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METHODOLOGICAL ARTICLE

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Some aspects of the methodological approach in the progeny testing of European larch in Poland

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Abstract

In Poland, the tree improvement programme was initiated in 2004, but the trials for European larch (*Larix decidua* Mill.) did not start until 2021. Our aim is to present certain aspects of the methodological approach of progeny testing for this species. The European larch, known for its rapid growth among native coniferous trees in Europe, holds great promise for forest breeding. Unfortunately, its natural range in Poland is limited, with rare but well-known valuable provenances. In 2023, six progeny tests were established using the same 130 open-pollinated families, derived from plus trees originating from valuable seed regions (Md51, Md61, Md71) and areas below 52° N latitude. After a decade of growth, the results will be used to identify valuable genotypes and establish advanced-generation seed orchards.

Key words

progeny test trial, half-sib families, common garden test, progeny of plus trees

Introduction

The genetic value of an individual tree is not the same as its phenotypic value. The most effective way to assess the genetic value of a provenance or a particular tree (referred to as seed sources) is to evaluate its progeny (Sabor 2002; White et al. 2007). Therefore, forest tree breeding programmes are being developed, in which selected seed sources are tested under different environmental conditions. The goal of these programmes is to evaluate the breeding (genetic) value of the tested material and to identify provenances or genotypes whose progenies have significantly better growth and quality traits and lower susceptibility to biotic and abiotic factors.

In Poland, a 'Programme for Progeny Testing of Selected Seed Stands, Plus Trees, Clonal Seed Orchards, and Seedling Seed Orchards' (hereafter referred to as the 'Tree Improvement Programme') was developed and approved in 2004 (Sabor et al. 2004). The implementation of the programme was started in 2005 by order of the State Forests National Forest Holding. Since then, genetic units (selected seed stands and plus trees) have been selected, seeds collected and seedlings produced, while sites for provenance and progeny testing have been selected and such trials established. From the beginning, the programme was coordinated by the Forest Research Institute (IBL) and implemented in cooperation with Institute of Dendrology of the Polish Academy of Sciences (ID PAN), Poznań University of Life Sciences (UP Poznan), University of Agriculture in Krakow (UR Kraków) and Warsaw University of Life Sciences (SGGW). The first set of provenance trials un-

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der the Tree Improvement Programme was established in 2006. By the end of 2023, a total of 209 provenance and progeny trials had been established. In particular, there are a series of trials for five species: *Fagus sylvatica* L., *Pinus sylvestris* L., *Abies alba* Mill., *Picea abies* (L.) H.Karst and *Larix decidua* Mill. However, activities for European larch (*Larix decidua* Mill.) did not begin until 2021. The goal of this paper is to present some aspects of the methodological approach in the Tree Improvement Programme for this species.

Studies on European larch

European larch is a coniferous tree species that currently accounts for 1.6% of the total wood supply in Polish forests. Its share has gradually increased in recent decades (FAO 2020). It is believed that its distribution was once more extensive, and some of its habitats were cleared for agricultural purposes (Tyszkiewicz 1972). European larch thrives in moderately fertile habitats with favourable water and air conditions; however, it is not well suited to dry or excessively wet sites (Leibundgut 1992; Bellon and Andrzejczyk 2000). This light-demanding species is well suited for introduction into open areas on post-agricultural lands and for forest tree plantations (Andrzejczyk et al. 2011). It exhibits rapid growth, with an early peak in both current (25 years) and average (55 years) volume increment (Burschel and Huss 2003). On fertile habitats (Lśw according to Święcicki 2012), the species can reach a volume of 350-400 m^3 at the age of 40 years (Bellon and Andrzejczyk 2000). European larch wood is widely used for the production of wood-based materials, joinery, furniture, building facades and decking. In the past, it was highly valued in sacred buildings (Kozakiewicz 2020). Due to its fast growth and multiple possibilities for economic use of the wood, the species seems to be one of the most promising forest tree species in the Polish Tree Improvement Programme. The greatest difficulty in selecting suitable genetic material is that Japanese larch (*Larix kaempferi* Sarg., *Larix leptolepis* (Sieb. i Zucc.) Gord., *Larix japonica* Carr.) was previously introduced into Polish forests. Japanese larch has the ability to form hybrids with European larch, which can lead to the displacement of valuable native provenances (Filipiak 1996).

The first provenance test trials were set up in the early 19th century (Giertych 1991; Chałupka 2023). Since then, numerous trials have been conducted to evaluate both local provenances and provenances from different geographical regions of Europe. According to L. Pâques (2013), the most important milestones in larch breeding were the IUFRO (International Union of Forest Research Organizations) international trials, particularly the 1940/44 and 1956/58 series. In Poland, studies on European larch provenances have focused mainly on growth traits (DBH – diameter at breast height, height, volume), quality traits (stem straightness) and health traits (resistance to larch canker) (Bellon et al. 1983; Kowalczyk and Matras 1999; Barzdajn 2000; Kulej 2000; Szeligowski et al. 2010). The results show that Polish populations have good adaptation and growth characteristics. However, special attention should be paid to the qualitative traits, especially to the straightness of the stem (Pâques 2013). The most valuable populations come from a few seed regions (Md51, Md61, Md71; Fig. 1.; Rozporządzenie 2015) within the natural range of European larch. Unfortunately, little is known about the individual variability of this species in Poland and a few studies have been conducted but not yet published. Large-scale progeny testing did not begin until 2021.

Testing the progeny of European larch plus trees

In Poland, long-term storage of forest tree seeds is carried out by the Forest Gene Bank in Kostrzyca (Sobierajski 2004). In the initial phase of progeny testing for European larch, an analysis of seed collections available at the Forest Gene Bank in Kostrzyca was conducted. The analysis focused on European larch plus trees. The available seed collections, categorised by seed zone for this species, are listed in Table 1 and the distribution of plus trees is shown in Figure 1.

Table 1. Description of the European larch seed stock available in the Forest Gene Bank in Kostrzyca (as of November 2021)

Seed region	Md10	Md20	Md50	Md51	Md61	Md71	Total
Seed weight (kg)	14.44	4.03	5.65	0.44	0.40	13.42	38.38
Number of plus trees	172	58	28	16	17	79	370

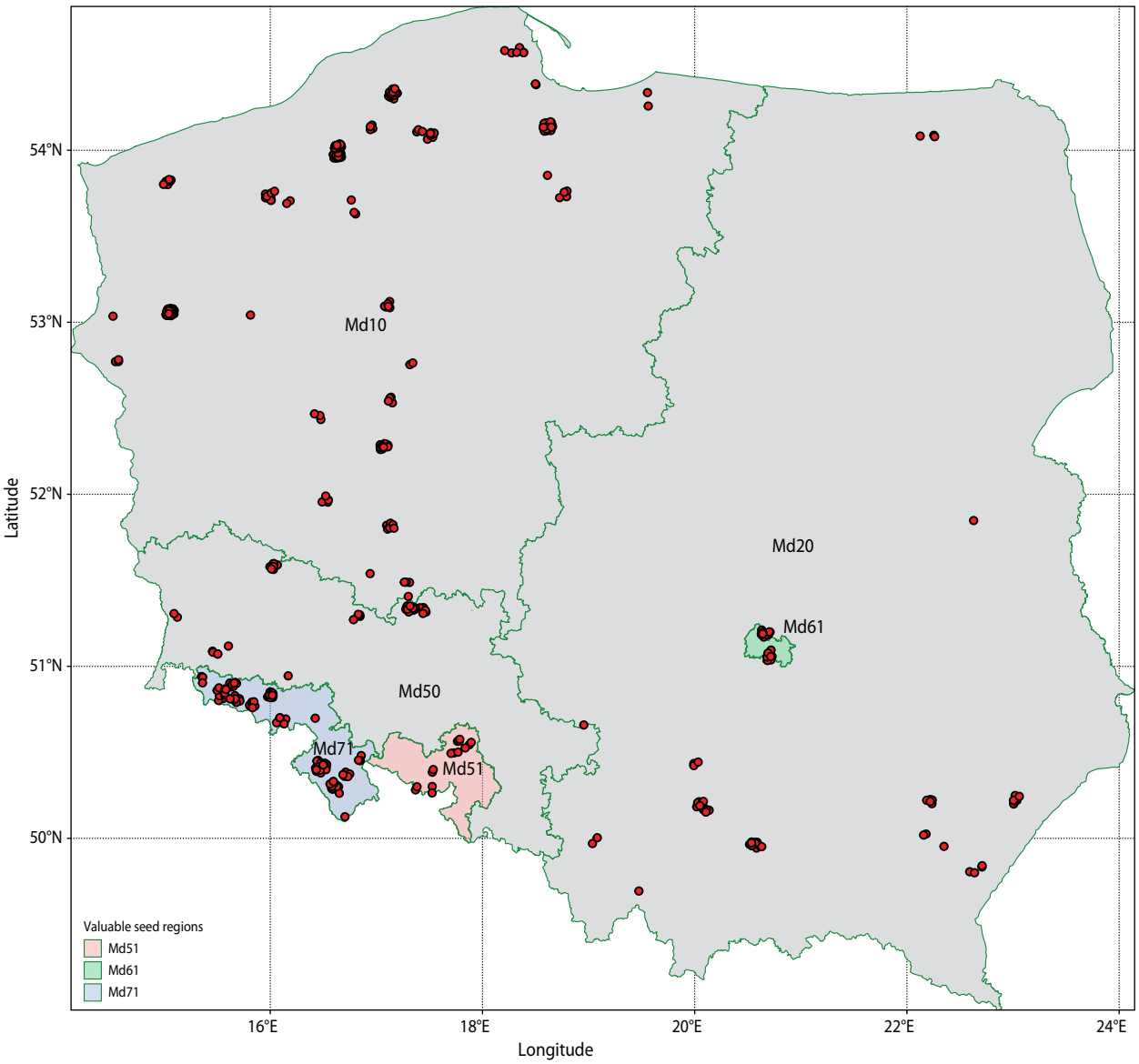

Figure 1. Seed regions of European larch in Poland and the locations of plus trees (red dots) whose seeds were available in the Forest Gene Bank in Kostrzyca (data as of November 2021). Green lines indicate the boundaries of seed regions (Rozporządzenie 2015), and the most valuable seed regions are additionally filled with different colours.

According to the Forest Gene Bank, a total of 370 seed collections obtained from the European larch plus trees were available. It is important to know that this species has a low germination rate. In some Polish provenances, the germination rate is often between 20–40% and the average weight of 1,000 seeds is typically between 4 and 5 g (Załęski 2002). The progeny tests required 10 g of seed from each plus tree, and most seed collections met this requirement; however, not all plus trees were included in the tests. Only the plus trees from the most valuable seed regions (Md51, Md61, Md71) and some other plus trees from areas below 52° N latitude were included in the tests (Fig. 1). This approach was determined by the existing knowledge about the variability of the European larch and the lower proportion of hybrids with Japanese larch in the forests of this region in Poland (Filipiak 1996; Pâques 2013). For this reason, a total of 130 plus trees were selected across three Regional Directorates of State Forests (RDLP): Katowice, Radom and Wrocław (Tab. 2). The largest number of

Table 2. Description of plus trees' seed collections categorised by RDLP (Regional Directorates of State Forests), seed regions and the year when seeds were harvested

Seed region	1998	2000	2004	2005	2006	2007	2008	2010	2011	2012	2013	2014	2017	Total
RDLP Katowice			3	3	2		2	3			3			16
Md51			3	3	2		2	3			3			16
RDLP Radom												3		3
Md61												3		3
RDLP Wrocław	59	2		13	3	8	6	8	1	2	2		7	111
Md10	4													4
Md50	11	1		2	1	4	4	3	1	1				28
Md71	44	1		11	2	4	2	5		1	2		7	79
Total	59	2	3	16	5	8	8	11	1	2	5	3	7	130

plus trees (111) for the test was chosen from the area of RDLP Wrocław. These plus trees were selected from three seed regions: Md10 (four trees), Md50 (28 trees) and Md71 (79 trees). A total of 19 plus trees were chosen from two other RDLPs: Katowice (16 plus trees, all from seed region Md51) and Radom (three plus trees, all from seed region Md61).

Seeds for a large group of plus trees (59) were collected in 1998, roughly 24 years before sowing took place. This is the only year when seeds were collected for such a large number of plus trees. For the other plus trees (71), the seeds were collected between 2000 and 2017 (Tab. 2).

The obtained seeds were planted in a container nursery in Jarocin Forest District (N: 51.9797; E: 17.4868) in the spring of 2022 (on May 10–11). During seeding, there were concerns about poor performance, primarily due to the long storage time of some seed collections (Tab. 2 and 3) and the limitations of small seed collections that prevented a standard germination test to assess seed viability (Tab. 3). However, the seed germination exceeded all fears, and the seedlings grew well, reaching satisfactory parameters by the end of the growing season. Furthermore, the root system of the seedlings developed well, which was very important for planting.

Table 3. Description of plus trees and seed collections used for establishing European larch progeny test trials

No. of plus tree	KRLMP ID[1]	IBL ID[2]	Seed region	Forest District[3]	Seed collection ID	Date of seed collection	Seed weight (kg)
1	2	3	4	5	6	7	8
1	MP/3/39622/05	16	Md61	Suchedniów	23/ZP/14-D16	23-10-2014	0.023
2	MP/3/38699/05	112	Md71	Zdroje	472/ZP/97-D112	25-05-1998	0.147
3	MP/3/38698/05	113	Md71	Zdroje	8/ZP/10-D113	26-11-2010	0.028
4	MP/3/38697/05	114	Md71	Zdroje	473/ZP/97-D114	25-05-1998	0.559
5	MP/3/38693/05	115	Md71	Zdroje	474/ZP/97-D115	25-05-1998	0.070
6	MP/3/38692/05	116	Md71	Zdroje	9/ZP/10-D116	26-11-2010	0.179
7	MP/3/38696/05	117	Md71	Zdroje	10/ZP/10-D117	26-11-2010	0.020
8	MP/3/38691/05	118	Md71	Zdroje	475/ZP/97-D118	25-05-1998	0.140
9	MP/3/38695/05	119	Md71	Zdroje	476/ZP/97-D119	25-05-1998	0.215

1	2	3	4	5	6	7	8
10	MP/3/38694/05	120	Md71	Zdroje	477/ZP/97-D120	25-05-1998	0.245
11	MP/3/38704/05	121	Md71	Zdroje	478/ZP/97-D121	25-05-1998	0.240
12	MP/3/38705/05	122	Md71	Zdroje	479/ZP/97-D122	25-05-1998	0.492
13	MP/3/38706/05	124	Md71	Zdroje	480/ZP/97-D124	25-05-1998	0.208
14	MP/3/38707/05	125	Md71	Zdroje	482/ZP/97-D125	25-05-1998	0.317
15	MP/3/38711/05	126	Md71	Zdroje	148/ZP/07-D126-TP	17-10-2007	0.007
16	MP/3/38639/05	127	Md71	Bystrzyca K.	450/ZP/97-D127	25-05-1998	0.019
17	MP/3/38640/05	128	Md71	Bystrzyca K.	451/ZP/97-D128	25-05-1998	0.140
18	MP/3/38646/05	129	Md71	Bystrzyca K.	452/ZP/97-D129	25-05-1998	0.308
19	MP/3/38644/05	130	Md71	Bystrzyca K.	456/ZP/97-D130	25-05-1998	0.403
20	MP/3/38645/05	131	Md71	Bystrzyca K.	458/ZP/97-D131	25-05-1998	0.153
21	MP/3/33379/05	477	Md51	Prószków	154/ZP/13-D477	09-07-2013	0.021
22	MP/3/33382/05	480	Md51	Prószków	155/ZP/13-D480	09-07-2013	0.018
23	MP/3/33371/05	496	Md51	Prószków	133/ZP/05-D496	18-10-2006	0.026
24	MP/3/33374/05	499	Md51	Prószków	407/ZP/01-D499	03-08-2004	0.034
25	MP/3/33375/05	500	Md51	Prószków	408/ZP/01-D500	21-01-2004	0.034
26	MP/3/33376/05	501	Md51	Prószków	409/ZP/01-D501	21-01-2004	0.020
27	MP/3/33306/05	512	Md51	Prószków	841/ZP/10-D512	24-11-2010	0.027
28	MP/3/33305/05	523	Md51	Prószków	842/ZP/10-D523	24-11-2010	0.013
29	MP/3/33277/05	540	Md51	Prudnik	1448/ZP/07-D540-TP	05-08-2008	0.004
30	MP/3/33279/05	542	Md51	Prudnik	1449/ZP/07-D542-TP	05-08-2008	0.003
31	MP/3/33262/05	545	Md51	Prudnik	132/ZP/05-DD545	14-07-2005	0.090
32	MP/3/33265/05	549	Md51	Prudnik	134/ZP/05-DD549	20-06-2005	0.020
33	MP/3/38854/05	1598	Md50	Lwówek Śl.	499/ZP/97-D1598	10-04-1998	0.136
34	MP/3/38855/05	1599	Md50	Lwówek Śl.	500/ZP/97-D1599	10-04-1998	0.084
35	MP/3/38856/05	1601	Md50	Lwówek Śl.	501/ZP/97-D1601	10-04-1998	0.716
36	MP/3/38956/05	1611	Md71	Śnieżka	170/ZP/05-DD1611	27-05-2005	0.546
37	MP/3/38955/05	1612	Md71	Śnieżka	164/ZP/05-DD1612	20-06-2005	0.112
38	MP/3/39644/05	1836	Md61	Suchedniów	602/ZP/13-D1836	23-10-2014	0.043
39	MP/3/33269/05	2047	Md51	Prudnik	130/ZP/05-D2047	18-10-2006	0.085
40	MP/3/33307/05	2049	Md51	Prószków	840/ZP/10-D2049	24-11-2010	0.015
41	MP/3/33378/05	2051	Md51	Prószków	156/ZP/13-D2051	09-07-2013	0.016
42	MP/3/38902/05	2488	Md10	Milicz	407/ZP/97-D2488	20-03-1998	1.002
43	MP/3/38904/05	2490	Md10	Milicz	405/ZP/97-D2490	20-03-1998	0.687
44	MP/3/38906/05	2492	Md10	Milicz	403/ZP/97-D2492	20-03-1998	0.262
45	MP/3/38743/05	2496	Md50	Oleśnica Śl.	274/ZP/05-D2496	15-11-2007	0.082

1	2	3	4	5	6	7	8
46	MP/3/38741/05	2497	Md50	Oleśnica Śl.	424/ZP/97-D2497	20-03-1998	0.051
47	MP/3/38742/05	2498	Md50	Oleśnica Śl.	919/ZP/07-D2498-TP	19-02-2008	0.018
48	MP/3/38744/05	2502	Md50	Oleśnica Śl.	267/ZP/05-D2502	23-08-2007	0.016
49	MP/3/38725/05	2503	Md50	Oleśnica Śl.	263/ZP/05-D2503	15-03-2006	0.594
50	MP/3/38726/05	2504	Md50	Oleśnica Śl.	270/ZP/05-D2504	23-08-2007	0.066
51	MP/3/38864/05	2507	Md50	Lwówek Śl.	180/ZP/10-D2507	23-11-2010	0.038
52	MP/3/38596/05	2703	Md71	Bardo Śl.	105/ZP/13-D2703	09-07-2013	0.025
53	MP/3/38595/05	2704	Md71	Bardo Śl.	504/ZP/09-D2704	26-11-2010	0.017
54	MP/3/38642/05	2706	Md71	Bystrzyca K.	460/ZP/97-D2706	25-05-1998	0.099
55	MP/3/38641/05	2708	Md71	Bystrzyca K.	463/ZP/97-D2708	25-05-1998	0.162
56	MP/3/38635/05	2710	Md71	Bystrzyca K.	466/ZP/97-D2710	25-05-1998	0.022
57	MP/3/38634/05	2711	Md71	Bystrzyca K.	467/ZP/97-D2711	25-05-1998	0.013
58	MP/3/38638/05	2712	Md71	Bystrzyca K.	468/ZP/97-D2712	25-05-1998	0.431
59	MP/3/38637/05	2713	Md71	Bystrzyca K.	470/ZP/97-D2713	25-05-1998	0.008
60	MP/3/38636/05	2714	Md71	Bystrzyca K.	471/ZP/97-D2714	25-05-1998	0.006
61	MP/3/38871/05	2718	Md71	Międzylesie	498/ZP/97-D2718	25-05-1998	0.292
62	MP/3/38714/05	2719	Md71	Zdroje	483/ZP/97-D2719	25-05-1998	0.218
63	MP/3/38703/05	2720	Md71	Zdroje	484/ZP/97-D2720	25-05-1998	0.544
64	MP/3/38700/05	2721	Md71	Zdroje	485/ZP/97-D2721	25-05-1998	0.162
65	MP/3/38972/05	2752	Md71	Wałbrzych	437/ZP/97-D2752	10-04-1998	0.013
66	MP/3/38786/05	2754	Md71	Kamienna G.	74/ZP/08-D2754-TP	01-08-2008	0.010
67	MP/3/38798/05	2755	Md71	Kamienna G.	440/ZP/97-D2755	10-04-1998	0.168
68	MP/3/38797/05	2756	Md71	Kamienna G.	441/ZP/97-D2756	10-04-1998	0.092
69	MP/3/38950/05	2757	Md71	Śnieżka	171/ZP/05-DD2757	20-06-2005	0.429
70	MP/3/38949/05	2758	Md71	Śnieżka	172/ZP/05-DD2758	20-06-2005	0.324
71	MP/3/38948/05	2760	Md71	Śnieżka	173/ZP/05-DD2760	20-06-2005	0.435
72	MP/3/38861/05	2763	Md50	Lwówek Śl.	503/ZP/97-D2763	10-04-1998	0.551
73	MP/3/38859/05	2765	Md50	Lwówek Śl.	505/ZP/97-D2765	10-04-1998	0.353
74	MP/3/38858/05	2766	Md50	Lwówek Śl.	506/ZP/97-D2766	10-04-1998	0.123
75	MP/3/38745/05	2769	Md50	Jawor	240/ZP/10-D2769	21-12-2011	0.018
76	MP/3/40494/05	2773	Md50	Pieńsk	643/ZP/97-D2773	22-08-2000	0.075
77	MP/3/38724/05	2780	Md50	Głogów	416/ZP/97-D2780	20-03-1998	0.181
78	MP/3/38720/05	2782	Md50	Głogów	414/ZP/97-D2782	20-03-1998	0.165
79	MP/3/38721/05	2783	Md50	Głogów	412/ZP/97-D2783	20-03-1998	0.079
80	MP/3/38722/05	2784	Md50	Głogów	540/ZP/11-D2784	10-05-2012	0.017
81	MP/3/38918/05	3018	Md50	Oborniki Śl.	274/ZP/10-D3018	23-11-2010	0.009

1	2	3	4	5	6	7	8
82	MP/3/38916/05	3020	Md50	Oborniki Śl.	275/ZP/10-D3020	23-11-2010	0.052
83	MP/3/38917/05	3021	Md50	Oborniki Śl.	427/ZP/97-D3021	20-03-1998	0.672
84	MP/3/38734/05	3029	Md50	Oleśnica Śl.	261/ZP/05-D3029	23-08-2007	0.078
85	MP/3/38733/05	3033	Md50	Oleśnica Śl.	909/ZP/07-D3033-TP	19-02-2008	0.056
86	MP/3/38727/05	3034	Md50	Oleśnica Śl.	910/ZP/07-D3034	19-02-2008	0.079
87	MP/3/38730/05	3038	Md50	Oleśnica Śl.	272/ZP/05-DD3038	14-07-2005	0.162
88	MP/3/38731/05	3039	Md50	Oleśnica Śl.	911/ZP/07-D3039-TP	19-02-2008	0.046
89	MP/3/38732/05	3040	Md50	Oleśnica Śl.	262/ZP/05-DD3040	20-06-2005	0.322
90	MP/3/38910/05	3045	Md10	Milicz	400/ZP/97-D3045	20-03-1998	0.146
91	MP/3/38784/05	3283	Md71	Kamienna G.	442/ZP/97-D3283	10-04-1998	0.366
92	MP/3/38795/05	3288	Md71	Kamienna G.	443/ZP/97-D3288	10-04-1998	0.079
93	MP/3/38796/05	3289	Md71	Kamienna G.	445/ZP/97-D3289	10-04-1998	0.204
94	MP/3/38690/05	3579	Md71	Zdroje	11/ZP/10-D3579	26-11-2010	0.021
95	MP/3/38702/05	3580	Md71	Zdroje	487/ZP/97-D3580	25-05-1998	0.317
96	MP/3/38701/05	3581	Md71	Zdroje	488/ZP/97-D3581	25-05-1998	0.494
97	MP/3/38708/05	3582	Md71	Zdroje	489/ZP/97-D3582	25-05-1998	0.031
98	MP/3/38709/05	3583	Md71	Zdroje	490/ZP/97-D3583	25-05-1998	0.008
99	MP/3/38713/05	3584	Md71	Zdroje	491/ZP/97-D3584	25-05-1998	0.051
100	MP/3/38710/05	3585	Md71	Zdroje	492/ZP/97-D3585	25-05-1998	0.030
101	MP/3/38712/05	3586	Md71	Zdroje	493/ZP/97-D3586	25-05-1998	0.009
102	MP/3/38689/05	3587	Md71	Zdroje	494/ZP/97-D3587	25-05-1998	0.236
103	MP/3/39635/05	4097	Md61	Suchedniów	603/ZP/13-D4097	23-10-2014	0.050
104	MP/3/33270/05	5635	Md51	Prudnik	131/ZP/05-DD5635	14-07-2005	0.019
105	MP/3/38931/05	6848	Md71	Szklarska P.	197/ZP/17-D6848	26-04-2017	0.049
106	MP/3/38924/05	6850	Md71	Szklarska P.	642/ZP/97-D6850	22-08-2000	0.062
107	MP/3/38936/05	6851	Md71	Szklarska P.	821/ZP/07-D6851	24-02-2017	0.019
108	MP/3/38933/05	6852	Md71	Szklarska P.	160/ZP/07-D6852	24-02-2017	0.037
109	MP/3/38935/05	6853	Md71	Szklarska P.	34/ZP/12-D6853	10-05-2012	0.023
110	MP/3/38934/05	6854	Md71	Szklarska P.	26/ZP/05-D6854	12-04-2006	0.415
111	MP/3/46964/06	6855	Md71	Świeradów	815/ZP/07-D6855-TP	27-08-2007	0.016
112	MP/3/46965/06	6856	Md71	Świeradów	816/ZP/07-D6856-TP	27-08-2007	0.039
113	MP/3/46966/06	6857	Md71	Świeradów	817/ZP/07-D6857-TP	27-08-2007	0.049
114	MP/3/38783/05	6888	Md71	Kamienna G.	446/ZP/97-D6888	10-04-1998	0.078
115	MP/3/38782/05	6889	Md71	Kamienna G.	447/ZP/97-D6889	10-04-1998	0.012
116	MP/3/38779/05	6891	Md71	Kamienna G.	448/ZP/97-D6891	10-04-1998	0.177
117	MP/3/38780/05	6892	Md71	Kamienna G.	449/ZP/97-D6892	10-04-1998	0.034

1	2	3	4	5	6	7	8
118	MP/3/38781/05	6893	Md71	Kamienna G.	69/ZP/08-D6893-TP	18-09-2008	0.006
119	MP/3/38957/05	6904	Md71	Śnieżka	169/ZP/05-DD6904	20-06-2005	0.148
120	MP/3/38946/05	6906	Md71	Śnieżka	163/ZP/05-DD6906	25-05-2005	0.326
121	MP/3/38945/05	6907	Md71	Śnieżka	165/ZP/05-DD6907	25-05-2005	0.220
122	MP/3/38944/05	6908	Md71	Śnieżka	166/ZP/05-DD6908	14-07-2005	0.182
123	MP/3/38926/05	6911	Md71	Szklarska P.	163/ZP/07-D6911	24-02-2017	0.023
124	MP/3/38932/05	6912	Md71	Szklarska P.	198/ZP/17-D6912	26-04-2017	0.018
125	MP/3/38928/05	6943	Md71	Szklarska P.	199/ZP/17-D6943	26-04-2017	0.052
126	MP/3/38930/05	6945	Md71	Szklarska P.	67/ZP/12-D6945	10-01-2013	0.017
127	MP/3/38929/05	6946	Md71	Szklarska P.	823/ZP/07-D6946	24-02-2017	0.053
128	MP/3/38958/05	6956	Md71	Śnieżka	162/ZP/05-DD6956	20-06-2005	0.180
129	MP/3/38942/05	6957	Md71	Śnieżka	167/ZP/05-DD6957	13-07-2005	0.172
130	MP/3/38943/05	6958	Md71	Śnieżka	168/ZP/05-D6958	15-03-2006	0.034

[1] KRLMP ID – plus tree ID number according to National Register of Forest Basic Material (https://bnl.gov.pl/krajowy_rejestr_lesnego_materialu_podstawowego,109.asp); [2] IBL ID – plus tree id number according to Forest Research Institute documentation; [3] Bardo Śl. – Bardo Śląskie, Bystrzyca K. – Bystrzyca Kłodzka, Kamienna G. – Kamienna Góra, Lwówek Śl. – Lwówek Śląski, Oborniki Śl. – Oborniki Śląskie, Oleśnica Śl. – Oleśnica Śląska, Szklarska P. – Szklarska Poręba.

According to the general concept of the Tree Improvement Programme, the test trials are established in groups based on the seed zone requirements and seed transfer rules. Due to the small and scattered natural range of European larch in Poland (and numerous occurrences of hybrids with Japanese larch in the northern part of the country), the general concept of the Tree Improvement Programme for this species has been slightly modified. Specifically, the test regions were redefined to delineate the area where genetic material from the best Polish provenances could be used. As with other species, the trials were established under different site and climatic conditions, taking into account seed zones and seed transfer rules. The locations of the test trials were adapted to areas where the tested material can be effectively utilised, based on the results obtained and the relevant regulations for the transfer of forest reproductive material. In accordance with general assumption of the Tree Improvement Programme progeny test trials established with a single tree plot design. However, the spacing between planted trees was increased and changed from 1.5 × 1.5 to 2.0 × 2.0 m or 2.5 × 2.0 m to meet the principles of practical forestry and the requirements of the species.

The single tree plot design allows for consideration of microsite effects on planted seedlings that later grow into trees. For all progeny tests, we use the PLANTAGRAF program (Zajączkowski 1993) to define a spatial distribution design for seedlings at each site. PLANTAGRAF ensures that progeny of each plus tree is evenly distributed over the entire area of the experimental site. Next, all seedlings in the nursery are labelled according to their position in the row and column (Klisz and Jastrzębowski 2013).

In this series, seedlings were labelled in early spring 2023 under the supervision of the Department of Silviculture and Genetics of Forest Trees of Forest Research Institute. In accordance with the chosen design, an average of 50 seedlings from each open pollinated family were labelled and prepared for planting at each site. Seedlings were planted in April and May 2023 in six locations (Tab. 4 and Fig. 2) under the supervision of IBL (Kartuzy, Miastko, Bogdaniec and Wałbrzych Forest Districts), UP Poznań (Babki Forest District) and UR Kraków (Opole Forest District). Progeny test trials were set up in various forest site types (Tab. 4; Święcicki 2012). These included one trial each in a deciduous forest (Lśw), a mixed deciduous forest (LMśw),

Table 4. Description of European larch progeny test trials established in spring 2023

ID[1]	204/Md/ D/I/1/DM1	205/Md/ D/I/2/DM1	206/Md/ D/I/3/DM1	207/Md/ D/I/4/DM1	208/Md/ D/I/5/DM1	209/Md/ D/I/6/DM1
Testing region	I	I	I	I	I	I
Regional Directorate	Gdańsk	Szczecinek	Szczecin	Poznań	Katowice	Wrocław
Forest District	Kartuzy	Miastko	Bogdaniec	Babki	Opole	Wałbrzych
Forest Range	Wieżyca	Biały Bór	Bogdaniec	Babki	Krasiejów	Wałbrzych
Forestry	Sikorzyno	Biały Bór	Białcz	Mieczewo	Dąbrowice	Stare Bogaczowice
Compartment	167d	714a	559f	132d	24a	61m
Latitude (N)	54.1756	53.8878	52.6954	52.2531	50.7512	50.8231
Longitude (E)	18.0402	16.8133	14.9156	17.0161	18.3546	16.2121
Altitude (masl)[2]	207	184	57	94	236	476
Number of half-sib families	130	130	130	130	130	130
Total number of seedlings	6267	7503	6272	6267	6267	5482
Supervisor[3]	IBL	IBL	IBL	UP Poznań	UR Kraków	IBL
Forest site type[4]	R IV a	BMśw	BMśw	Lśw	LMśw	LMGśw
Land type	Agricultural land	Clear-cut	Clear-cut	Clear-cut	Clear-cut	Clear-cut
Spacing	2 × 2	2 × 2	2 × 2	2 × 2	2 × 2	2.5 × 2

[1] ID – trial ID according to the Forest Research Institute documentation; [2] Altitude (meters above sea level) defined with FreeMapTools according to the coordinates of the sites (https://www.freemaptools.com/elevation-finder.htm); [3] IBL – Forest Research Institute, UP Poznań – Poznan University of Life Sciences, UR Kraków – University of Agriculture in Krakow; [4] R IVa – arable soils of average quality (Class IV a; Rozporządzenie 2012), BMśw – mixed coniferous forests, LMśw – mixed deciduous forest, LMGśw – mixed deciduous mountain forest, Lśw – deciduous forest (Święcicki 2012).

Figure 2. Location of European larch progeny test trials (established spring 2023) with Forest District as labels (detailed trial descriptions in Tab. 4). Regional Directorates of State Forests (RDLP) boundaries in Poland indicated by gray lines

and a mixed deciduous mountain forest (LMGśw). Two trials were established in mixed coniferous forests (BMśw) and one trial was set up on former agricultural land. At five sites, a spacing of 2 × 2 m between seedlings was maintained, whereas in the Wałbrzych Forest District, a larger spacing of 2.5 × 2 m was chosen due to the complex terrain (higher elevation, uneven ground, and rocky soil).

The tested genotypes will be utilised for the establishment of seed orchards, and the following character-

istics will be considered in the evaluation of plus trees and their progenies:

– survival rate (defined as the percentage of live seedlings relative to seedlings planted in the trial; this trait will be analysed 1, 2, 5 and 10 years after planting);
– growth traits (total height 5 and 10 years after planting; DBH 10 years after planting) and
– qualitative traits (stem straightness, forking and multistems, branch thickness and crown width will be analysed 10 years after planting).

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