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A COMPARATIVE STUDY ON THE EVOLUTION OF PLANTED BLACK PINE SAPLINGS ON THE STERILE DUMPS FROM RECEA ȘUNCUIUȘ QUARRY, BIHOR COUNTY

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Abstract

This study analyses the performance of black pine (Pinus nigra Arn.) seedlings planted in 2008-2009, of local origin, and those planted in 2023, with Austrian origins, on the waste dumps of the Recea Şuncuiuş Quarry in Bihor County. The survival rate of the seedlings was assessed, and their diameters and heights were measured across different slope categories. Preliminary results show that the seedlings planted in 2023 exhibit strong growth in both height and diameter, particularly on medium slopes. The overall survival rate of the seedlings planted in 2008-2009 was around 84%. The study also examines the impact of pests on the black pine stand on the Recea Quarry waste dump. Lastly, the health of the trees planted in 2008-2009 was assessed.

***Key words**: afforestation, health status, pine, Pinus, survival rate.*

INTRODUCTION

Ecological restoration is a process aimed at rehabilitating ecosystems impacted by human activities or other disturbances. This can involve restoring natural habitats, reintroducing native species, managing natural resources sustainably, and implementing various strategies to restore balance and enhance biodiversity (Miyawaki & Golley, 1993; Stanturf et al., 2014; Chen et al., 2024).

The primary goal of ecological restoration is to recreate a healthy, functioning environment that sustains life and benefits both nature and human communities. This process can be complex, often requiring collaboration among stake-holders, including academia, research institutes, governments, non-governmental organizations, local communities, and conservation experts (Reid et al., 2021; Schweizer et al., 2021).

Afforestation represents one of the main components of ecological restoration worldwide (Cui et al., 2021; Korneeva, 2021). Pine species, especially black pine (*Pinus nigra* Arn.) and Scots pine (*Pinus sylvestris* L.) are among the most planted tree species worldwide (Enescu, 2015; Vacek et al., 2021; Yildiz et al., 2022).

Over time, the primary purpose of conifer plantations has evolved: whereas they were originally established primarily for wood production, today they are crucial for protecting soil and water resources and for restoring degraded forests (Tavankar et al., 2018; Constandache et al., 2021). Pines are among the most widely planted species globally (Malkamäki et al., 2018; McEwan et al., 2020; Uribe et al., 2020), accounting for 40% of all plantations worldwide (Brown & Ball, 2007).

Pines are the dominant tree species across large areas of the Northern Hemisphere, but over the past few centuries, human activities have shaped the distribution, composition, and structure of pine forests (Richardson et al., 2007).

As a result, black pine now has a fragmented distribution range that extends from North-Western Africa, through southern Europe, to Asia Minor (Kaya & Temerit, 1994; Enescu et al., 2016).

Currently, black pine occupies over 3.5 million hectares (Isajev et al., 2004), making it one of the most widely distributed conifer species in the Balkans and Asia Minor. Its largest global range is in Turkey, where it covers more than 2.5 million hectares (Sevgi & Akkemik, 2007).

In recent decades, black pine has been extensively used in Romania for the afforestation of degraded lands (Crăciunescu et al., 2014; Silvestru-Grigore, 2018; Tudoran et al., 2023). The main objective of this paper was to assess the growth of black pine seedlings planted in 2023 in Recea Șuncuiuș Quarry (Bihor County). Secondly, the vegetation status of the pines planted in 2008-2009 in the same area was assessed.

MATERIALS AND METHODS

The experiments were carried out within the 2.89 km² Recea perimeter, located in the Șuncuiuș refractory clay deposit in the northern part of the Pădurea Craiului Mountains, Bihor County (46°55'11"N, 22°30'34"E).
According to Annex 2 of Ministerial Order no. 2533/2022 - Guide to Good Practices for Compositions, Schemes, and Technologies for Forest Regeneration and Afforestation of Degraded Lands (MMAP, 2022), the type of landfill site in the analyzed case is classified as YD1B. The symbol represents: Y for landfill; D for hill region; 1 for raw waste dumps or terrigenous material resulting from mining, geological exploration, excavations, or various digging activities; and B for anthropogenic material composed of small (coarse or fine) materials such as sand, gravel, loess, and clay.
This annex also provides the afforestation compositions and planting schemes for these types of degraded lands.
In March-April 2023, four experimental plots, each measuring 50 m² were established within the perimeter (Figure 1).

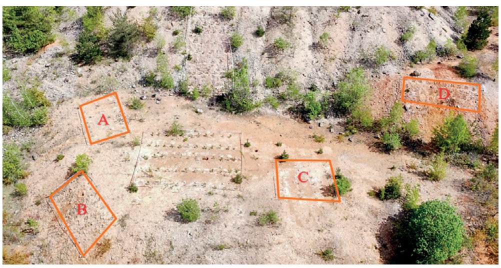

Figure 1. Location of the 4 experimental plots

One-year-old black pine seedlings were planted in these plots, following a 2x1m planting pattern (2 meters between the rows and 1 meter between the seedling in the same row), with 25 seedlings per plot.
Additionally, five seedlings of common hazel (*Corylus avellana* L.) were planted in each plot. Hazel seedlings were selected due to the rapid decomposition of their leaves, which release micronutrients such as Sulphur (S), Calcium (Ca) and Potassium (K), essential for plant growth (Laekemariam & Elka, 2022; Bolat et al., 2025). This process also increases soil organic matter, enhancing soil structure and water retention capacity (Gupta & Malik, 1999), diminishing at the same time the runoff and other associated processes of land degradation.
The experimental plots were established in lands where natural regeneration has not taken place, and previous attempts at artificial regeneration have been unsuccessful, except for some Scots pine specimens planted 10-12 years ago.
These lands consist of a terrace created by levelling the waste rock from clay extraction, along with the adjacent slopes. In 2016, black locust (*Robinia pseudoacacia* L.) saplings were planted on the terrace, but they failed to adapt due to excess of moisture.
The slopes chosen for the experiment have a steep gradient of 30-40°, and previous plantings in these areas have produced very poor results.
The four experimental fields were labelled as follows (Figure 2):

- Variant A, code Pi.n. S1P1N: low slope P1≤10°, N - unfertilized substrate;
- Variant B, code Pi.n. S2P2N: large slope P2>10°, N - unfertilized substrate;
- Variant C, code Pi.n. S3P1F: low slope P1≤10°, F - fertilized substrate;
- Variant D, code Pi.n. S4P2F: large slope P2>10°, F - fertilized substrate.

Typically, seedlings are planted in regular pits (30/30/30 cm), as recommended by specialized literature on establishing pure pine plantations (Traci & Untaru, 1986).
However, in this case, enlarged regular pits (40/40/40 cm) were used because, although the root system volume of the seedlings was small, an additional nutrient substrate is necessary for degraded lands.
Immediately after planting, each seedling was provided with 5 liters of water in each pit.

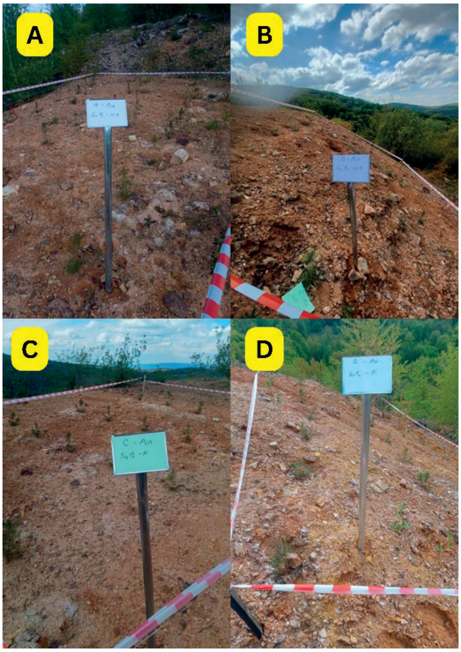

Figure 2. Details regarding the 4 experimental plots

For planting, black pine seedlings, sourced from Austria, and grown in containers measuring 70 mm x 100 mm were used (Figure 3).

Figure 3. Seedlings grown in containers

The holes were dug manually with a spade and pickaxe to remove any boulders. Borrowed soil was then placed at the bottom of each hole, and the seedling was positioned in the center of the holes. Around the seedling's roots, alternating layers of topsoil, acidic peat, and sterile peat with high clay content were added. This mixture helps reduce water evaporation during dry periods and aids the seedling in acclimating to the new soil conditions more quickly.

In the experimental plots located on very steep slopes, the soil was stabilized with dry stone masonry to prevent waste rock from blocking the seedlings over the winter. Fertilization was applied immediately after planting to half of the experimental plots, using a fertilizer designed for softwood seedlings with the following composition: 14% N, 7% P_2O_5, 17% K_2O, 2% MgO, 9% S, 0.02% B, 0.01% Zn. The fertilizer was spread around the planted seedlings, with 20 grams applied to each seedling (Figure 4).

Figure 4. Applying fertilizers

In the third decade of April 2023, at the start of the first year of vegetation, observations were made to assess the onset of seedling growth (the degree of survival after planting). The following characteristics were measured:

- the degree of survival after planting in the field, expressed as a percentage;
- the degree of seedling survival, recorded at the end of the first vegetation period, expressed as a percentage;
- seedling height (cm), measured from ground level to the top of the main stem;
- seedling diameter at the root collar (mm) at the end of the first vegetation year in the field;
- the number of whorls;
- the number of branches per whorl.

The diameter at the root collar was measured using a digital caliper (Figure 5), and the height was measured with a height measuring tape (Figure 6).

Figure 5. Measuring the root collar with a digital caliper

For most of the analyzed characteristics (degree of survival after planting, degree of survival after the first year, plant height, diameter at the root collar, number of whorls, and number of branches per whorl), the arithmetic mean was calculated using the standard formula: $x = \sum x/n$.

Figure 6. Measuring the height with a measuring tape

For the number of branches per first whorl, as each sample contained groups of plants with varying numbers of branches (ranging from 0 to 6 branches per whorl per plant), the weighted arithmetic mean was used, calculated with the following formula:

$$X_{med.pond.} = \frac{\bar{x}_1 n_1 + \bar{x}_2 n_2 + \ldots + \bar{x}_k n_k}{N},$$

in which: $N = n_1 + n_2 + \ldots + n_k$;

$\bar{x}_1 \ldots \bar{x}_k$ = group averages.

To determine the degree of survival after planting in the field, the following formula was used:

$$Gp(\%) = \frac{Pveg}{Pplant} 100,$$

where: P_{veg} represents seedlings started in vegetation on April 20, 2023;

P_{plant} accounts for planted seedlings.

To determine the degree of survival after planting in the field, the following formula was used:

$$Gm(\%) = \frac{Pviab}{Pveg} 100,$$

where: Pviab represents viable seedlings at the time of determination;

Pveg represents the number of seedlings that started growing on April 20, 2023.

The results from the biometric measurements of the mentioned characteristics were statistically analyzed using analysis of variance, appropriate for monofactorial experiments conducted in randomized blocks. The significance of the differences between the two tested varieties was determined using the DL test or the multiple comparisons test ($DS_{5\%}$). For certain characteristics, the "t" test (Student) was also applied (Ardelean et al., 2005; Ardelean, 2011). The coefficients of variability (s%) were calculated using data from the series of measurements taken on the 25 individuals in each variant. The applied formula was (Ardelean, 2011):

$$s\% = \frac{s}{\bar{x}}\,100, \%$$

where: s represents the standard deviation;
x is the average of the series.

Simple correlation coefficients were calculated using Microsoft Excel, with their significance assessed at the 5% and 1% levels.

A secondary objective of the research was to evaluate the health status of the saplings planted in 2008-2009 in the same area, that recorded in 2023 an 84% survival rate (Bodea et al., 2023). The study was conducted, in January 2025, according to the recommendations of Technical Norms No. 6 – Technical Standards and Guidelines for Forest Protection (MAPAM, 2003). Defoliation and discoloration were expressed in percentages (from 5 to 5). Mechanical (physical) damages were grouped as follows: Animals, Insects, Fungi, Abiotic, Anthropogenic, Other damages. Their intensity was noted with the following classes: 0 - no damage, 1 - weak damage, 2 - medium damage, 3 - strong damage.

RESULTS AND DISCUSSIONS

Measurements taken on all seedlings prior to planting confirmed their classification into quality classes I and II based on stem height and average diameter at the root collar. The detailed results of these measurements, conducted in March and November 2023, are presented in Table 1.

The average diameters measured for all 100 seedlings at the beginning and at the end of the 2023 growing season are given in Figure 7.

Table 1. Mean values of collar diameter and heigh recorded in March and November 2023

Plot	Collar diameter [mm]		Height [cm]	
	March	November	March	November
A	9.53	9.92	9.28	30.79
B	8.44	8.70	8.40	25.79
C	9.21	10.03	8.89	30.78
D	8.62	8.89	9.52	25.04
Mean	8.95	9.39	9.02	28.10

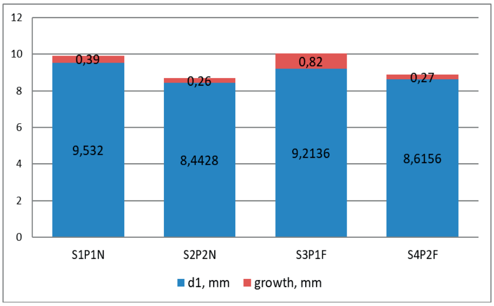

Figure 7. Average diameters measured at planting (d_1) and growth in 2023

Figure 8 presents the average heights of all 100 seedlings measured at the start and end of the 2023 growing season.

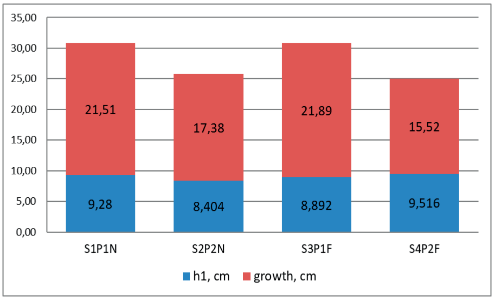

Figure 8. Average heights measured at planting (h_1) and growth in 2023

The primary data, recorded for 25 individuals from variant A (no slope, unfertilized), indicate that the seedlings' heights at the end of the first growing season ranged from 22 to 42 cm, with a coefficient of variation of 14.8%, reflecting medium variability.

The calculation and interpretation of results from the bifactorial experiments involve the following factors:

- Factor A: Fertilization method, with two levels: N (unfertilized) and F (fertilized).

- Factor B: Slope, with two levels: P1 (0-10°) and P2 (>10°).

The experiment was conducted using a randomized block design with 25 replications (n = b = 25). The total number of experimental variants (v = 4) was determined by multiplying the levels of the two factors (2 x 2 = 4).

Each plot consisted of 25 seedlings, and the average height growth for each replication area was calculated by averaging the measurements taken from all 25 seedlings within that plot.

Analysis of variance for the bifactorial experiment (2 x 2) with slope and fertilization mode is given in Table 2.

Table 2. Analysis of variance for the bifactorial experiment (2 x 2) with slope and fertilization mode

Cause of variability	SP	DF	s^2	Sample F		5%	1%
Total	2223.24	99					
Blocks	544.0196	24				5%	1%
Fertilization	13.7641	1	13.76	1.05	<	3.98	7.01
Slope	689.0625	1	689.06	52.50	>	3.98	7.01
Fertilization x slope	31.47	1	31.47	2.40	<	3.98	7.01
Error	944.92	72	13.124				

According to the data from Table 2 it can be seen that the calculated F values for slope exceed the theoretical F values at the $P_{5\%}$ level. This indicates that the slope factor significantly influences seedling height growth in the first year after planting.

The significance of the differences between the variants is assessed in the following. Since multiple types of comparisons can be made, the analysis of variance method enables the calculation of s_d and LSD (Least Significant Difference) values for each comparison. In Table 3, the variants are compared to a control variant.

Table 3. Summary of the results

No. Var	Variant name	hm, cm	h rel, %	± d, cm	Significance of difference
11	NP1 (Mt)	21.5	100.0	-	-
12	NP2	17.4	80.8	-4.1	ooo
21	FP1	21.9	101.8	0.4	-
22	FP2	15.5	72.1	-6.0	ooo

LSD 5%= 2.04
LSD 1%= 2.72
LSD 5%= 3.51

A highly significant difference in seedling height growth was observed on a steep slope compared to the control variant (unfertilized NP1 on a gentle slope).

As for post-planting survival, the losses were minimal, with only 1% (1 seedling out of 100) drying out.

The health status of the 124 saplings planted in 2008-2009, in the same area is given in Table 4.

Table 4. Assessment of the health status of trees planted in 2008-2009

Slope categories	No. of sampling plot	Mechanical (physical) injuries, injury degree 0-3						Defoliation [%]	Discoloration [%]
		Animals	Insects	Fungi	Abiotic	Anthropogenic	Others		
slope < 5	S1	-	0.00	1.67	0.00	-	-	26.11	31.11
	S2	-	0.10	2.05	0.10	-	-	32.38	36.43
	Mean	-	0.05	1.86	0.05	-	-	29.25	33.77
slope 5…15	S1	-	0.06	1.56	0.17	-	-	25.00	39.50
	S2	-	0.14	1.68	0.14	-	-	25.91	31.14
	Mean	-	0.10	1.62	0.15	-	-	25.45	35.32
slope > 15	S1	-	0.04	1.42	0.13	-	-	1.42	20.83
	S2	-	0.10	1.76	0.14	-	-	27.38	32.62
	Mean	-	0.07	1.59	0.13	-	-	14.40	26.73

The degree of damage caused by insects is very low, between 0.05-0.10 (on a scale from 0 to 3), the maximum being recorded on surfaces with medium slopes. Similar results were recorded also in the case of the damage due to abiotic factors, the values being between 0.05 and 0.15. The presence of fungi led to the appearance of weak to medium damages, respectively 1.59 on large slopes and 1.86 on small slopes (on a scale from 0 to 3).

Regarding the degree of defoliation and discoloration, the observed values are shown in Figure 9.

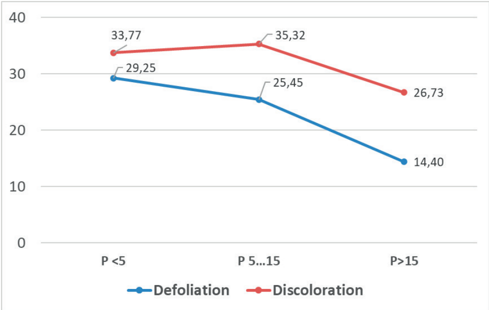

Figure 9. Degrees of defoliation and discoloration of trees (in %) on the 3 slope categories (P)

CONCLUSIONS

Black pine seedlings of Austrian origin planted in 2023 have a high survival rate (99%) compared to those from 2008-2009, where the degree of survival after 13-14 years after planting was 72-96%, depending on the slope, as it was previously reported (Bodea et al., 2023).

Although the one-year-old seedlings planted in 2023 were grown in pots (containers) and the planting holes were relatively large (40 x 40 x 40 cm), the fertilizers applied to half of the seedlings did not impact their growth in diameter or height. However, the slope was a significant factor that influenced growth.

In the case of the trees planted in 2008-2009, and analysed in January 2025, the average degree of tree damage caused by fungi was 1.69 on a scale from 0 to 3. They exhibit symptoms of successive or complex diseases, resulting from the simultaneous presence of multiple pathogens, including *Dothistroma pini* Hulbary, *Lophodermium pinastri* (Schrad.) Chevall., *Sphaeropsis sapinea* (Fr.:Fr) Dyko & Sutton in Sutton, and *Cyclaneusma minus* (Butin) DiCosmo, Peredo and Minter.

These combined infections contribute to the gradual deterioration of the trees and may accelerate the decline of pine trees in the Recea Mine tailings dump.

On the small slope, the degree of defoliation is the highest, namely 29.25%. Needle discoloration is more pronounced and affects pine specimens, the degree of discoloration being over 33% on small and medium slopes.

The main factors limiting their development are drought and the deficiency of nutrients in the soil. In addition, the attack of foliar fungi reduces the ability of trees to carry out photosynthesis, which leads to a lower intake of nutrients, slower growth and increased vulnerability to stress factors.

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