

Data Descriptor

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Data Descriptor

The VIS-Spectrometric Data of Scots Pine Individual Seed Reveal Forecasting Potential for Container-Grown Germination and Seedling's Dickson Quality Index

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Abstract: To follow the growth and development of each tree (N = 1200) *Pinus sylvestris* L., var. Negorelskaya starting from the seed and continuing at the juvenile (or even generative) stage is the goal of an ambitious project to create a plant passport if possible. Five datasets of replenished empirical (tabular and file) and systematic data reflect the early results of a unique ongoing experiment conducted with families moved along a climatic gradient from the collection area (1731 degree days, 722 mm) to the experimental area (2326 degree days; 786 mm). Datasets of morphometric, VIS-spectrometric, and germination seed data, combined with the first results of biometric data (including the Dickson quality index) of seedlings produced from these seeds, will allow scientists in the future to conduct correlation and other statistical analysis, or train a neural network to determine the presence of connections between a seed and a plant. These data contribute to the early non-destructive diagnosis and grading of seeds according to VIS-spectrometric properties. This dataset structure can complement the FLR-Library. In the future, by tracing seedlings in their early growth (for example, over three growing seasons at the site being restored), it will be possible to determine the degree of intensification of FRM production depending on the initial properties of the seed.

Datasets: 1. Morphometric data of individual seeds (N = 1200) of the Negorelskaya variety *Pinus sylvestris* L. (empirical dataset) DOI: 10.17632/8g258nbgmf.1.; 2. VIS-Spectrometric data of individual seeds (N = 1200) of the Negorelskaya variety *Pinus sylvestris* L. (empirical dataset). DOI: 10.17632/dt78jhyw2j.1; 3. Germination data of individual seeds (N = 1200) of the Negorelskaya variety *Pinus sylvestris* L. (empirical dataset). DOI: 10.17632/hrs3fgc8tt.1.; 4. Biometric data (include DQI) of individual seedlings produced from seeds of the Negorelskaya variety *Pinus sylvestris* L. (empirical refilled dataset). DOI: 10.17632/9kyz2gmrj.1.; 5. Systematic data on trends in the scientific landscape in the field of studying the spectrometric properties of seeds (reference refilled dataset). DOI: 10.17632/mrnc48tfx.1

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Keywords: *Pinus sylvestris* L.; Scots pine; seed spectrometric feature; individual seed; container-growm germination; RGB color space; L*a*b* color space; seed size; individual seed mass; Dickson quality index (DQI); forest landscape restoration (FLR)

1. Summary

The library of forest reproductive material (FRM-Library) [1], based on Pravdin's conjecture [2,3], is expanding and filling with data on individual parameters and indicators of each single seed of Scots pine (*Pinus sylvestris* L., var. Negorelskaya) and the seedlings obtained from it.

New dataset blocks will be included in the FRM-Library here (**Figure A1, Appendix A**):

- Seed morphometric block (from Dataset 1: Morphometric data of individual seeds (N = 1200) of the Negorelskaya variety *Pinus sylvestris* L. (empirical dataset). The tabular dataset represents

the results of direct measurements of the geo-metric dimensions (length, width and thickness in mm) and mass in grams of each individual seed, as well as calculated values of the projection area and volume of the described ellipsoid based on these parameters. The dataset allows for correlation and regression analyses between geometric parameters and individual seed weight, and can also be linked to other datasets in the FLR Library [2] to form summary queries

- seed VIS-spectrometric block (from Dataset 2: VIS-Spectrometric data of individual seeds (N = 1200) of the Negorelskaya variety *Pinus sylvestris* L. (empirical dataset).
- The file dataset represents the results of direct scanning by a charge-coupled device of 30 seed groups (the number of seeds in group n = 40 and their location on the scanner glass coincides with their future location in a side-slit container during sowing), in the RGB color space of the visible (VIS) spectrum with a resolution of 300, 600 and 1 200 dpi. The dataset can allow scientists to use the [Particle Analysis] add-in of the Fiji open source software to segment the image of an individual seed (for example, as in Bernardes et al. (2022) [4] or A. Loddo et al. (2023) [5]) and obtain quantitative data of two projections of a single seed in integrated RGB-, L*a*b*-, HSV-spaces or separate channels of the visible region of the spectrum. The dataset can also be linked to other datasets in the ADC Library [2] to form summary queries and study the effect of VIS-spectrometric seed parameters on germination and early growth;
- seed germination block (from Dataset 3: Germination data of individual seeds (N = 1200) of the Negorelskaya variety *Pinus sylvestris* L. (empirical dataset). The tabular dataset includes the results of container-grown germination studies of each of the 1200 seeds on the 30th and 50th days in 120 cm³ cells of 40-cell side-slit containers filled with peat substrate and mulched with perlite. The dataset allows for correlation and regression analyses of the effect of individual seed parameters on the indicator of seed sowing qualities, and can also be linked to other datasets in the FLR Library [2] to generate summary queries to predict the effect, for example, geometric parameters on 50-day container germination
- seedling growth block (from Dataset 4: Biometric data (include DQI) of individual seedlings produced from seeds of the Negorelskaya variety *Pinus sylvestris* L. (empirical refilled dataset). The tabular dataset includes the results of direct measurements of biometric parameters (height and diameter of the root neck) and bio-mass parameters of the underground and aboveground parts of the plant in the wet and dried state of container-grown seedlings obtained from these seeds. Also, based on the calculation of known ratios (for example, HDR – Height Diameter Ratio) between these parameters, the dataset presents integral indicators of the Dickson quality index DQI [6], the compactness index CP, the seedling health index SHI, the root quality index RQI. The dataset allows for correlation and regression analyses between these parameters, and can also be linked to other datasets in the FLR Library [2] to generate summary queries to predict the effect, for example, of VIS-spectrometric properties of seeds on DQI.

Additionally, to evaluate the R&D vector in the field of research and testing of spectrometric properties of seeds according to efficiency criteria, it is advisable to create and annually replenish Dataset 5: "Systematic data on trends in the scientific landscape in the field of studying the spectrometric properties of seeds (reference refilled dataset)". The tabular dataset is based on the analysis of relevant references in peer-reviewed journals and contains information on seven criteria for the effectiveness of methods for studying the spectrometric properties of seeds:

- criterion of the degree of radiation exposure to seeds;
- criterion of the degree of organizational costs for conducting R&D;
- the criterion of the degree of financial costs for conducting R&D;
- criterion of the degree of time spent on R&D;
- criteria for the degree of use of the technique using portable devices;
- criterion of the degree of accuracy of seed identification;
- •* criterion for the possibility of machine learning using neural networks.

Moreover, the dataset contains tabular data on references, on the countries of R&D and changes in the average annual temperature in their territories, on methods for studying spectrometric

properties, on types of forest plants, on types of electromagnetic radiation, on types and manufacturers of devices and equipment for studying spectrometric properties of seeds.

Rational assessment of the effectiveness of the application of reforestation technology [7,8] by hybrid crops of Scots pine (*Pinus sylvestris* L. var. *Negorelskaya*) when moving seeds according to A.I. Novikov and co-authors [9] to the place of sowing according to the climatic gradient - "dependence of accumulated precipitation on accumulated degree days" [9], used in this study, is based on the hypothesis of the existence of the influence of morphometric and spectrometric parameters of seeds on sowing qualities (indicators of germination in plate for 30 and 50 days [10] in containers of automated forestry equipment).

The accuracy of non-destructive [11–13] detection of forest seeds using electromagnetic waves from different regions increases with the assessment of each single seed [14–32] individually, determined by the focal distance [33] from the sensor to the place of reflection of the electromagnetic beam from the top of the seed coat [34]. At the same time, depending on the type and nature of exposure to electromagnetic radiation, the biophysical [13,35] (spectrometric) parameters of the seed correlate with different properties and indicators of a single seed [2,5,7,9,11,12,12–16,21,23–28,31,34,36–110,110–217,217–222]: the biochemical content of lipids, starch, protein, trace elements, etc., as well as physiological germination.

The accuracy of detection depends on the quality of the seed (size, heterogeneity) and the characteristics of the detector. Esteve Agelet et al. (2014) conclude from a systematic search of 168 references for the identification of a single seed that "although no measurement mode (reflectance, transmittance) have lead to the best re-reported calibrations, when dealing with heterogenic seeds reflectance is the best working mode [123]". Most studies of the forest single seed [14–16,20,21,24,26–32,99,123,136]. Expensive devices are used to create and detect electromagnetic radiation with long exposure. However, the use of an inexpensive scanner [4] or a smartphone may be quite accurate for the initial assessment of the seed lot.

To quantify the color of the seed coat of a single seed, the $L^*a^*b^*$ color space is most often used, converted from Dataset 2 file data (scans in RGB space with a resolution of 300, 600 or 1200 dpi) using the open source program Fiji. In the $L^*a^*b^*$ color space, the value of L^* varies from 0 (black) to 100 (ideally white); a^* ranges from -100 to 100 and measures green when negative and red when positive; and b^* , which also varies from -100 to 100, is an indicator of blue when negative and yellow when positive.

An ongoing funded research project based on Datasets 1-5, has been supported by the grants the Russian Science Foundation, RSF 23-26-00228, <https://rscf.ru/project/23-26-00228/>. Grants name is «The study of seeds spectrometric parameters as a basis for the intensification of the "Negorelskaya" Scots pine afforestation».

The effectiveness of forest plantations (forest plantations, forest seed plots, in particular) depends on the productivity and resistance to biotic and abiotic environmental factors of the forest crops used." In turn, these characteristics are determined at the genetic level and determine the quality of reproductive material. The productivity of forest crops can be improved through breeding tests. Hybrid of scots pine (*Pinus sylvestris* L., var. *Negorelskaya*) is a breeding variety, characterized by intensive growth and early abundant seed production. This will increase the efficiency of seed plantations and the productivity of artificial plantations (up to 15%). At the same time, the quality of seedlings (*Pinus sylvestris* L., var. *Negorelskaya*), all other things being equal, will be determined by the quality of the seeds. The quality of the seeds is closely correlated with their spectrometric properties. Moreover, the effectiveness of performing a group of seeding operations (including aerial seeding [231] on hard-to-cultivate areas) depends on the quality of seeds [3,6,12,13,34,72,79,85,89,107,111,115,139,143,175,203,217,223–230].

The scope of the project is to trace, evaluate, optimize and analyze the entire cycle of obtaining forest reproductive material using the example of the common pine of the *Negorelskaya* variety, collecting a data bank, starting from the results of studying the spectrometric and morphological properties of the seed to observing the biometric parameters of the ontogenetic development of the seedling, taking into account the natural production conditions of growth.

For this purpose, interdisciplinary research is carried out, bringing together specialists, including young scientists, in the fields of forest genetics and ecology, automation of forestry processes, and also the development of professionally oriented information systems (databases) of a forest profile.

The following paper has been published with the information support of Dataset1 and Dataset3: Novikov, A.I.; Rebko, S.V.; Novikova, T.P.; Petrishchev, E.П. The effect of the individual seed mass of Negorelskaya variety Scots pine (*Pinus sylvestris* L.) on 30-day germination in 40-cell SideSlit growing containers. *Forestry Engineering Journal* **2023**, *13*, 59–86, doi:10.34220/issn.2222-7962/2023.2/4.

In the future, projects and collaborations based on this data descriptor are possible, for example, with a group of scientists led by Clissia Barboza Mastrangelo [4], will be aimed at developing informatization of forest management systems and will combine the ambitious goal of tracing and ensuring the ability to effectively manage the process of restoring forest landscapes "from seeds to forest crops" on the example of the common pine (*P. sylvestris* L.). In the future, it is planned to expand research "from seeds to forest crops" to other types of woody plants.

2. Data Description

2.1. Seed morphometric block

Seed morphometric block (from Dataset 1) содержит табличные данные 1 200 индивидуальных семян of the Negorelskaya variety *Pinus sylvestris* L. The data in the block is generated in accordance with Table 1.

Table 1. The table data format of the 23-26-00228-RSF-DataSet-SeedNG-Morphometry.xlsx file from Dataset 3. **Total Number** – ordinal global seed number (from 1 to 1200), key field, data type – numeric, variable type – categorical, nominal; **Sample's number** – number of a sample (batch) of seeds selected from different parts of the seed pile by quartering [232], data type – numeric; variable type – categorical, nominal (takes values from 1 to 3); **Seed mass**: data type – numeric; variable type – quantitative (direct measurement using analytical scales); **Seed length**: data type – numeric; variable type – quantitative (direct measurement using a micrometer); **Seed width**: data type – numeric; variable type – quantitative (direct measurement using a micrometer); **Seed thickness**: data type – numeric; variable type – quantitative (direct measurement using a micrometer); **Seed square**: data type – numeric; variable type – quantitative (calculation according to subsection 3.1); **Ellipsoid volume**: data type – numeric; variable type – quantitative (calculation according to subsection 3.1).

Total number	Sample's number	Seed mass, mg	Seed length, mm	Seed width, mm	Seed thickness, mm	Seed square, mm ²	Ellipsoid volume, mm ³
1	1	0,013	4,50	2,57	1,61	36,31	9,74
...	...	...	...	...	...	...	...
1166	3	0,0102	5,25	2,75	1,50	45,33	11,33
1167	3	0,0055	4,02	2,44	1,19	30,80	6,11
1168	3	0,0065	4,50	2,51	1,17	35,47	6,92
1169	3	0,0060	4,13	2,66	1,39	34,50	7,99
1170	3	0,0055	4,37	2,41	1,15	33,07	6,34
1171	3	0,0065	3,92	2,42	1,37	29,79	6,80
1172	3	0,0065	4,67	2,55	1,37	37,39	8,54
1173	3	0,0035	3,64	2,37	0,97	27,09	4,38
1174	3	0,0045	3,53	2,00	1,13	22,17	4,18
1175	3	0,0035	3,48	1,92	1,13	20,98	3,95
1176	3	0,0065	4,90	2,31	1,33	35,54	7,88
1177	3	0,0045	4,10	2,08	1,20	26,78	5,36
1178	3	0,0060	4,52	2,24	1,24	31,79	6,57
...	...	...	...	...	...	...	...

2.2. Seed VIS-spectrometric block

Seed VIS-spectrometric block formed from Dataset 2: «VIS-Spectrometric data of individual seeds (N = 1200) of the Negorelskaya variety *Pinus sylvestris* L. (empirical dataset)». The block contains file data of 1,200 individual seeds, arranged in scans of 40 seeds according to the number of cells in the container. The formation of file data in the block occurs as follows.

Three main folders of the file dataset were formed in accordance with Figure 1, corresponding to three samples of scots pine seeds (*P. sylvestris* L., var. Negorelskaya), selected for the study according to subsection 3.1.

- 1NG(1-400);
- 2NG(401-800);
- 3NG(801-1200);

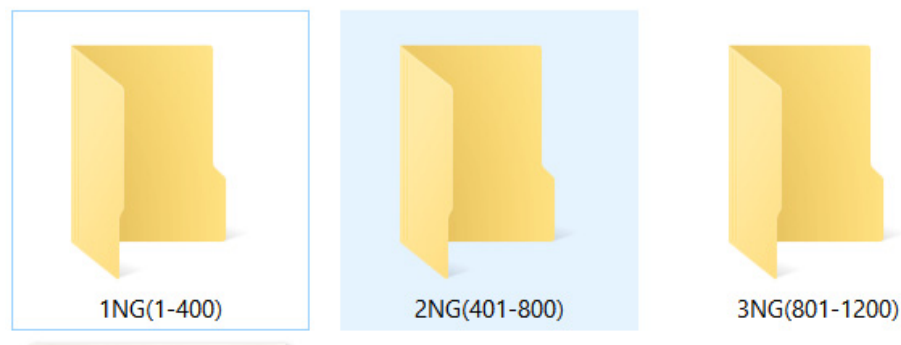


Figure 1. The structure of the first level of the file dataset containing VIS scans of Scots pine seeds (*P. sylvestris* L., var. Negorelskaya) for the study of spectrometric parameters.

Inside each folder in Figure 1, three second-level folders were formed in accordance with Figure 2:

- XNG@300;
- XNG@600;
- XNG@1200; here X is the sample number (1, 2 or 3).

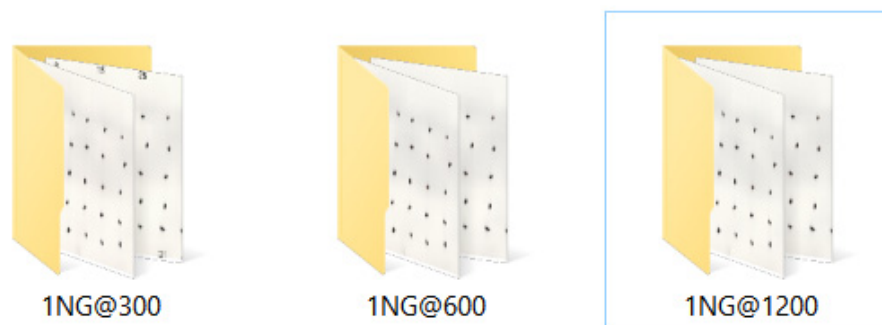


Figure 2. The structure of the second level of the file dataset using the example of folder 1 NG(1-400) containing VIS scans of Scots pine seeds (*P. sylvestris* L., var. Negorelskaya) for the study of spectrometric parameters: @300 – with a resolution of obtaining an optical image in the visible wavelength range of 300 point/inch; @600 – 600 point /inch; @1200 – 1200 point/inch.

Inside each folder of the second level – XNG@YYY, file data was formed according to Figure 2 in accordance with Figure 3:

- dZ(NS-NF)@YYY=Scan;
- vZ(NS-NF)@YYY=Scan.

Here d is the dorsal side of the seeds; v is the ventral side (with a 180 degree rotation) seeds; Z is the side-drain number of the container for subsequent seed sowing; NS is the initial seed number in the container; NF is the final seed number in the side-drain container; YYY is the resolution of the VIS scan obtained in the optical wavelength range (300, 600 or 1200).

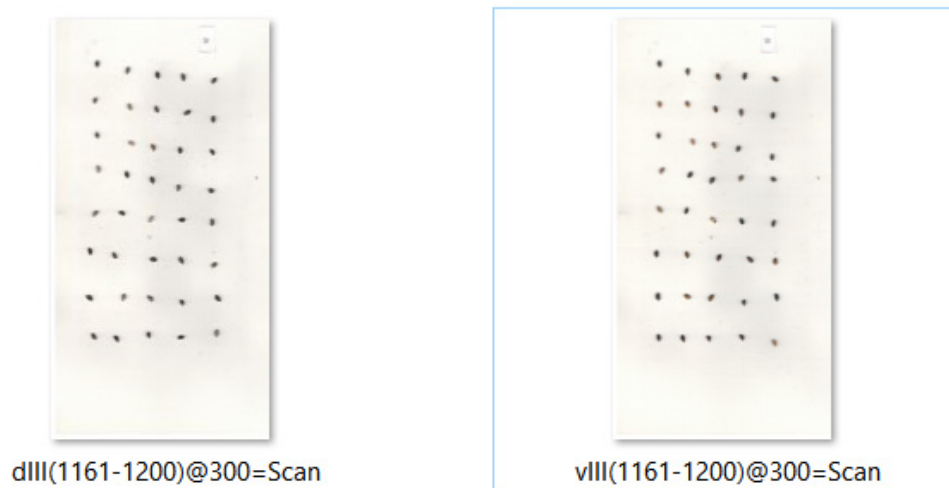


Figure 3. The structure of the third level of the file dataset using the example of folder 3NG@300, containing VIS scans of Scots pine seeds (*P. sylvestris* L., var. Negorelskaya) for the study of spectrometric parameters: the Roman numeral indicates the container number.

For the subsequent study of spectrometric properties and to ensure a sufficient level of subsequent segmentation of the image of the dorsal and ventral projections of the seed of Scots pine (*P. sylvestris* L., var. Negorelskaya)" with a square of 124×124 pixels, for example, as in Rodrigo K. Bernardes and co-authors [4], a sufficient level of randomization, as well as minimization of the noise of the CCD scanner matrix, provided for the location of the seeds of Scots pine (*P. sylvestris* L.) of the Negorelskaya variety at a distance of at least 20 mm from the edge of the tablet in the order corresponding to the order of subsequent sowing of seeds in side-ingot containers.

2.3. Seed germination block

Seed germination block formed from Dataset 3: «Germination data of individual seeds (N = 1200) of the Negorelskaya variety *Pinus sylvestris* L. (empirical dataset)». Блок содержит табличные данные container-grown 30-day- (Table 2) and 50-day-germination (Table 3) день каждого из 1 200 индивидуальных семян. Формирование данных в блоке происходит в соответствии с таблицами 2 и 3.

Table 2. The table data format of the *23-26-00228-RCF-DataSet-SeedNG-G30.xlsx* file from Dataset 3.

Total Number – ordinal global seed number (from 1 to 1200), key field, data type – numeric, variable type - categorical, nominal; **Sample's number** – number of a sample (batch) of seeds selected from different parts of the seed pile by quartering [232], data type – numeric; variable type – categorical, nominal (takes values from 1 to 3); **Seed's number** – the number of the seed inside the sample (batch) selected from the seed pile, data type – numeric; variable type – categorical, nominal (takes values from 1 to 400); **Container's number** – the number of the container in which the studied seeds were sown, data type – numeric; variable type – categorical, nominal (takes values from 1 to 40); **G30** – germination index of each individual seed on the 30th day from the moment of sowing in a side-slit container, data type – numeric; variable type – categorical, rank (takes only two values 0 – there is no seed germination; and 1 – there is a viable plantlet).

Total Number	Sample's number	Seed's number	Container's number	G30, (0-No 1-Yes)
...	...	...	...	...
480	2	80	12	0
481	2	81	13	1
482	2	82	13	1
483	2	83	13	1
484	2	84	13	1
485	2	85	13	1
486	2	86	13	0
487	2	87	13	0
488	2	88	13	1
489	2	89	13	0
490	2	90	13	1
491	2	91	13	1
492	2	92	13	1
493	2	93	13	1
494	2	94	13	1
495	2	95	13	1
496	2	96	13	0
497	2	97	13	0
498	2	98	13	1
499	2	99	13	1
500	2	100	13	1
...	...	...	...	...

* The gray color of the cell represents the beginning of another container, ** the red color of the cell clearly demonstrates the absence of a seedling (zero germination of the seed).

Table 3. The table data format of the 23-26-00228-RCF-DataSet-SeedNG-G50.xlsx file from Dataset 3. Total Number – ordinal global seed number (from 1 to 1200), key field, data type – numeric, variable type – categorical, nominal; Sample's number – number of a sample (batch) of seeds selected from different parts of the seed pile by quartering [232], data type – numeric; variable type – categorical, nominal (takes values from 1 to 3); Seed's number – the number of the seed inside the sample, data type – numeric; variable type – categorical, nominal (takes values from 1 to 400); Container's number – the number of the container in which the studied seeds were sown, data type – numeric; variable type – categorical, nominal (takes values from 1 to 40); G50 – germination index of each individual seed on the 50th day from the moment of sowing in a side-slit container, data type – numeric; the type of variable is categorical, rank (it takes only two values 0 – there is no seed germination; and 1 – there is a viable plantlet).

Total Number	Sample's number	Seed's number	Container's number	G50, 0-No 1-Yes
...	...	...	...	...
480	2	80	12	0**
481*	2	81	13	1
482	2	82	13	1
483	2	83	13	1
484	2	84	13	1
485	2	85	13	1
486	2	86	13	0
487	2	87	13	0
488	2	88	13	1
489	2	89	13	0
490	2	90	13	1
491	2	91	13	1
492	2	92	13	1
493	2	93	13	1
494	2	94	13	1
495	2	95	13	1
496	2	96	13	0
497	2	97	13	0
498	2	98	13	1
499	2	99	13	1
500	2	100	13	1
...	...	...	...	...

* The gray color of the cell represents the beginning of another container, ** the red color of the cell clearly demonstrates the absence of a seedling (zero germination of the seed).

2.4. Seedling growth block

Seedling growth block formed from Dataset 4: «Biometric data (include DQI) of individual seedlings produced from seeds of the Negorelskaya variety *Pinus sylvestris* L. (empirical refilled dataset)». The block contains tabular data of biometric and mass parameters of container-brown seedlings, randomly selected on the 60th day after sowing the seeds. The block also contains calculated indices of seedling quality. The data in the block is generated in accordance with Table 5.

Table 5. The table data format of the 23-26-00228-RCF-DataSet-SeedlingNG-DQI-60day.xlsx file from Dataset 4. Seedling Number – the sequence number of the seedling (from 1 to 30), randomly selected on the 60th day from each container, key field, data type - numeric, variable type – categorical, nominal; Root collar diameter (RCD) – data type – numeric; variable type – quantitative (direct measurement using a digital caliper); Average root diameter (ARD) – data type – numeric; variable type – quantitative (direct measurement using a digital caliper); Seedling Heights (SH) - data type – numeric; variable type – quantitative (direct measurement with a ruler); Total root length (TRL) – data type – numeric; variable type – quantitative (direct measurement with a ruler); Total Dry Weight (TDW) – data type – numeric; variable type – quantitative (direct measurement using digital scales); Dry mass of the root RDW – data type – numeric; variable type – quantitative (direct measurement using digital scales); Stem Dry Weight (SDW) – data type – numeric; variable type – quantitative (direct measurement using digital scales); Height Diameter Ratio (HDR) – seedling endurance index, data type – numeric; variable type – quantitative (calculated by Eq 1); Shoot-to-root dry ratio (SRR) – seedling balance index, data type – numeric; variable type – quantitative (calculated by Eq 2); Diameter Height Ratio (DHR) – data type – numeric; variable type – quantitative (calculated by Eq 3); Root Sturdiness Quotient (RSQ) – data type – numeric; variable type – quantitative (calculated by Eq 4); Dickson Quality Index (DQI) – data type – numeric; variable type – quantitative (calculation according to Eq 5); Root Quality Index (RQI) – data type – numeric; variable type – quantitative (calculated by Eq 6); Compactness index (CP) – data type – numeric; variable type – quantitative (calculated by Eq 7); Seedling Health Index (SHI) – data type – numeric; variable type – quantitative (calculated by Eq 8); Aerial Plant Volume (APV) – data type – numeric; variable type – quantitative (calculated by Eq 9);

Seedling number	RCD, mm	ARD, mm	SH, mm	TRL, mm	HDR	DHR	RSQ	DQI	RQI	CP, mg cm^{-1}	SHI	APV	TDW, mg	SRR	RDW, mg	SDW, mg
1	0,8	0,5	82	68	102,50	0,0098	0,0074	1,1573	13,2105	14,3902	0,1290	13,7392	130	9,83	12	118
2	1,2	0,6	95	68	79,17	0,0126	0,0088	2,3850	25,8311	19,4737	0,3266	35,8142	208	8,04	23	185
3	1,1	0,8	88	37	80,00	0,0125	0,0216	1,4667	13,1715	13,6364	0,1650	27,8764	132	10,00	12	120
4	1,1	0,6	85	68	77,27	0,0129	0,0088	1,8749	10,5968	19,5294	0,1372	26,9261	176	16,60	10	166
5	1,2	0,5	96	45	80,00	0,0125	0,0111	2,0709	15,0879	18,5417	0,1888	36,1911	192	12,71	14	178
6	0,8	0,4	70	35	87,50	0,0114	0,0114	0,7576	6,5153	9,8571	0,0745	11,7286	75	11,50	6	69
7	1	0,6	74	37	74,00	0,0135	0,0162	0,9878	10,1045	9,7297	0,1368	19,3732	81	8,00	9	72
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...

3. Methods

3.1. Seed collecting

Three sets ($n = 400$) of seeds were selected by quartering from a batch of harvested seeds of Scots pine (*P. sylvestris* L.) of the Negorelskaya variety harvested in 2023, collected in (53.577939, 27.056128, 180 m asl).

Currently, there is a tendency to move [233] seeds of Scots pine (*P. sylvestris* L.) for growth experiments in the gradation function of the accumulated annual precipitation (mm) depending on the accumulated degree days [234] of the region. The current experiment is no exception: 1200 varietal (*P. sylvestris* L., variety "Negorelskaya") seeds were moved from the collection area (1731 degree-days, 722 mm) to the experimental area (2326 degree-days; 786 mm).

3.2. Morphometric data of individual seed: obtaining and calculating

For each seed from three sets (total number of seeds $N = 1200$), the dimensions, weight, area, volume of the ellipsoid were measured according to the methodology developed on the basis of [4,5,235] and placed in transparent pockets under an individual number.

The individual weight of the seed was recorded using special laboratory analytical scales. The average temperature and humidity in the laboratory during the study were 25 °C and 21%, respectively. The weight of each seed was recorded using laboratory analytical scales with an accuracy of 0.0001 g. Before measuring, the scales were installed with the possibility of excluding the effects of vibration, heat sources, air flows and sudden temperature fluctuations, balanced using an integrated bubble indicator, set to zero. Next, the measured seed was placed with tweezers in the center of the circle, transparent flaps were closed to prevent the influence of air movement and the seed mass readings were recorded after stabilization of the corresponding arrow. The readings were recorded in a special journal.

The research methodology provided for the determination of the geometric characteristics of the seeds of the common pine variety "Negorelskaya", among which such parameters as the surface area of the seed (mm^2) and the volume of the seed (mm^3) were selected.

The surface area of the seed was calculated using the formula of the area of the ellipse, which most fully resembles the seed of the common pine in shape:

$$S_c = \pi \cdot L \cdot W,$$

где S_c – the surface area of the seed, mm^2 ; π is a constant value equal to 3.14; L is the length of the seed, mm; W is the width of the seed, mm.

The volume of the seed was calculated using the formula of the volume of an ellipsoid, most closely resembling in shape and volume the seed of an Scots pine:

$$V_c = 4/3 \cdot \pi \cdot 0,5L \cdot 0,5W \cdot 0,5T,$$

где V_c – the volume of the seed, mm^3 ; π is a constant value equal to 3.14; L is the length of the seed, mm; W is the width of the seed, mm; T is the thickness of the seed, mm.

3.3. VIS-Spectrometric data: obtaining and calculating

Scanning, according to the proposed method of the author T. Novikova, was performed for 40 seeds, placing them on the scanner glass in the order of future sowing in containers (Figure 4). The seeds were removed from individual pockets with an individual number and placed on the scanner glass in accordance with Figure 4.

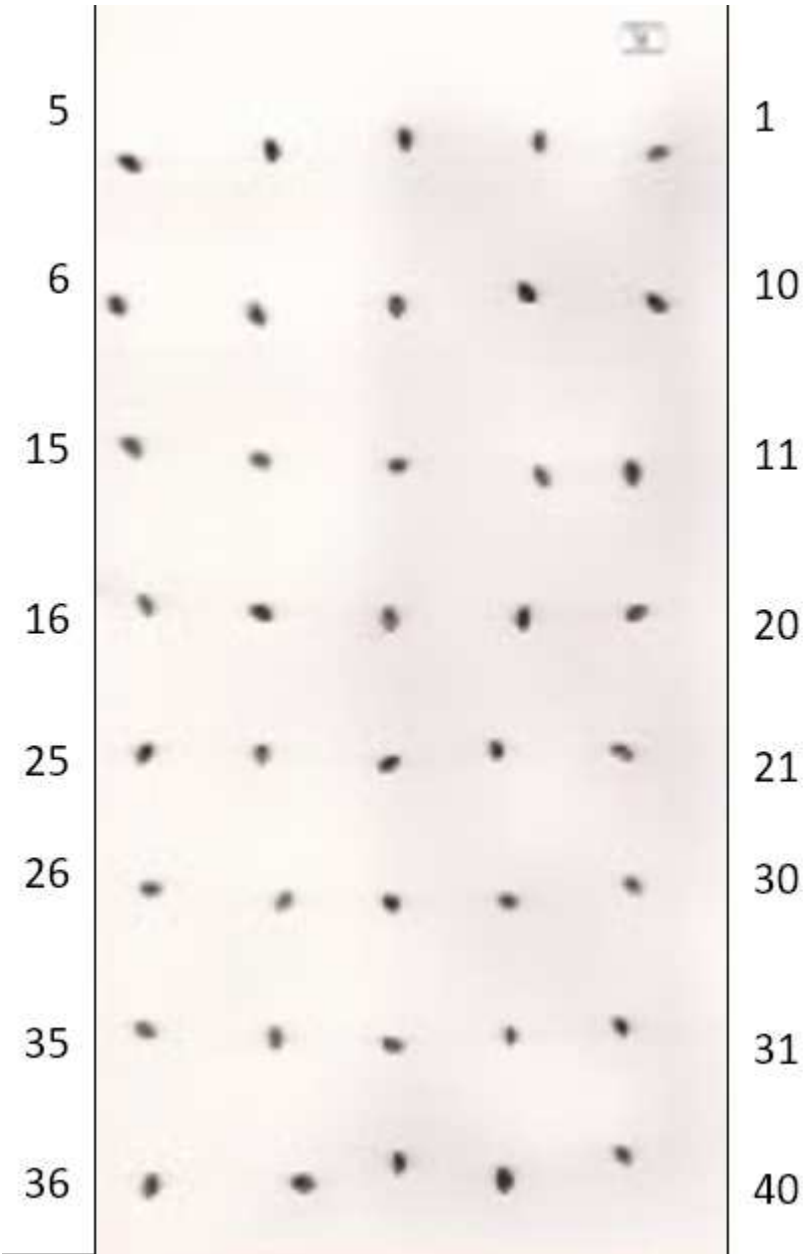


Figure 4. A fragment of the location of the seeds on the scanner glass. The St-mark was set for the beginning of the countdown.

We pre-configured the field size of the 40-seed scan by clicking the [Preview] button in the Scan window of the scanner interface (Brother DCP). The scan paper size was cut to 280*145 mm.

The scanning resolution was set to 300 dpi, the scanning mode was color, and the brightness was set by default. At the same time, the paper size in pixels was set to 1718*3309 pixels. Next, the [Scan] button was pressed and the scan timing was determined using a smart stopwatch background, the value of which was entered into the Excel table For the period of scanning the sample, the time from the appearance of the "Data Transfer" window to the appearance of a thumbnail of the scanned seed image in the left menu of the ABBYY Fine Reader program was assumed. The resulting seed scan was saved in uncompressed TIFF format with a file name of the form dI(1-40)@300=Scan where d(v) is the conditional dorsal (ventral) orientation of the seed relative to the scanner glass; I (II, III) is the number of a random sample of seeds from the seedlot; 1-40 is the unique seed cipher in the current study; @300 (600,1200) is the scanning resolution, dots per inch; =Scan is the color of the reflective substrate of the scanner or colored paper.

The resulting file (scan) has the following numbering of each individual seed. After scanning a sample of 40 seeds corresponding to the future location in side-ingot containers, the resolution and size of the paper were changed by 600 dots per inch and 3436*6619 pixels, respectively. Moreover, the timing was determined for a resolution of 600 dpi and entered into the corresponding cell of the Excel table. After saving the scan, the resolution and paper size were changed by 1200 dpi and 6873*13238 pixels respectively.

Thus, for each orientation of seeds with a certain color of the substrate, intended for sowing in one container (1-40), three files with a resolution of 300, 600 and 1200 dpi were obtained.

 dIII(1161-1200)@300=Scan	tif	17 055 034	21.06.2023 20:28
 dIII(1161-1200)@600=Scan	tif	68 229 868	21.06.2023 20:29
 dIII(1161-1200)@1200=Scan	tif	272 958 298	21.06.2023 20:31
 vIII(1161-1200)@300=Scan	tif	17 055 034	21.06.2023 20:34
 vIII(1161-1200)@600=Scan	tif	68 229 868	21.06.2023 20:35
 vIII(1161-1200)@1200=Scan	tif	272 958 298	21.06.2023 20:37

Figure 5. A fragment of the listing of files (Total Commander) obtained by scanning seeds 1161-1200 intended for sowing in a 30 container.

The subsequent conversion of the VIS RGB scan of an individual pine seed into L*a*b* or HSV color channels for quantitative studies is planned to be carried out by the weighted integration method [33] in the open source software product Fiji, version 9.12, using the grain segmentation routine. The L*a*b* model finds application in areas related to color correction, color matching, pattern recognition, and other tasks where a more accurate and consistent color description is required. In the L*a*b* model, color is represented by three components: Lightness, component a and component b. The lightness indicates the brightness of the color and varies from 0 to 100. Components a and b represent color deviations from neutral gray: component a represents the range from green (-128) to red (+127), and component b represents the range from blue (-128) to yellow.

3.4. Germination data: obtaining and calculating

The seeds were sown manually on June 23, 2023, into each of the 40 cells with a volume of 120 cm³ of HIKO V-120 SideSlit containers pre-filled with an acid reaction peat substrate (size LSHG 352*216*110 mm, 526 seedlings per square meter; BCC AB, Sweden), placing the seed in the center of the cell on the depth is 0.5 cm. The location of the seeds for subsequent identification was carried out in accordance with Figure 6, a indicating the initial reference cell from the outside with a special marker as in Figure 6b. After sowing 40 seeds, the container was filled with mulch in the form of perlite and placed on a pallet for transportation to the greenhouse. Each set of 400 seeds was placed in 10 containers. After 30 and 50 days, germination was calculated (as a percentage) for each of the 30 containers (N = 1,200 seeds) and the individual germination of each seed (0 – did not germinate; 1 – rose).

5	6	15	16	25	26	35	36
4	7	14	17	24	27	34	37
3	8	13	18	23	28	33	38
2	9	12	19	22	29	32	39
1	10	11	20	21	30	31	40

(a)



(b)

Figure 6. Manual sowing (author T.P. Novikova) of 1,200 individual seeds ($N = 400 \text{ seeds} \times 3 \text{ samples}$) of Scots pine (*P. sylvestris* L.) sorta "Negorelskaya" in SideSlit-containers HIKO V-120 (size LWH 352*216*110 mm, 526 seedlings per sq. m; BCC AB, Sweden) for testing the production technology planting material, taking into account the spectrometric and morphometric characteristics of seeds: scheme of placement of individual seeds in a container (a); manual seeding and labeling of SideSlit containers (b);.

The moment of accounting for the germination of seeds of the Negorelskaya variety in SideSlit containers was set to a 30-day (July 22, 2023) and 50-day (August 12, 2023) period from manual seeding into each of the 40 cells of the container, as implemented by Mañas et al. (2009) [236], A. V. Pimenov (2015) [237] A. Novikov (2019) [10].

3.5. Biometric data (include Dickson [238] Quality Index – DQI): obtaining and calculating

Seedlings were removed from the cells one from each of the 30 side-slit containers on the 60th day from the moment of sowing. Next, the seedlings were washed in water from the substrate and shaken from water droplets. After that, the seedlings were weighed, direct measurements were made of SH (ruler, accuracy 0.5m), RD, RD and CTRL (digital vernier caliper, accuracy 0.1 mm). Then they were laid out on a boat and dried at a temperature of 105 ° C for 1 hour (convection oven). After drying, they were weighed to obtain the parameters DW, DW, and SW (digital scales, accuracy 1 mg). Then, the seedling quality indicators were calculated using the following equations.

This is Height Diameter Ratio (HDR) calculated of an equation:

$$HDR = SH \cdot RCD^{-1}, \quad (1)$$

where is SH – seedling heights, mm; RCD – root collar diameter, mm.

This is Shoot-to-Root dry Ratio (SRR) calculated of an equation:

$$SRR = SDW \cdot RDW^{-1}, \quad (2)$$

where is SDW – stem dry weight, mg; RDW – root dry weight, mg. The balance index SRR – the ratio of the dry mass of the aboveground part of the plant (stem with leaves | needles) to the underground part of the plant – characterizes the balance between the water-evaporating and water-absorbing surfaces [239] of a single seedling of Scots pine. (*Pinus sylvestris* L., var. Negorelskaya)

This is Diameter Height Ratio (DHR) calculated of an equation:

$$DHR = RCD \cdot SH^{-1}, \quad (3)$$

where is SH – seedling heights, mm; RCD – root collar diameter, mm.

This is Root Sturdiness Quotient (RSQ) calculated of an equation:

$$RSQ = ARD \cdot TRL^{-1}, \quad (4)$$

where is ARD – average root diameter, mm; TRL – total root length, mm.

This is Dickson Quality Index (DQI) calculated of an equation:

$$DQI = TDW \cdot (HDR + SRR)^{-1}, \quad (5)$$

where is TDW – total dry weight for seedling, mg; HDR – height diameter ratio from Eq 1; SRR – shoot-to-root dry ratio from Eq 2.

This is Root Quality Index (RQI) calculated of an equation:

$$RQI = TDW \cdot (RSQ + SRR)^{-1}, \quad (6)$$

where is TDW – total dry weight for seedling, mg; RSQ – root sturdiness quotient from Eq 4; SRR – shoot-to-root dry ratio from Eq 2.

This is Compactness Index of seedling (CP) calculated of an equation:

$$CP = SDW \cdot SH^{-1}, \quad (7)$$

where is SDW – stem dry weight, mg; SH – seedling heights, mm.

This is Seedling Health Index (SHI) calculated of an equation:

$$SHI = TDW \cdot DHR \cdot (RDW \cdot SDW^{-1}), \quad (8)$$

where is TDW – total dry weight for seedling, mg; DHR – diameter height ratio from Eq 3; RDW – root dry weight, mg; SDW – stem dry weight, mg.

This is Aerial Plant Volume (APV) calculated of an equation:

$$APV = \frac{1}{3} \pi \left(\frac{1}{2} RCD \right)^2 SH, \quad (9)$$

where is SH – seedling heights, mm; RCD – root collar diameter, mm. Aerial Plant Volume The index characterizes the degree of adaptation of a single seedling of Scots pine (*Pinus sylvestris* L., var. Negorelskaya) to climatic conditions [239,240].

4. User Notes

Using the constantly updated descriptor of systematic data (Dataset 5) in the field of studying the spectrometric properties of forest seeds, it will be possible to evaluate the effectiveness of seed detection techniques (single) and conduct a cluster analysis of trends in the scientific landscape according to efficiency criteria.

Moreover, combining in the future the VIS-image descriptor of spectrometric data (Dataset 2) of Scots pine seeds with a descriptor of morphometric/gravimetric data for an individual seed (Dataset 1) and a descriptor of germination data (Dataset 3), biometric data (Dataset 4), including the Dickson quality index, for the obtained from an individual seed of an individual seedling, the FLR-Library

database [7,186] will be significantly supplemented for effective management of forest landscape restoration.

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Appendix A

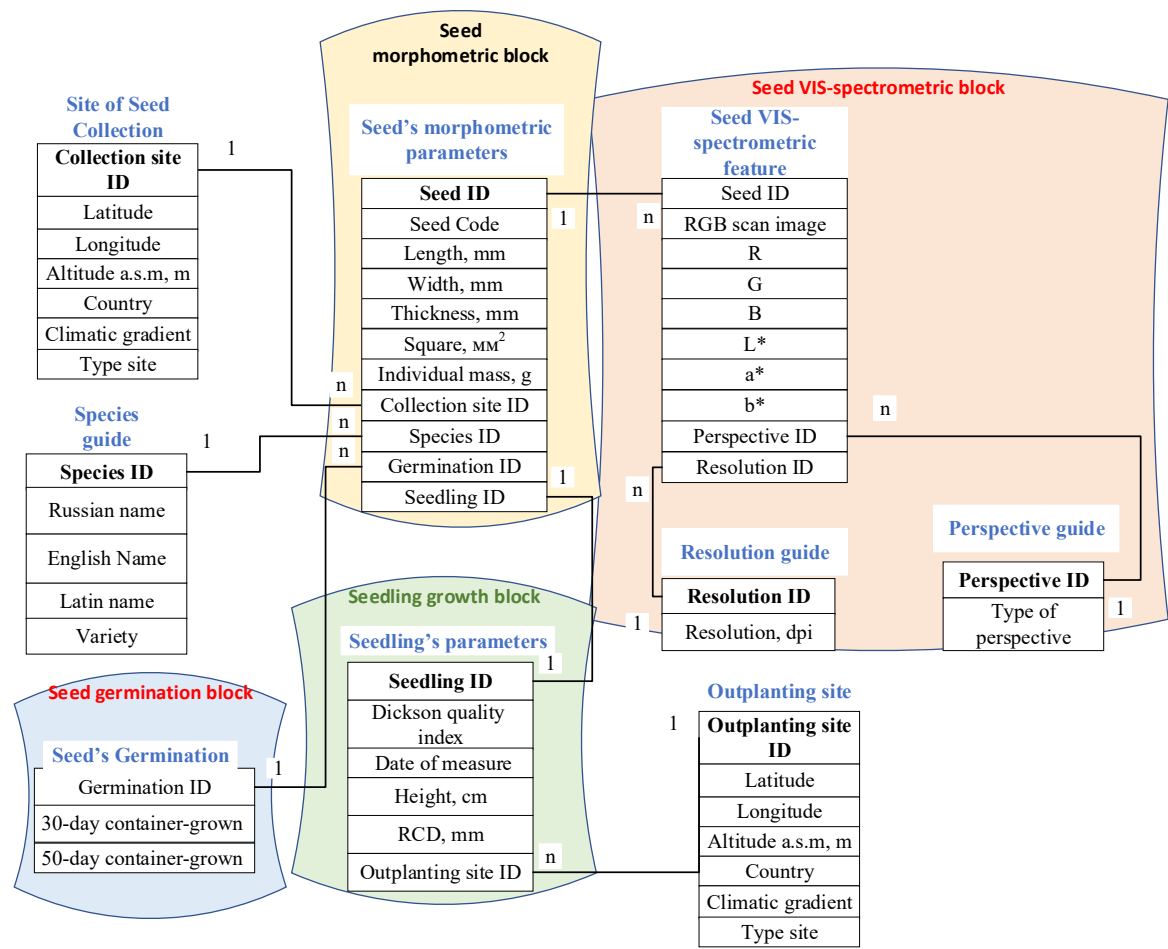


Figure A1. The relational model (enlarged) of the data of the individual passport *P. sylvestris* L. var. *Negorelskaya* sows. This relational model takes into account the morphometric and gravimetric (individual seed mass) (Seed morphometric block), VIS-spectrometric (Seed VIS-spectrometric block) properties of a single seed in RGB and L*a*b*-channels.

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