as well as for its economic value in timber production, construction, and pulp and paper industries (Tsedendash, 1993).

Despite the recent intensification of Scots pine plantations, challenges remain. Survival rates are low, growth is slow, and adaptation to local climatic and soil conditions is often poor. These problems are largely linked to seed quality, the origin of planting stock, and inadequate rehabilitation techniques. Successful forest restoration depends on various factors, including soil conditions, climate, species traits, and the genetic quality of seeds (Li W et al., 2011). In rural areas, the lack of specialized laboratories and equipment for seed quality assessment further reduces the effectiveness of plantation efforts.

Because the cone and seed are the primary reproductive organs of Scots pine, their morphology and physiological quality directly determine regeneration success. Cone traits such as size, scale number, and shape are closely related to seed development and potential productivity, while seed characteristics—length, width, weight, and color—are reliable indicators of maturity, viability, and adaptation potential. Understanding the variability of these traits across natural and cultivated populations is therefore critical for identifying superior seed sources, ensuring genetic diversity, and improving the efficiency of afforestation programs. Moreover, in a country such as Mongolia, where extreme climatic fluctuations strongly influence seed survival, systematic evaluation of cone and seed parameters provides essential insights into the ecological resilience and long-term sustainability of Scots pine forests.

Thus, it is essential to develop cost-effective, practical methods for assessing seed quality and to apply scientific criteria in the selection of seed trees. Key selection indicators include seed maturation time, morphological traits, thousand-seed weight, and overall productivity (Titov, 2007; Deneko, 2012). Deneko (2012) reported that the reproductive capacity of cultivated trees, as measured by cone production over 10–12 years and seed yield from trees up to 25 meters tall, fell short of the standards observed in natural forest populations. However, a study on Scots pine in Mongolia revealed significant variation in cone and seed traits—such as cone size and shape, number of scales, seed count per cone, and seed weight—among trees growing in the Khentii Mountains (Udval et al., 2013). These characteristics, shaped by both genetic and ecological factors, are critical for evaluating seed quality and identifying superior trees. The study highlighted the potential for establishing permanent seed collection stands in natural forests, developing seed plantations, and identifying genetically heterogeneous genotypes for future use.

Against this backdrop, the present research aims to compare the morphological and physiological characteristics of cones and seeds from Scots pine populations in the Khentii Mountains and the Botanic Garden of Ulaanbaatar. Specifically, the study will assess and compare morphometric parameters (cone length, width, shape index, and number of scales) and seed traits (germination rate, growth performance, thousand-seed weight, and color). By expanding such research, it will be possible to develop plantation strategies for Scots pine that are well adapted to Mongolian environmental conditions, while simultaneously enhancing ecological resilience, economic value, and local livelihoods.

Research sample, Methodology, and Data processing

Study Area. The natural samples were collected from Bayan-Uul soum of Dornod Province and Bayan-Adarga soum of Khentii Province, while the cultivated sample was obtained from the Botanic Garden of Ulaanbaatar (Figure 1; Table 1). Tree characteristics in natural forests were recorded following the forest inventory method of Anuchin (1982), which includes parameters such as tree density, height, and diameter at breast height (DBH), and the methodology of Jamyansuren (1988). Representative plots were established at each site to ensure systematic sampling and data collection.

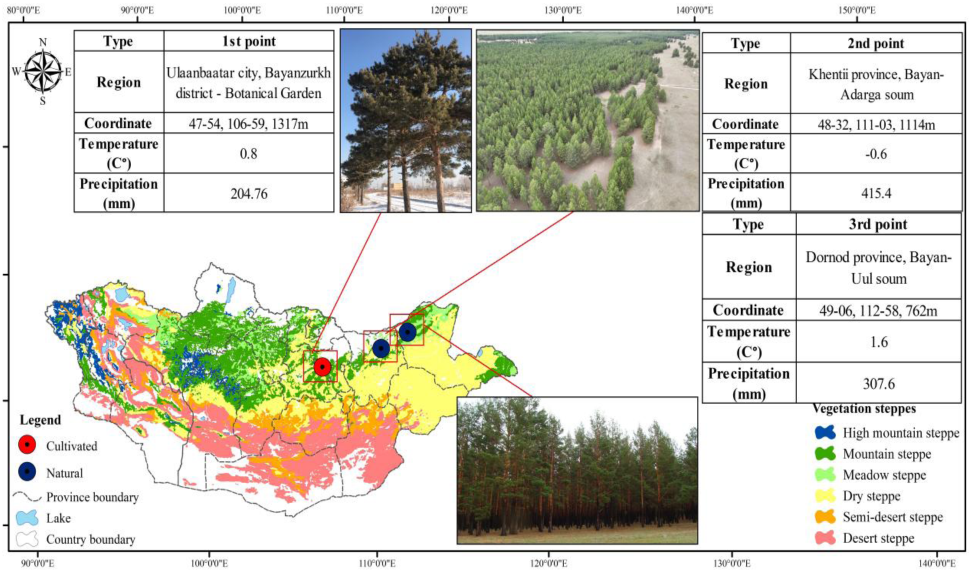

Figure 1. Map showing the geographic locations of the survey sites and key characteristics of the study areas.

Table 1. Characteristics and details of the study sites where samples were collected.

№	Sites	Age (years)	Tree height (m)	DBH (cm)
1	***Dornod province**, **Bayan-Uul soum**, **Narsan bulag***	86	15.8±2.3	26.4±2.7
2	***Khentii province, Bayan-Adarga soum**, **Duurlig nars***	79	12.9±1.9	19.8±3.9
3	***Ulaanbaatar city, Botanic Garden***	76	11.6±1.2	19.6±3.8

Sample Collection and Climatic Conditions. Natural cone samples were collected in February 2023, while cultivated Scots pine samples were collected in February 2025 from trees transplanted to the Botanic Garden of the Mongolian Academy of Sciences from Shaamar soum, Selenge Province, in 1976. All research samples were stored in the Gene Bank of Natural Plant Seeds at the Botanic Garden and Research Institute of the Mongolian Academy of Sciences, under controlled conditions of 3.5 °C and approximately 45% relative humidity (Temuujin., 2020).

The average annual air temperature and total precipitation at the natural sampling sites were 1.6 °C and 307.6 mm in Dornod Province, −0.6 °C and 415.4 mm in Khentii Province, and 0.8 °C and 204.8 mm in Ulaanbaatar (Botanic Garden). In all three regions, temperature and precipitation increase steadily from April to September and decrease during the colder months. This seasonal pattern indicates that the combined peak of heat and moisture during summer defines the active vegetation growth period. Precipitation reaches its maximum in July in Bayan-Adarga, with 45 mm and an average temperature of 20 °C. In Bayan-Uul, the highest precipitation occurs between June and August, whereas in Ulaanbaatar, the highest temperature is observed in July, with peak precipitation of around 50 mm occurring in August (Figure 2).

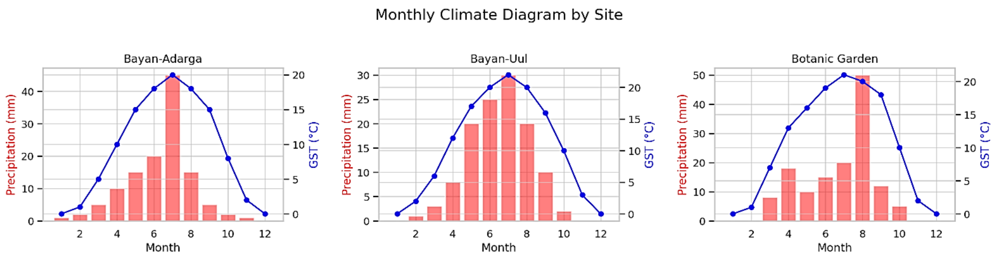

Figure 2. Climatic diagrams (ombrothermic diagrams) of the study sites.

Cone Measurements. From each site, 100 cones were collected from trees of comparable age, height, and DBH. Cone length (mm), width (mm), and number of scales were recorded prior to cone dehiscence. The cone shape index was calculated as the ratio of length to width (Pravdin, 1964). According to Pravdin's classification, cones are categorized as long-shaped (index 2.5–3.0), long and thick-shaped (2.0–2.5), egg-shaped (1.5–2.0), or round-shaped (1.0–1.5).

In the laboratory, cone length (measured as the distance between the two ends) and width (measured at the widest point) were determined using digital calipers with an accuracy of 0.001 mm (Table 3). Cones were dried at 200 °C for 10 days until natural dehiscence occurred (Figure 3).

Seed Measurements. Seed morphometric and quality assessments were conducted following the methodologies of Bat-Erdene (1995) and Odgerel (2001). Seeds collected from each study site were categorized into three color groups—black, brown, and light—and a total of 300 seeds were measured (Figure 4). Seed color was determined immediately after extraction by visual inspection, with representative photographs provided (Figure 5). Morphological parameters, including seed length (mm) and width (mm), were measured using an AmScope binocular microscope equipped with an MU1803 camera and AmScope Imaging 3.0 software (Temujin, 2020). Seed length was defined as the distance between the two ends of the seed, while seed width was recorded at the widest point.

Seed Sterilization. Seeds were surface-sterilized by immersion in 70% ethanol for 30 seconds, followed by 2.5% sodium hypochlorite (NaOCl) for 6 minutes. They were then rinsed 3–5 times with distilled water and incubated in Petri dishes under controlled conditions (25 ± 2 °C) in a culture room to evaluate germination and germination rate.

Statistical Analysis. Data analyses were performed in R (v.4.4.0; R Core Team, 2025). Differences among regions were assessed using one-way ANOVA, followed by Tukey's HSD post-hoc tests. Pearson correlation analysis was applied to evaluate relationships among seed parameters, and graphical outputs were generated using RStudio.

Results

Results of Cone Measurements. Based on Pravdin's cone index classification, the majority of cone samples were egg-shaped: 67% in Bayan-Uul, 71% in Bayan-Adarga, and 73% in the Botanic Garden. Thick-shaped cones accounted for 28.3% of the total across all sites, while round-shaped cones were rare, occurring only in Bayan-Adarga (3%) and the Botanic Garden (1%) (Table 2).

Table 2. Cone shape classification according to Pravdin (1964) (n = 300).

№	**Sites**	**Cone shape**				
	long-shaped		**thick-shaped**	**egg-shaped**	**round-shaped**	**Total**
1	*Dornod province*, *Bayan-Uul soum*, *Narsan bulag*	0	30	67	3	100
2	*Khentii province, Bayan-Adarga soum*, *Duurlig nars*	0	29	71	0	100
3	*Ulaanbaatar city, Botanic Garden*	0	26	73	1	100
F value		0	85	211	4	300

Cone Size Variation. The cones of *P. sylvestris* exhibited considerable variation in size. Cone length ranged from 43.1 to 49.4 mm, cone width from 22.0 to 25.1 mm, and the number of scales from 61.4 to 72.1 (Table 3). Cone length ranged from 43.1 ± 3.1 mm in Bayan-Uul to 49.4 ± 4.2 mm in the Botanic Garden, indicating that cultivated pines tend to produce longer cones compared with their natural counterparts. Conversely, cone width was greatest in Bayan-Adarga (25.1 ± 2.4 mm) and narrowest in the Botanic Garden (22.0 ± 1.1 mm), suggesting differences in cone morphology related to growth environment. The number of seeds per cone was highest in Bayan-Adarga (73.4 ± 8.1) and lower in Bayan-Uul (67.3 ± 2.3) and the Botanic Garden (68.6 ± 6.1). Similarly, the number of scales was greater in cones from Bayan-Adarga (71.2 ± 4.8) and the Botanic Garden (72.1 ± 6.3) than in Bayan-Uul (61.4 ± 5.6).

The calculated cone index values (1.7–1.8) confirmed that cones across all three sites fall into the egg-shaped category, though their size and proportion varied. These differences likely reflect both ecological conditions and management history: cones from natural forests were shorter but relatively broader, while cones from cultivated trees were longer and narrower. Such patterns may be linked to differences in soil fertility, moisture availability, and competition intensity between plantation and natural environments.

Table 3. Morphometric characteristics of P. sylvestris cones, n=300

№	Sites	Cone length mm	Cone width mm	Number of seed per cone	Number of scales	Cone index	Cone shape
1	*Dornod province, Bayan-Uul soum, Narsan bulag*	43.1±***3.1***	23.6±***1.9***	67.3±***2.3***	61.4±***5.6***	1.7	Egg-shaped
2	*Khentii province, Bayan-Adarga soum, Duurlig nars*	46.3±***2.9***	25.1±***2.4***	73.4±***8.1***	71.2±***4.8***	1.8	Egg-shaped
3	*Ulaanbaatar city, Botanic Garden*	49.4±***4.2***	22.0±***1.1***	68.6±***6.1***	72.1±***6.3***	1.8	Egg-shaped

Results of Seed Measurements. Scots pine seeds collected from the three study locations were classified by color and evaluated for germination, germination rate, 1000-seed weight, and seed morphometric parameters. Comparative results are presented in Table 4. Across all sites, black seeds showed the highest germination and germination rate, confirming their status as the most viable and mature seed group. In Bayan-Adarga, germination reached 83.7% with a 69.1% germination rate, while in Bayan-Uul these values were slightly lower (79.6% and 71.3%, respectively). By contrast, the Botanic Garden showed much lower germination for black seeds (37.2% and 32%), highlighting the negative impact of cultivation conditions on seed viability. Brown seeds exhibited intermediate germination values (64.3%–71.1% in natural sites), but again showed very low performance in the Botanic Garden (8.6% germination, 4% germination rate). Light-colored seeds were consistently the poorest performers, with germination below 50% in natural sites (46.8% in Bayan-Adarga; 49.7% in Bayan-Uul) and negligible values in the Botanic Garden (1% germination, 0% germination rate).

1000-Seed weight. Seeds from the Botanic Garden were consistently heavier than those from natural forests, regardless of color group. Black seeds had the highest weight (7.21 g), followed by brown (6.9 g) and light (6.2 g). In natural sites, weights were lower (5.8–6.9 g), indicating that although natural seeds are lighter, they maintain higher viability compared to cultivated seeds. This suggests that seed weight alone is not a sufficient predictor of germination success.

Morphometric Parameters (Length and Width). Seed length was relatively consistent across sites, ranging from 4.2 to 4.9 mm. Black seeds were generally the longest, particularly in the Botanic Garden (4.9 mm). Seed width showed less variation, averaging 2.3–2.9 mm. Again, black seeds were slightly wider (up to 2.9 mm in the Botanic Garden), while light-colored seeds were narrowest (2.3–2.4 mm). The relatively small differences in seed length and width suggest that color and physiological maturity, rather than size alone, are stronger determinants of germination success (Table 4).

Table 4. Seed characteristics of Pinus sylvestris from different study sites.

№	Seed color groups	Sites	Germination %	Germination rate %	1000 seed weight gr	Seed morphometric	
						Seed length mm	Seed width mm
1	Black	*Bayan-Adarga*	*83.7*	*69.1*	*6.9*	*4.6±0.4*	*2.8±0.2*
		Bayan-Uul	*79.6*	*71.3*	*6.9*	*4.7±0.6*	*2.7±0.2*
		Botanic Garden	*37.2*	*32*	*7.21*	*4.9±0.6*	*2.9±0.3*
2	Brown	*Bayan-Adarga*	*64.3*	*64.8*	*6.4*	*4.6±0.4*	*2.7±0.2*
		Bayan-Uul	*71.1*	*62.2*	*6.1*	*4.5±0.4*	*2.6±0.2*
		Botanic Garden	*8.6*	*4*	*6.9*	*4.6±0.3*	*2.5±0.1*
3	Light	*Bayan-Adarga*	*46.8*	*33.1*	*5.8*	*4.2±0.1*	*2.3±0.2*
		Bayan-Uul	*49.7*	*42.3*	*5.9*	*4.2±0.1*	*2.3±0.1*
		Botanic Garden	*1*	*0*	*6.2*	*4.2±0.1*	*2.4±0.1*

Statistical Comparison of Seed Dimensions. Results of the Tukey HSD test indicated no significant difference in seed length between the Bayan-Uul and Bayan-Adarga groups ($p > 0.05$). However, seed length in the Botanical Garden sample did not differ significantly from either of the two natural populations (Figure 4). In contrast, significant differences were observed in seed width: the Botanical Garden and Bayan-Uul samples differed statistically, while Bayan-Adarga exhibited intermediate values, showing partial similarity to both groups (Figure 3).

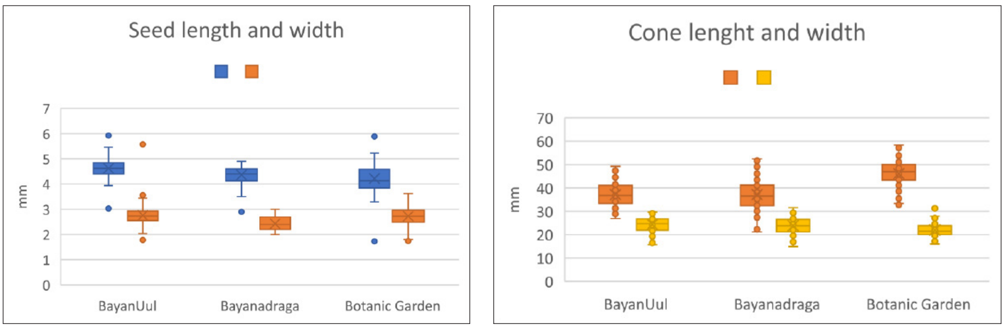

Figure 3. Comparison of seed length among study sites.

Seed Color and Germination. Across all study sites, seed coat color was strongly associated with germination performance and seed quality. Black seeds consistently demonstrated the highest values, with germination reaching up to 83.7% and germination rate 71.3% in natural populations. They also exhibited superior seed size and 1000-seed weight, confirming their maturity and physiological vigor. These findings indicate that black seeds represent the fully matured group, with well-developed embryos and sufficient nutrient reserves to support early seedling growth. Brown seeds showed intermediate performance across sites, with germination ranging from 62.2% to 71.1% in natural forests. Although these values are lower than those of black seeds, they still suggest relatively good viability. Brown seeds may represent a transitional stage of maturation, with partially developed nutrient reserves and somewhat reduced germination vigor compared to black seeds. Light-colored seeds performed poorest in all parameters. Germination percentages were less than 50% in natural forests (46.8% in Bayan-Adarga and 49.7% in Bayan-Uul) and nearly absent in the Botanic Garden (1% germination, 0% germination rate). Their small size, reduced weight, and pale coat color suggest incomplete maturation, underdeveloped embryos, or a lack of stored nutrients.

As a result, these seeds showed very weak viability and survival potential. When comparing natural and cultivated populations, natural forest seeds outperformed Botanic Garden seeds in germination across all color groups. For example, germination of black seeds was more than twice as high in natural populations (83.7%) compared with cultivated populations (37.2%). This demonstrates that although cultivated seeds tend to be heavier, their physiological quality is poor, possibly due to environmental stress, artificial growing conditions, or limited genetic variability. Overall, the data confirm that seed coat color is a reliable and simple morphological marker of seed quality. Black seeds indicate full maturity, high nutrient content, and strong viability, while light-colored seeds are immature and of low quality. This relationship underscores the practical value of using seed color in seed selection protocols for afforestation and reforestation programs in Mongolia, where cost-effective and rapid indicators of seed viability are urgently needed (Figure 4).

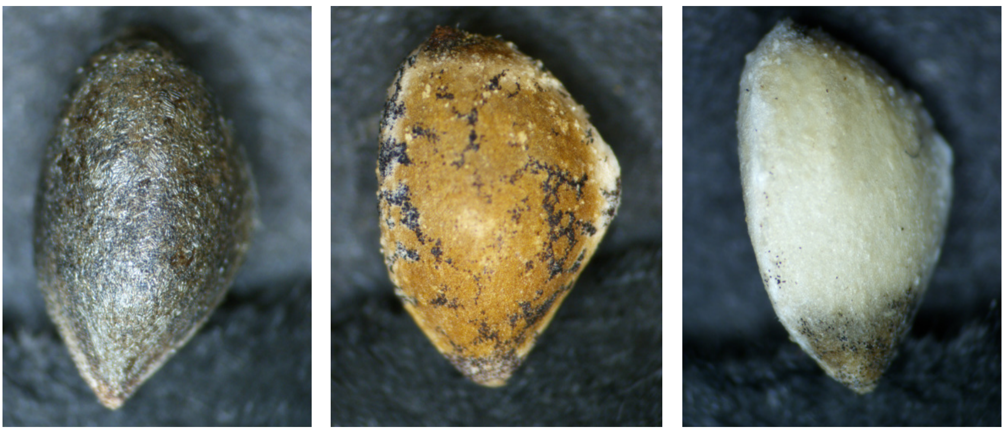

Figure 4. Differences in seed quality among color groups of Pinus sylvestris.

Seed Color Groups and Embryo Development. When comparing Pinus sylvestris seeds by color group, black seeds consistently exhibited the largest embryo area, which is directly associated with higher nutrient storage and developmental maturity. These seeds also achieved the highest germination rates, confirming that they possess the strongest physiological potential. Because the germination rate is a fundamental indicator of seed viability and seedling survival, it serves as a critical criterion for evaluating overall seed quality and for predicting the success of afforestation programs. By contrast, brown seeds showed smaller embryo areas and moderate germination rates, suggesting partial maturation and reduced energy reserves, while light-colored seeds exhibited the smallest embryo development and almost negligible germination. This clear gradient across seed color groups reinforces the conclusion that embryo size and development, reflected in coat color, are reliable predictors of seed quality (Table 4; Figure 5). These findings emphasize that simple morphological markers such as seed coat color and embryo area can be used as cost-effective and practical tools for rapid seed quality assessment, particularly in regions like Mongolia where laboratory resources are limited.

Black Brown Light

Figure 5. Differences in embryo development among seed color groups of Pinus sylvestris.

Seed Germination and Seedling Vigor.

Figure 6 illustrates the germination percentage and subsequent seedling vigor of Pinus sylvestris seeds collected from three sites: Bayan-Uul (“Narsan bulag”), Bayan-Adarga (“Duurlig narts”), and the cultivated population at the Botanic Garden of Ulaanbaatar. The results clearly demonstrate that seeds from natural forest stands outperformed those from the cultivated site in both parameters.

In terms of germination, seeds from Bayan-Adarga exhibited the highest success (75%), followed by Bayan-Uul (65%), while the Botanic Garden seeds showed markedly lower germination (45%). A similar trend was observed for seedling vigor, with Bayan-Adarga again showing the highest value (65%), Bayan-Uul slightly lower (58%), and the Botanic Garden the lowest (35%). These findings indicate that seeds originating from natural forests are both more viable and more vigorous than those collected from cultivated stands.

The photographs of Petri dishes further support these quantitative results, showing dense and healthy germination in seeds from natural populations compared to weaker and more sporadic germination in seeds from the Botanic Garden. The contrast underscores the influence of growing conditions and genetic diversity: natural populations, shaped by environmental pressures and broader genetic variation, produce seeds with greater developmental potential, whereas cultivated trees, despite producing heavier seeds, appear to generate seed lots with reduced viability and vigor (Figure 6).

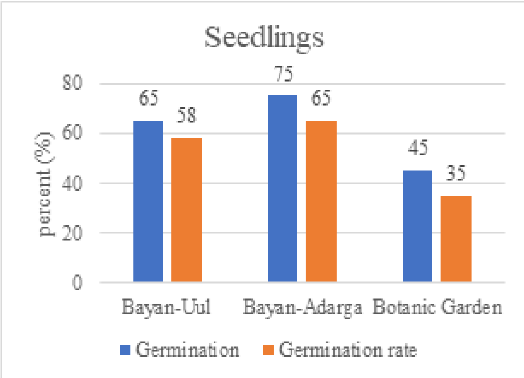

Figure 6. Comparison of germination percentage and germination rate among Scots pine seed samples.

Discussion

Comparison of cone morphometric parameters and seed dimensions across the three study sites revealed that cultivated Scots pine trees in the Botanic Garden differed significantly from the natural populations of Bayan-Adarga and Bayan-Uul soums. In particular, the mean seed width in the Botanic Garden was higher, and the Tukey HSD test indicated a statistically significant difference ($p < 0.05$). This suggests that seeds from the Botanic Garden trees were more fully matured, with relatively greater nutrient accumulation.

Cone length did not differ significantly between the two natural sites (Bayan-Adarga and Bayan-Uul). While some cone and seed parameters of the Botanic Garden trees were similar to those of the natural populations, they did not completely overlap. This difference is likely attributable to the more stable growing conditions in the plantation, including irrigation, soil fertility, and reduced competition. Previous studies similarly reported that plantation-grown trees tend to produce cones that are more uniform, lighter in structure, and characterized by improved seed maturation (Li et al., 2011; Bilir et al., 2007).

By contrast, seeds from natural forest trees exhibited greater variability in morphometric traits, reflecting the influence of tree age, physiological condition, and environmental stress. For example, Bayan-Adarga seeds displayed the smallest mean width, though their length was comparable to those from Bayan-Uul, suggesting a shorter seed maturation period and potentially greater sensitivity to climatic variability. Differences between plantation and natural stands may therefore be explained not only by environmental influences but also by genetic diversity of parent trees, pollen sources, soil conditions, and variation in water and heat availability (Gonçalves, 2023; Udval et al., 2013). Overall, seeds from plantation-grown trees appear to be more uniform and of higher quality than those from natural forests.

Seed color proved to be an important morphological characteristic associated with maturity, nutrient reserves, and viability. Numerous studies have documented correlations between seed color, germination, and survival (Ahmet et al., 2009; Gonçalves, 2023). In this study, black seeds exhibited the highest germination

(83.7%) and germination rate (69.1%) across all sites, indicating full maturity and strong physiological viability. In contrast, brown and light-colored seeds showed reduced germination, with light-colored seeds from the Botanic Garden exhibiting only 1% germination and no subsequent growth, confirming that color differences provide a reliable indicator of seed quality.

These findings are consistent with Gonçalves (2023), who reported that fully mature pine seeds are typically dark brown, with well-developed seed coats and high nutrient reserves. Burczyk (1997) also emphasized that seed color reflects the physiological stage of seed development in pine forests, while Udval et al. (2013) demonstrated that dark seeds in Mongolian Scots pine populations had higher germination rates than light-colored seeds.

Taken together, these results highlight seed color as a simple, reliable, and cost-effective indicator of seed viability and early growth potential. Incorporating seed color into seed selection protocols could therefore improve afforestation success and enhance the efficiency of large-scale reforestation programs in Mongolia.

Conclusion

This study shows that cone and seed traits of Pinus sylvestris differ systematically between natural stands (Bayan-Adarga, Bayan-Uul) and the cultivated stand at the Ulaanbaatar Botanic Garden. Natural seeds achieved consistently higher germination and vigor, whereas cultivated seeds were heavier but less viable; cone dimensions also varied among sites. These outcome patterns reflect interacting biological and environmental drivers. First, the cultivated stand likely represents a narrower pollen pool and reduced genetic diversity compared with the naturally outcrossing forest populations, which can depress seed vigor despite producing morphologically large seeds. Second, management and site conditions in the plantation—stable irrigation, higher soil fertility, and lower competition—favor longer cones and heavier seeds but can also promote thicker seed coats or incomplete physiological maturation under episodic stress, lowering germination. Third, natural stands are exposed to stronger environmental filtering, so fully mature, dark-colored seeds with well-developed embryos are disproportionately represented, which explains their superior germination metrics. Finally, local climatic regimes constrain the seed-development window differently across sites, reinforcing the observed contrasts in seed size and performance. Together, these mechanisms explain why heavier, more uniform seeds from the plantation performed worse physiologically than lighter but better-matured seeds from natural forests. Practically, seed-color screening (favoring dark/black lots), routine germination testing, and the use of genetically diverse natural seed sources—supplemented by improved plantation management to mitigate stress—should raise afforestation success and long-term stand resilience in Mongolia.

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Хэнтийн нурууны байгалийн болон тарималжуулсан нарс /Pinus sylvestris L./-ны боргоцойн морфологи, үрийн шинж чанарын харьцуулсан судалгаа

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Хураангуй: Энэхүү судалгааны зорилго нь Зүүн Хэнтийн нуруунд хамаарах Дорнод, Хэнтий аймгийн байгалийн нарсан ой болон Улаанбаатар хотод байрлах ШУА-ийн Ботаникийн цэцэрлэгт тарималжуулж буй нарс модны үрийн шинж чанарын ялгааг тодорхойлоход оршино. Эгэл нарсны үр нь хэмжээ болон өнгөөрөө ялгаатай байв. Үрийн чанарыг шалгахдаа үрийн бүрхүүлийн өнгөөр хар, бор, цайвар гэсэн үндсэн гурван бүлэгт хуваав. Үрийн чанарыг 1000 үрийн жин, соёололтын хувь болон соёололтын эрчмээр тодорхойлсон. Судалгааны үр дүнд үрийн бүрхүүлийн өнгө хооронд үрийн чанар ихээхэн ялгаатай байгааг харуулсан. Хар үрийн соёололт хамгийн өндөр буюу 83.7%, бор үрийх 64.3% бол цайвар үр 46.8% байсан ба тарималжуулж буй модны хар үр 37.1%, бор үр 8.6% бол цайвар үр 1%-тай байсан. Байгалийн үр нь тарималжуулж буй моднoос соёололт болон ургах эрчмээр өндөр байсан. Гэвч 1000 үрийн жингээр Ботаникийн цэцэрлэгийн хар үр 7.2 гр, бор үр 6.9 гр, цайвар үр 6.2 гр байсан нь байгалийн үрээс илүү байна.

Түлхүүр үгс: Боргоцойн хэлбэр, үрийн өнгө, үрийн чанар, соёололт, ургах эрчим

Эшлэл авахдаа: Бямбаагийн Тэмүүжин[1,2], Энхбатын Түвшинсанаа[1], Баясгаланхүүгийн Лянхуа[1], Төмөрбаатарын Ариунбаатар[1]. Хэнтийн нурууны байгалийн болон тарималжуулсан нарс /*Pinus sylvestris* L./-ны боргоцойн морфологи, үрийн шинж чанарын харьцуулсан судалгаа. Монголын ботаникийн сэтгүүл, 07(33): 115-129.