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RESISTANCE OF LARCHES OF POLISH PROVENANCES TO LARCH CANKER *LACHNELLULA WILLKOMMII* (HARTIG.) DENNIS UNDER MOUNTAIN CONDITIONS OF THE SACZ BESKID

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ABSTRACT

This study is a fragment of a long-term research on a genetic-silvicultural value of larches of Polish provenances (Table 1, Fig. 1) tested under mountain conditions of the Sšcz Beskid range within the All-Polish Provenance Experiment of Larch 1967. Investigations were based on numerical data on the degree of infection of trees of analyzed partial larch populations with a pathogen *Lachnellula willkommii* (Hartig.) Denis during 1984–1999, i.e. when trees were 20, 25, 30, and 35 years old. Results showed a significant diversification of tested provenances in respect of resistance to larch canker, and a certain tendency of its decrease with age of trees (Tables 2 and 3). Provenances of various regions of Poland were in the group of populations most susceptible to this disease, i.e. with trees showing symptoms above the experimental average (Fig. 3). The resistance to larch cancer of individual partial populations, under mountain conditions of the study area situated in experimental forests of Krynica, was in the first place determined by the genotype (Fig. 4). While the evaluation of the effect of the interaction genotype (provenance) x years of observation (age) pointed to a high stability of resistance to canker of larch populations of extreme values of this trait (Fig. 5). This creates, especially in the case of this provenance group, the possibilities to conduct the effective resistance selection in the early stage.

Key words: larch, provenance, selection, variation, resistance, interaction genotype (provenance) x years of observation (years).

INTRODUCTION AND STUDY AIM

The effect of origin of seeds on productivity of forest stands grown from them has been studied since long ago. Much attention in this respect has been paid to larch as a fast growing pioneer species, which should play a greater role in forestry than hitherto. The second reason for a special interest of larch is its scattered occurrence in Poland, in greater or smaller concentrations [2], which stimulated foresters to study its provenance diversity.

This study is a fragment of a long-term research in this respect, conducted by the Department of Tree Breeding, Agricultural University of Cracow, under the All-Polish Provenance Experiment of Larch 1967. This is the first

comparative experiment in Poland concerning larch growing under mountain conditions (the Sącz Beskid range), and including the largest number of provenance from the entire country, tested in Poland hitherto.

To date, the results on genetic variation of larch of different provenances showed that its silvicultural value depends, besides the growth dynamics and stem quality, also on health condition of trees, and especially on resistance to larch canker [7, 8, 10, 11, 12, 13, 19, 21, 24, 25, 26, 28, 29].

The purpose of this study was to determine the variation of susceptibility of larches of 20 partial populations, growing on the experimental area in Krynica, to larch canker *Lachnellula willkommii* (Hartig.) Dennis.

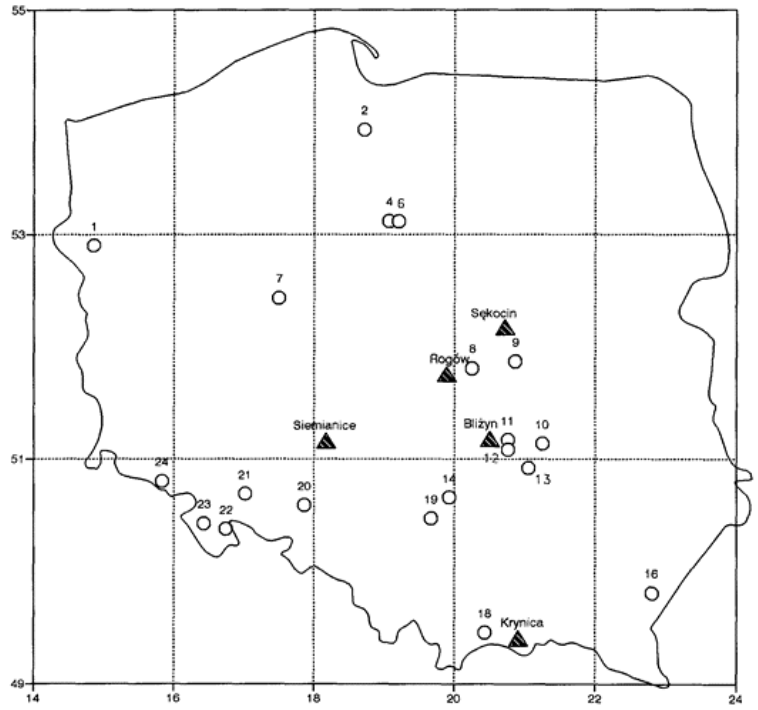
MATERIAL AND STUDY AREA

The study concerned 20 provenances from the entire area of Poland represented on the experimental area situated in the forest of the Forest Experimental Station in Krynica. The parental stands of analyzed provenances were growing on altitudes from 60 m to 660 m (Table 1). Their location is shown on Fig. 1.

Table 1. Location of parental stands of larches investigated on test site in Krynica within 1967 All-Polish Provenance Experiment of Larch; 1-24- numbering of provenances according to Kocięcki [6]

Prov. No	Provenance name	Geographical coordinates		Altitude [m]	Natural-forest region	Natural-forest province
		latitude	longitude			
1	Myślibórz-Północ	52°54’	14°52’	50–75	I – Bałtycka	Niziny Szczecińskiej
2	Pelplin	53°56’	18°43’	50–75	I – Bałtycka	Pojezierza Drawsko-Kaszubskiego
4	Konstancjewo “Płonne”	53°07’	19°04’	50–75	III – Wielkopolsko-Pomorska	Pojezierza Chełmińsko-Dobrzyńskiego
6	Konstancjewo “Tomkowo”	53°07’	19°04’	50–75	III – Wielkopolsko-Pomorska	Pojezierza Chełmińsko-Dobrzyńskiego
7	Czerniejewo	52°26’	17°30’	100–120	III – Wielkopolsko-Pomorska	Niziny Wielkopolsko-Kujawskiej
8	Rawa Mazowiecka	51°48’	20°15’	180	IV – Mazowiecko-Podlaska	Równiny Warszawsko-Kutnowskiej
9	Grójec	51°52’	20°52’	180	IV – Mazowiecko-Podlaska	Równiny Warszawsko-Kutnowskiej
10	Marcule	51°08’	21°15’	200–220	VI – Małopolska	Radomsko-Iłżecka
11	Skarżysko	51°10’	20°46’	350–400	VI – Małopolska	Gór Świętokrzyskich
12	Bliżyn	51°05’	20°45’	280–320	VI – Małopolska	Gór Świętokrzyskich
13	Świętokrzyski PN	50°55’	21°04’	300–400	VI – Małopolska	Gór Świętokrzyskich
14	Moskorzew	50°39’	19°56’	250	VI – Małopolska	Wyżyny Środkowomałopolskiej
16	Hołubla	49°48’	22°48’	300–350	VIII – Karpacka	Pogórza Karpackiego
18	Krościenko	49°27’	20°26’	640–660	VIII – Karpacka	Gorców i Beskidu Sądeckiego
19	Pilica	50°28’	19°40’	450	VI – Małopolska	Wyżyny Krakowsko-Częstochowskiej
20	Prószków	50°35’	17°52’	180	V – Śląska	Równiny Opolskiej
21	Henryków	50°41’	17°01’	300–350	V – Śląska	Przedgórza Sudeckiego i Płaskowyżu Głubczyckiego
22	Kłodzko	50°22’	16°45’	300–450	VII – Sudecka	Sudetów Środkowych
23	Szczytna Śląska	50°25’	16°26’	500–550	VII – Sudecka	Sudetów Środkowych
24	Kowary	50°48’	15°50’	500–550	VII – Sudecka	Sudetów Zachodnich

Fig. 1. Location of parental stands of larches of provenances investigated on test site at Krynica Experimental Forest Station; O – location of provenances, p – location of test sites, 1–24 – provenance number and name: 1 – Myslibórz Północ, 2 – Pelplin, 4 – Konstancjewo "Płonne", 6 – Konstancjewo "Tomkowo", 7 – Czerniejewo, 8 – Rawa Mazowiecka, 9 – Grójec, 10 – Marcule, 11 – Skarżysko, 12 – Bliżyn, 13 – Swiętokrzyski Park Narodowy, 14 – Moskorzew, 16 – Hołubla, 18 – Kroscienko, 19 – Pilica, 20 – Prószków, 21 – Henryków, 22 – Kłodzko, 23 – Szczytna Slšska, 24 – Kowary



The experimental area is situated in VIII – Carpathian natural-forest region, province of the Gorce and Sącz Beskid ranges, in Wojkowa forest section of the Forest Experimental Station in Krynica (altitude 785 m, longitude 20°21' E, latitude 49°21' N). Its site represents the mountain forest site type. The tested partial populations were planted in five replications (100 plots, each 20x20 m) in arrangement of a "Latin rectangle". A detailed characteristics of the parental stands and trees of larches of tested provenances may be found in an earlier paper of the author [11].

METHODS

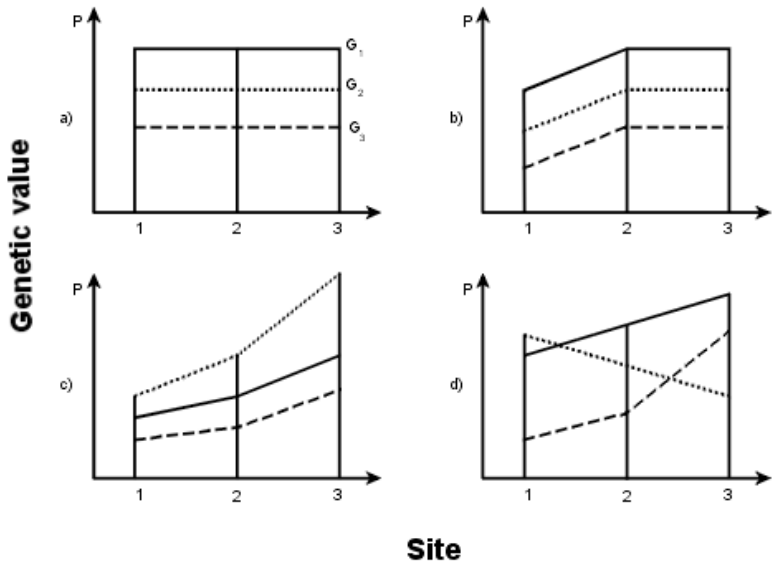
The resistance to larch canker of the provenances under investigations was determined on the basis of the per cent of trees with disease symptoms of this pathogen. Observations covered the entire study material, i.e. 20 partial larch populations (in five replications), when trees were 20 (1984), 25 (1989), 30 (1994), and 35 (1999) years old. Only the disease symptoms present on the tree stem were recorded. Empirical data of the analyzed trait was characterized by the arithmetic mean, standard deviation, and coefficient of variation. In the statistical analysis of results, the transformation of values of the investigated trait expressed in per cent into angular units was made according to the formula : $phi = arcsin \sqrt{p}$ (with p – per cent value of analyzed trait).

The effect of the provenance (genotype) on the degree of infection of larch stems by larch canker was determined on the basis of the analysis of variance and Snedecor F test. The significance of differences was tested using the Duncan's test, at significance level $\alpha = 0.99$ [9].

The relationship between the resistance to larch canker and the elements of location of parental stands (latitude, altitude) was determined using coefficients of linear correlation. The verification level of coefficients obtained was determined on the basis of the Student's t-test [17].

The genetic effect of the investigated trait was determined by per cent of provenance variation in the total variation [4]. While the effect of interaction "genotype (provenance) x years of observation (age)" – G x E_{age} was analyzed on the basis of changes in ranking positions, and estimation of reactivity of larch of respective provenances according to the Gallais's classification, assumed after Sabor [18]; 1 – positive, 2 – negative, 3 – with modification of classification, 4 – a lack of age effect (Fig. 2).

Fig. 2. Reaction of genotypes ($G_{1,2,3}$) to three different forest sites (E); 1–3 – increasing productivity: a) no effect of forest site, b) additive effect of forest site and genotype, c) $G \times E$ interaction without change in rank, d) $G \times E$ interaction with change of rank (according to Gallais 1990)



RESULTS

Larches of Pilica and Henryków provenances turned out to be the most strongly attacked by larch canker *Lachnellula willkommii* (hartig.) Dennis during the study period 1984 – 1999, while the most resistant were larches from Skarżysko and Grójec. The coefficients of variation showed that the diversification of the analyzed trait was decreasing with age of trees – from V% = 45.44 for 20-year-old trees to V% = 19.5 for 35-year-old trees, while the number of trees with disease symptoms was increasing, and this means that intensity of this trait was increasing during consecutive years of observation. The difference between larches of the highest and the lowest degree of larch canker infection, when trees were 20, 25, 30, and 35 years old (1984–1999) was from 60 to 83% (Table 2).

The investigated larch populations varied statistically in respect of resistance to larch canker. It was found on the basis of the analysis of variance that this trait significantly varied among provenances during the entire 15-year period (1984–1999) at $\alpha = 0.01$.

In larches of Pilica, when trees were 35 years old, as many as 148 trees out of 156 tested, were attacked by the canker, i.e. 94.9% (Table 3). Also a high percentage of attacked trees was found for the provenances from Henryków (93.3%), Hołubla (81.3%), and Kroscienko (79.4%). While in the case of provenances: Konstancjewo-Tomkowo, Czerniejewo, and Pelplin the larch canker attacked 70.7 – 79.4% of trees. The least susceptible to this disease were larches from Skarżysko and Grójec (35.1 – 37.7% of attacked trees).

Table 2. The degree of infection of larches of investigated provenances by *Lachnellula willkommii* (Hart.) during the period from 1984 to 1999. phi* = arc sin√p, where p – percentage of traits

Prov. No	Provenence name	Study year and tree age							
		1984 20 years		1989 25 years		1994 30 years		1999 35 years	
		%	phi*	%	phi*	%	phi*	%	phi*
1	Myślibórz Północ	10.9	19.28	21.6	27.69	37.7	37.88	47.9	43.85
2	Pelpin	48.6	44.20	65.4	53.97	68.4	55.80	76.6	61.07
4	Konstancjewo - Płonne	17.9	25.03	31.4	34.08	39.4	38.88	62.6	52.30
6	Konstancjewo - Tomkowo	18.8	25.70	42.7	40.80	68.3	55.73	70.7	57.23
7	Czerniejewo	24.7	29.80	39.8	39.11	56.2	48.56	73.1	58.76
8	Rawa Mazowiecka	29.2	32.71	36.5	37.17	51.1	45.63	68.6	55.92
9	Grójec	3.5	10.78	7.3	15.68	21.9	27.90	37.7	37.88
10	Marcule	17.2	24.50	42.0	40.40	59.7	50.59	67.9	55.49
11	Skarżysko	1.8	7.71	7.8	16.22	14.1	22.06	35.1	36.33
12	Biżyn	7.2	15.56	24.6	29.73	40.0	39.23	57.3	49.20
13	Świętokrzyski PN	24.0	29.33	42.1	40.46	63.6	52.89	68.3	55.73
14	Moskorzew	10.7	19.09	17.6	24.80	35.1	36.33	50.5	45.29
16	Hołubla	43.3	41.15	65.1	53.79	73.7	59.15	81.3	64.38
18	Krościenko	32.5	34.76	54.0	47.29	71.9	57.99	79.4	63.01
19	Pilica	67.4	55.18	88.1	69.82	97.5	80.90	94.9	76.95
20	Prószków	14.4	22.30	32.8	34.94	55.5	48.16	70.1	56.85
21	Henryków	58.9	50.13	79.4	63.01	87.0	68.87	93.3	75.00
22	Kłodzko	20.3	26.78	39.4	38.88	42.2	40.51	52.3	46.32
23	Szczytna Śląska	16.0	23.58	42.0	40.40	58.1	49.66	59.1	50.24
24	Kowary	6.9	15.23	28.9	35.52	41.3	39.99	53.5	47.01
Mean		23.7	27.6	40.4	39.2	54.1	47.8	65.0	54.4
Standard deviation		-	12.2	-	13.4	-	13.2	-	10.4
Coefficient of variation		-	44.28	-	34.15	-	27.64	-	19.05

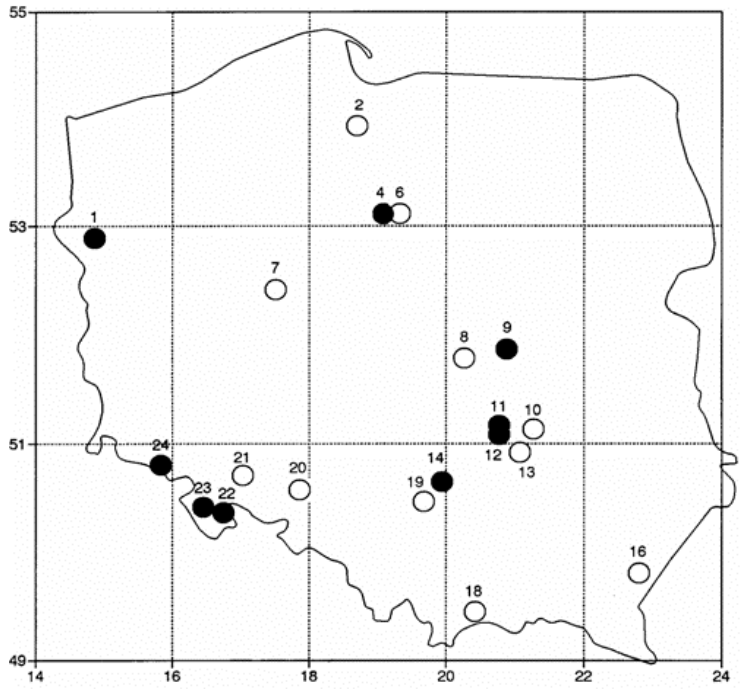
The resistance to larch canker of 35-year-old larches from Pilica, Henryków, and Hołubla was very similar for these three partial populations. The differences among them in this respect were statistically insignificant. But all three were significantly different from the remaining populations. Most of the tested populations, however, belonged to three neighboring homogeneous groups, distinguished on the basis of the Duncan's test (Table 3).

The resistance of the tested larch partial populations to larch canker did not correlate significantly with elements of location of their parental stands, i.e. latitude and altitude, which was shown by values of correlation coefficients "r": 0.1201 – 0.2215 and 0.0624 – 0.2137 respectively. Thus, provenances of different regions of the country belonged to provenances most susceptible to larch canker attack, such as Pelplin, Konstancjewo-Tomkowo, Czerniejewo, Rawa Mazowiecka, Marcule, Holy Cross National Park, Pilica, Prószków, Henryków, Kroscienko, and Hołubla, while provenances from western Poland and those situated at southern borders of the Holy Cross (Swiętokrzyskie) Mountains were the most resistant ones (Fig. 3).

Table 3. Diversification of the degree of infection of larches of investigated provenances with *Lachnellula willkommii* (Hartig.) Dennis at age of 35 years (1999). phi* = arc sin√p, where p – percentage of traits

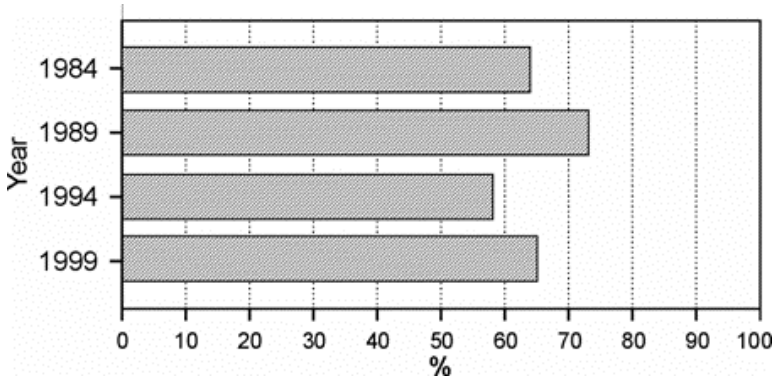
Prov. No	Provenance name	Number of trees	Trees with canker			| - difference insignificant α = 0.01
			No.	%	phi*	
19	Pilica	156	148	94.9	76.95	
21	Henryków	164	153	93.3	75.00	
16	Hołubla	139	113	81.3	64.38	
18	Krościenko	189	150	79.4	63.01	
2	Pelplin	154	118	76.6	61.07	
7	Czerniejewo	156	114	73.1	58.76	
6	Konstancjewo „Tomkowo”	164	116	70.7	57.23	
20	Prószków	211	148	70.1	56.85	
8	Rawa Mazowiecka	156	107	68.6	55.92	
13	Świętokrzyski P.N.	161	110	68.3	55.73	
10	Marcule	140	95	67.9	55.49	
4	Konstancjewo „Płonne”	219	137	62.6	52.30	
23	Szczytna Śląska	193	114	59.1	50.24	
12	Bliżyn	178	102	57.3	49.20	
24	Kowary	202	108	53.5	47.01	
22	Kłodzko	195	102	52.3	46.32	
14	Moskorzew	188	95	50.5	45.29	
1	Myślibórz Północ	196	94	47.9	43.85	
9	Grójec	191	72	37.7	37.88	
11	Skarżysko	188	66	35.1	36.33	
Mean				65.0	54.44	
Standard deviation					10.63	
Coefficient of variation					19.5%	

Fig. 3. Geographical variation of susceptibility to *Lachnellula willkommii* (Hartig.) Dennis of larches of investigated provenances at age of 35; ● – susceptibility below mean, ○ – susceptibility above mean, 1–24 – provenance number according to Table 1



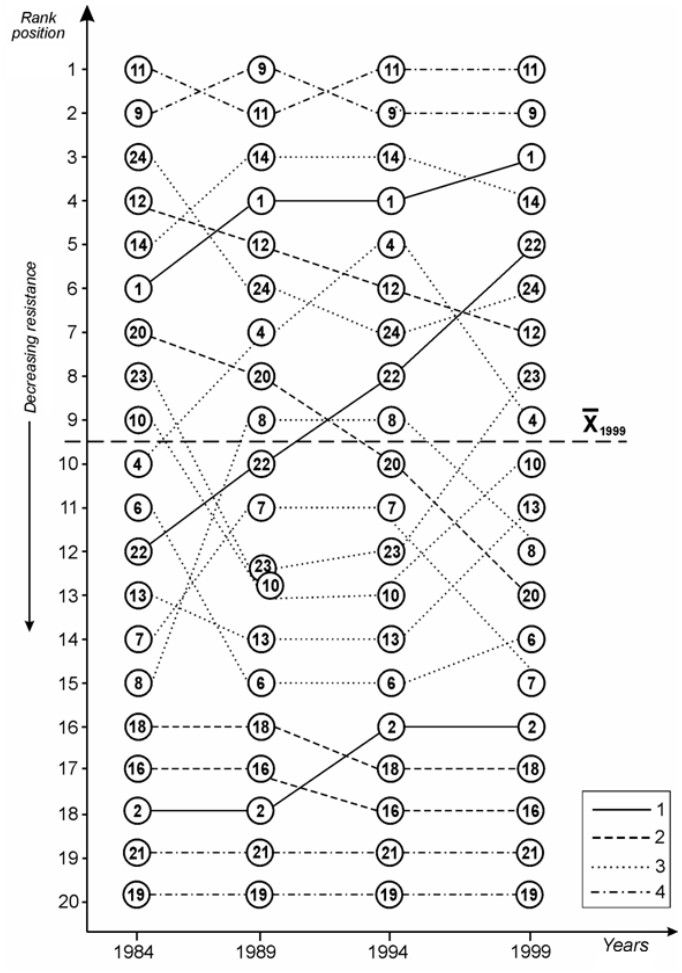
Genetic variation of larch resistance to larch canker (effect of provenance) turned out to be large. Since the contribution of the genotype effect determined by the percentage of the provenance variation in total variation (Fig. 4) during the study period 1984–1999 varied from 57% to 73%, at a relatively small diversification reaching 15% in consecutive years of observation (1984, 1989, 1994, 1999).

Fig. 4. Contribution of genotype effect (provenance) to total variation (100%) of larch canker resistance of investigated larches



The analysis of the effect of interaction "genotype x age" showed that 9 tested provenances were characterized by the effect of interaction "genotype x age" with modification of classification (Fig. 5). Larches from Bliżyn and Prószków, and the Carpathian provenances (Kroscienko, Hołubla), were characterized by a negative effect of interaction G x E_{age} expressed by worsening of ranking positions. While the progeny of larches from Myslibórz, Pelplin, and Kłodzko positively reacted to the age factor (improved their locations in ranking). Populations, the most (Pilica and Henryków) and the least (Skarżysko and Grójec) infected with larch canker, were characterized by a high stability in the entire study period.

Fig. 5. Resistance to larch cancer (*Lachnellula willkommii*). Ranking order of provenances during 1984–1999; 1–24 – provenance number according to Table 1; interaction: 1 – positive, 2 – negative, 3 – with change of classification, 4 – no effect of age



DISCUSSION

The estimation of the degree of infection of larches of tested partial populations with larch canker, carried out during this study, showed a very high diversification among populations in respect of susceptibility to this disease. It was found that variation of this trait decreased with age of trees from V% = 45.44% when trees were 20 years old to V% = 19.5% when trees were 35 years old, while the numbers of trees with disease symptoms increased during consecutive observation periods (1984 – 1999). This result confirmed the results of Lines [12] and Zycha [29]. Provenances of Polish larch from Grójec and Skarżysko turned out to be the most resistant to larch canker. A high resistance of larch from the Holy Cross mountains, and from Mała Wies near Grójec has been confirmed by results of international provenance studies. The percentage of infected trees in provenances from these regions, in comparison with the Alpine ones, was on most foreign study areas very little, a few per cent [7, 8, 13, 19, 21, 25]. A considerable resistance of larch provenances from the Holy Cross mountains was also found under laboratory conditions, with artificial infection of larch [16, 22, 23]. On the other hand, the report from the 1930s [14] about a high resistance to larch canker of larches from the Sudetes has not been confirmed. The provenances from the Sudetes, under mountain conditions of the research area of Krynica, were characterized by the greatest diversification in this respect, since the infection of 35-year-old trees with larch canker varied from 52.3% of trees (Kłodzko) to 93.3% (Henryków). Therefore, the results of this study are closer to results of more recent studies reporting a considerable diversification of susceptibility to larch cancer among populations from the Sudetes [5, 19, 21, 24, 26, 28].

The resistance to larch cancer is in the first place determined by the provenance, which was reflected in a high contribution of the effect of genotype (60 – 70%) in total variation of this trait. However, it also depends in a considerable degree on site conditions. This has been proved by the comparison of results obtained under mountain conditions of the Sacz Beskid range with results concerning the same larch provenances tested under conditions of central Poland on a comparative research area in Rogów, where climate is considerably milder than in Krynica. In Rogów, the percentage of trees with wood canker symptoms on their stems was only 0.9% [1]. The dependence of the development of the pathogen, and at the same time the resistance to larch canker, on the cultivation conditions has been pointed out by such authors as Schober [19, 20], Wachter [27], St'astný [26], and Sindelář [24]. No relationship between the health condition of larches of investigated partial populations and the definite provenance region was observed. This concerned larch provenances from outside the natural range of larch in Poland, as well as the Holy Cross mountains and Sudetes. In each of these regions there are provenances of high and low level of infection with larch canker, which was shown by the geographic variation of the analyzed trait. Results obtained in Krynica proved, in the author's opinion, that among tested provenances there were no provenances resistant to larch canker, but there were provenances more or less susceptible to this disease. The latter ones were represented in the first place by Polish larch from known localities in the Holy Cross mountains, and from central Poland, characterized by a thick bark [15]. Unexpected, and at the same time controversial, seem to be a high correlation (for $\alpha = 0.01$ and 0.05) between the weight of 1000 of seeds of parental trees and the resistance of their progeny to larch canker found during earlier research of the author [11]. This result may suggest that weight of 1000 seeds affects the susceptibility of larch to *Lachnellula wilkommi* (Hartig.) Dennis. However, the author is of the opinion that it is too early for such a conclusion, and its proving requires further detailed investigations. The results obtained did not confirm the opinion of Weisgerber and Sindelář [28] that larches of provenances of a very high growth potential are less attacked by larch canker, while those growing slower are more attacked. The correlation of these traits was negative, but statistically insignificant [11].

Almost a half of the number of investigated partial populations was characterized by the interaction effect "genotype x age" with modification of classification. Practically, larches of all provenance regions were in this group. Larches from Bliżyn and Prószków as well as the Carpathian provenances (Kroscienko and Hołubla) were characterized by a negative effect of interaction ($G \times E_{age}$) expressed by worsening of ranking positions in respect of resistance to canker along with age of trees. While the reaction of progeny of larch stands from Myslibórz, Pelplin, and Kłodzko to the age factor was positive, and this improved the position of these provenances. Larches of the provenances least (Grójec and Skarżysko) and most (Pilica and Henryków) susceptible to larch canker turned out to be stable in respect of resistance to this disease, at lack of the age effect. The presented estimation of the interaction effect "genotype (provenance) x age" (years of observation) points to a high stability of resistance to larch canker of larch populations of extreme values of the analyzed trait. This creates, especially in the case of this group of provenances, the possibility to conduct effective resistance selection in an early stage, yielding a permanent genetic gain.

CONCLUSIONS

1. There was a significant diversification among partial larch populations, tested under mountain conditions of the Sącz Beskid range, in respect of resistance to the pathogen *Lachnellula willkommii* (Hartig) Dennis. This concerned not only larch from two main regions of its occurrence in Poland, i.e. the Holy Cross (Swiętokrzyskie) mountains and the Sudetes, but also the provenances from outside its natural range in Poland.
2. The resistance of larch to larch canker is determined by the genotype. The variation of the analyzed trait decreased as the age of trees increased. The greatest diversification in this respect was found in the group of larches from provenances of the Sudetes.
3. Practically, there are no provenances "resistant" to larch canker among 20 larch provenances tested under conditions of the research area of the Forest Experimental Station in Krynica. The lowest susceptibility to *Lachnellula willkommii* (hartig.) Dennis was found for Polish larch from documented localities Grójec and Skarżysko, characterized by the thickest bark.

REFERENCES

1. Andrzejczyk T. 1992. Jakosc hodowlana modrzewi różnych pochodzeń na powierzchni proweniencyjnej w LZD Rogów [Silvivultural quality of larch of different provenances in the experimental plot of Rogów Experimental Station]. Sylwan, 133, 11/12, 43-52. [in Polish]
2. Boratyński A. 1986. Systematyka i geograficzne rozmieszczenie. [W:] Nasze drzewa lesne. Modrzewie [Taxonomy and geographical distibution. [In:] Our forest trees. Larches]. PWN, Poznań. 63-108. [in Polish].
3. Gallais H. 1990. Théorie de la sélection en amélioration des plantes [Theory of selection and improvement of plants]. Masson, Paris – Milan – Barcelone – Mexique. [in French].
4. Kleinschmit J., Sauer A. 1976. Variation in Morphology, Phenology and Nutrient Content among *Picea abies* Clones and Provenances and its Implications for Tree Improvement. [In:] Tree Physiology and Yield Improvement. Acad. Press., London – New York – San Francisco, 503-517.
5. Kocięcki S. 1962. Modrzew polski w uprawach doswiadczalnych [Polish larch in experimental plantations]. Sylwan, 106, 6, 23-33. [in Polish].
6. Kocięcki S. 1977. Badania nad wzrostem i formš modrzewia i przydatnoscia różnych pochodzeń w poszczególnych krainach przyrodniczo-lesnych [Studies on growth and form of larch, and usefulness of its various provenances in indyvidual natural forest regions]. Dokumentacja IBL, Warszawa. [in Polish].
7. Kočiová M. 1983. Vlyv prenosu na výskový rast, kvalitu a zdravotný stav rôznych proveniencii smrekovca [The effect of location on height growth, quality, and health condition of different provenances of larch]. Les. Čas., 29, 4, 243-327. [in Slovak]
8. Kri□an P. 1973. Untersuchungen über die Forstharte der Lärche (*Larix decidua* Mill.) in der Slowakei mit Rücksicht auf das Vorkommen [Studies of frost resistance of larch (*Larix decidua* Mill.) in Slovakia taking into account ist occurance]. Acta Inst. Forest. Zvolenensis, 4 29-39. [in German].
9. Krysicki W., Bartos J., Dyczka w., Królikowska K., Wasilewski M. 1995. Rachunek prawdopodobieństwa i statystyka matematyczna w zadaniach. Cz II. Statystyka matematyczna [Calculus of propability and mathematical statistics in problems. Part II. Mathematical statistics]. PWN, Warszawa. [in Polish].
10. Kulej M. 1989. Wartosc hodowlana modrzewi różnych pochodzeń krajowych w górskich warunkach powierzchni doswiadczalnej w Krynicy [Silvicultural quality of larch of different Polsih provenances under mountain conditions of the experimental plot in Krynica]. Sylwan, 133, 11/12, 31-41. [in Polish].
11. Kulej M. 2001. Zmiennosc oraz wartosc hodowlana modrzewi różnych pochodzeń z terenu Polski w warunkach siedliskowych Beskidu Sadeckiego [Variation and silvicultural quality of larch of different Polish provenances under site conditions of the Sšcz Beskid range]. Zesz. nauk. AR w Krakowie, ser. Rozprawy, No. 273: 159. [in Polish].
12. Lines R. 1965. Provenance and the suply of forest tree seed. Q. J. For., 59, 1, 7-15.
13. Morandini R., Tocci A.V. 1975. Espérienze sulle provenienze del larice [Provenance experiment with larch]. Annali dell' Inst. Sperim. Selv. Arezzo, 6, 279-316. [in Spanish].
14. Orzeł S., Kulej M. 1999. Bark thickness of larches of various Polish provenances in an experimental area of the Forest Experimental Station in Krynica. Folia Forestalia Polonica, Series A – Forestry, 41, 25-35.
15. Paques L.E., Sylvestre-Guinot G., Delatour C. 1999. Variabilité clonale de la race polonica du mélèze d'Europe pour la résistance à *Lachnellula willkommi*. [Clone variation of resistance of Polish races of European larch to *Lachnellula willkommi*]. Annales of forest Science, 56, 2, 155-166. [in French].
16. Platt Cz. 1981 Problemy rachunku prawdopodobieństwa i statystyki matematycznej [Problems of the theory of propability and mathematical statistics]. PWN, Warszawa. [in Polish].
17. Sabor J. 1998. Nasiennictwo, szkółkarstwo i selekcja drzew lesnych. Częsc III. Podstawy selekcji drzew. Skrypt do wykładów i ćwiczeń. [Seed science, nursery operations and selection of forest trees. Part III. Foundations of tree selection. Academic manuals for lectures and laboratory work]. Wyd. AR w Krakowie. [in Polish].
18. Schober R. 1958. Ergebnisse von Lärchen Art- und Provenienzversuchen [Results of provenance and genetic studies of larch]. Silvae Genetica, 7, 5, 137-154. [in German].
19. Schober R. 1977. Vom II. Internationalen Lärchenprovenienzversuch. Ein Beitrag zur Lärchenherkunfstfrage [Second International provenance experiment on larch. Contribution to the problem of larch origin]. Schriftenreiche der Forstlichen Fakultät der Universität Götingen, 49, 1-359. [in German].
20. Schober R. 1985. Neue Ergebnisse des II. Internationalen Lärchenprovenienzversuches von 1958/59 nach Aufnahmen von Teilversuchen in 11 europäischen Ländern und den U.S.A [New results of II international provenance experiment

on larch of 1958/59 according to documents of partial studies in 11 European countries and the U.S.A.]. Schriften aus der Forstlichen Fakultät der Universität Götingen und der Niedersächsischen Forstlichen Versuchsanstalt, 83. [in German].
21. Sylvestre-Guinot G., Delatour C. 1983. Possibilités d́appreciation de la sensibilité du genre *Larix* au *Lachnellula willkommii* (Hartig) Dennis par inoculations artificielles [Possibilities in determination of susceptibility of the genus Larix to *Lachnellula willkommii* (Hartig) Dennis towards artificial infection]. Ann. Sci. Forest., 40, 4, 337-354. [in French].
22. Szumowski B. 1995. Increasing the resistance of different provenances of Polish larch by means of tissue stimulation to production of phenolic substances that limit the magnitude of infection with *Lachnellula willkommii* (Hahn et Ayers) Dharen. Forestry and Wood Technology, 46, 3-12.
23. Sindelář J. 1992. Genetics and improvement of European larch (*Larix decidua* Mill.) Annales Forestales, 18, 1, 1-36.
24. S'astný T. 1962. Założenia teoretyczne selekcji słowackich proweniencji modrzewia europejskiego odpornych na raka *Trichoscyphella willkommii* Nanne [Theoretical assumptions of selection of Slovak provenances of European larch resistant to larch cancer *Trichoscyphella willkommii* Nanne]. Sylwan, 106, 6, 17-22. [in Polish].
25. S'astný T. 1971. Modifikovanie prejavu genetickej podstaty rastu *Larix decidua* Mill. vplyvom rozdielnych podmienok prostredia [Modification of the genetic basis of growth of *Larix decidua* Mill. under infulence of different enviromental conditions]. Lesnické Stúdie, VÚLH, Zvolen, 10, 1-101. [in Slovak].
26. Wachter H. 1964. Über den Stammkrebsbefall an der europäischen Lärche [About occurrence of stem cancers on European larch]. Forst-wiss. Cbl., 83, 9/10, 5, 257-281. [in German].
27. Weisgerber H., Sindelář J. 1992. IUFRO's Role in Coniferous Tree Improve-ment. History, Results, and Future of Research and International Cooperation with European Larch (*Larix decidua* Mill.). Silvae Genetica, 41, 3, 150-161.
28. Zycha H. 1980. Lärchen und Stammkrebsbefall. Zur Bewertung von Krebsbefall auf Robelflächen [Larches and occurrence of stem cancers. Estimation of the occurence of extrenal cancers]. Allg. Forst-u. Jagdztg, 151 6-7, 112-117. [in German].

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