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Natural regeneration of the European silver fir in the Sudety Mountains on soils with different particle size distribution

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Abstract: In the 40 fir localities in the Sudety Mountains, varying in site conditions and the degree of natural regeneration development were taken soil samples from the mineral horizon and were subjected to particle size distribution analysis. The best regeneration of fir stands has been reported on medium-textured soils, containing a few percents of the clay fraction and from 50 to 60% of sand. The poorest regeneration was reported on silty soils, located in the lower parts of slopes. In comparision with the Carpathians, spectrum of conditions in which firs grow in the Sudety Mountains is clearly shifted from coarse-textured soils to medium-textured soils.

Additional key words: plant ecology, soil habitat, restitution, silviculture

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Introduction

Two hundred years ago, the European silver fir was one of the most important forest trees in the Sudety Mountains, however, today it is a rare tree in this area, dispersed and heavily damaged by strong pressure of industrial pollution.

The silver fir, contrary to any other native conifer, is associated with fertile and heavy-textured soils (Ilmurzyński 1969, Włoczewski 1968, Jaworski and Zarzycki 1983, Podlaski 2001) and grows on such soils in the Carpathians, especially in their north-west part (Jaworski and Zarzycki 1983) and in Beskid Sądecki (Baran 1977). If the silver fir grows on lighter soils, like in the Świętokrzyskie Mountains (Fabijanowski and Zarzycki 1965), the Łódzka Upland (Uggla and Bachman 1956) and Pomorze Zachodnie (Pacyniak 1966), the soils are usually well supplied with water and relatively fertile. In the Sudety Mountains, where the silver fir is rather scarce nowadays (Filipiak 2002), practically, there have been no studies on the condition of soil it grows on.

Earlier publications on silver fir in the Sudety Mountains pointed to a very poor regeneration of this tree and constantly decreasing share of younger age classes in the tree stands (Jaworski 1979b, Bernadzki 1983, Boratyński and Filipiak 1997). The share of silver fir in the tree stand and its vitality depend to a large extent on the soil environment, particularly on the particle size distribution, which, to a large degree, determines the physical, chemical and water properties of the soil. This paper presents the results of studies on silver fir regeneration on autogenic soils in the Sudety Mountains characterized by different texture of the surface horizons.

Material and methods

As a result of a field survey of 854 silver fir locations, 40 stands varying in site conditions and the degree of natural development have been selected. In the main, the selection was random, although it was carried out separately for particular parts of the Sudety Mountains. The selection was also limited to stands with a larger number of silver fir trees (at least a dozen or so). It was also assumed that at least 30% of the areas investigated should be characterized by a good silver fir regeneration. In reality, only ca 5% of stands meet these requirements (Filipiak 2002). In the selected stands samples were taken from the mineral horizon A lying up to 20 cm under the organic horizon. The samples with a volume approximating 1 liter were dried and subject to particle size distribution analysis. The analysis was carried out using the aerometric method, in line with standard PN-R-04033: 1998. Sand fractions were separated wet on sieves. Soil texture classes were determined in accordance with the Soil Survey Manual (Soil Survey Division Staff 1993).

Results and discussion

The testing areas selected for the study are located in south-west Poland (Fig. 1), within brown forest and brown forest podzolic soils of different subtypes, developed of various kinds of parent materials. According to the tests performed, silver fir within the area under investigation occurs on soils with texture characteristic of loamy coarse sand to silts, containing from 1 to 15% of clay (Table 1, Fig. 2). The texture diversity in the investigated area falls into 4 soil texture classes, i.e. loamy sand, sandy loam, loam and silt, of which sandy loams (27 samples) and silts (8 samples) dominate.

According to Zarzycki (Jaworski and Zarzycki 1983) in the north-west Carpathians the fir requirements are met by clayey soils, loams and only some of the loamy sands (with a higher clay fraction). According to our study the spectrum of conditions in which firs grow in the Sudety Mountains clearly shifts from coarse-textured soils to medium-textured soils. The share of sandy loam and silt is considerable and there is a complete absence of clays. According to Zarzycki (Jaworski and Zarzycki 1983), in the Carpathians these conditions are more favorable for the growth of the European beech than the silver fir. Hence, the beech competition can significantly limit the regener-

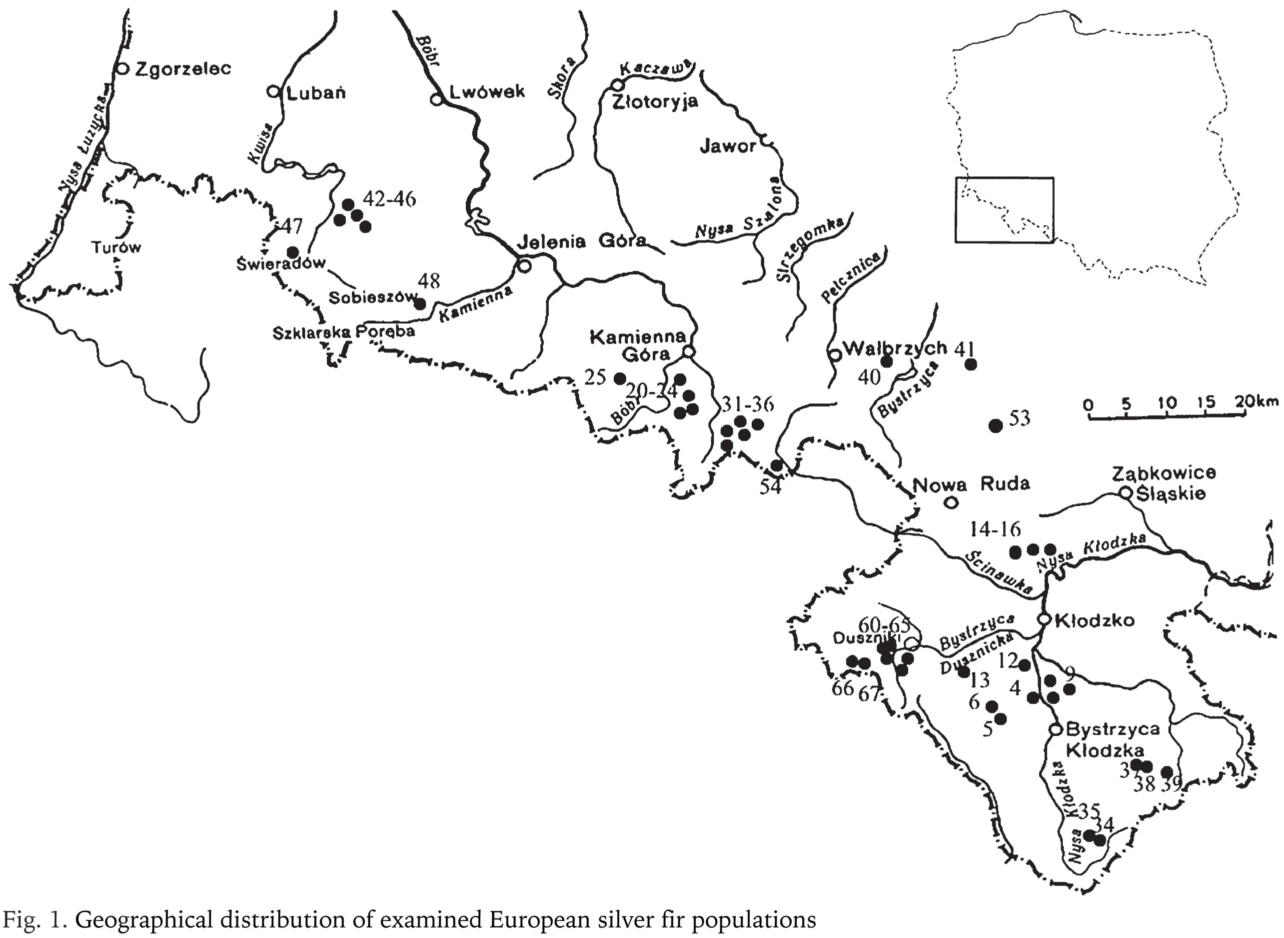

Fig. 1. Geographical distribution of examined European silver fir populations

Table. 1. Soil texture of samples from examined European silver fir populations

Forest ranger	Subcompartment	No.	Natural regeneration state	Percentage of soil separates at diameter ϕ (mm)									Sum of fraction: Sand	Silt	Clay	Soil Texture USDA
				2,0–1,0	1,0–0,5	0,5–0,25	0,25–0,1	0,1–0,05	0,05–0,02	0,02–0,01	0,005–0,002	<0,002	2,0–0,05	0,05–0,002	<0,002	
Bardo	148s	1	poor	23,7	17,5	8,8	3,4	15,6	8	12	6	5	69	26	5	csl
Bardo	256c	2	poor	3,6	4,7	4,7	6,4	15,6	24	26	10	5	35	60	5	sil
Bardo	257a	3	poor	4,2	7,9	9,1	10,2	17,6	19	17	8	7	49	44	7	fsl
Bystrzyca	6j	4	good	0,4	2,0	2,4	17,6	36,6	18	15	6	2	59	39	2	vfsl
Dolnik	110a	34	poor	13,7	1,3	7,5	19,5	14,1	15	18	6	5	56	39	5	fsl
Dolnik	110b	35	poor	0,3	2,0	1,5	9,7	39,4	29	8	4	6	53	41	6	vfsl
Dobromyśl	318a	29	good	10,3	0,2	4,9	28,6	17,1	14	16	5	4	61	35	4	fsl
Dobromyśl	217c	26	good	9,7	0,4	8,0	43,4	17,5	7	7	2	5	79	16	5	lfs
Głuszyca	127d	53	poor	2,0	6,3	6,7	3,7	33,4	22	18	2	6	52	42	6	vfsl
Głuszyca	126h	51	poor	5,3	14,1	11,1	8,9	11,5	12	15	7	15	51	34	15	l
Głuszyca	127d	52	good	4,1	16,7	11,1	1,9	24,2	19	14	4	5	58	37	5	fsl
Głuszyca	127a	50	poor	0,5	7,4	9,9	11,1	19,1	24	21	5	2	48	50	2	fsl
Kamienna Góra	155p	21	poor	7,2	9,7	4,7	3,3	22,0	27	17	7	2	47	51	2	sil
Lubawka	142d	23	poor	13,1	0,4	8,3	15,9	9,2	26	20	4	3	47	50	3	fsl
Mieroszów	375f	58	poor	3,5	5,4	6,9	6,7	44,5	13	15	2	3	67	30	3	vfsl
Mieroszów	374i	54	poor	1,5	6,1	8,7	12,6	20,1	14	16	9	12	49	39	12	l
Międzylesie	31b	33	poor	0,1	0,6	1,2	17,2	32,8	25	14	7	2	52	46	2	vfsl
Międzylesie	27a	32	poor	0,4	1,4	3,1	18,0	37,1	17	17	1	5	60	35	5	vfsl
Międzylesie	110b	36	good	0,3	0,0	0,9	4,1	23,7	22	24	12	13	29	58	13	sil
Okrzeszyn	334f	19	poor	10,8	0,1	7,2	8,9	6,0	25	31	7	4	33	63	4	sil
Okrzeszyn	320d	18	poor	13,5	0,5	9,0	34,3	8,6	10	15	4	5	66	29	5	fsl
Piskorzów	154j	41	poor	10,1	0,5	10,0	24,9	21,5	12	12	5	4	67	29	4	fsl
Polanica	235p	57	good	9,2	0,2	5,2	31,2	13,2	10	20	7	4	59	37	4	vfsl
Rebiszów	28b	43	poor	13,1	0,6	8,5	16,1	18,6	22	13	4	4	57	39	4	fsl
Rebiszów	29c	42	poor	9,6	0,7	4,9	8,5	12,3	22	23	8	11	36	53	11	sil
Spalona	99a	11	poor	1,8	8,7	9,4	6,0	24,2	25	20	4	1	50	49	1	fsl
Spalona	99a	10	poor	0,9	7,9	10,9	11,4	18,9	15	17	12	6	50	44	6	fsl
St. Łomnica	18g	5	poor	3,0	16,5	11,5	15,3	15,7	11	16	4	7	62	31	7	fsl
St. Łomnica	351c	13	good	28,6	0,1	2,1	6,9	3,2	8	20	16	15	41	44	15	l
Waliszów	313a	7	poor	2,5	10,9	9,5	8,1	20,9	20	19	8	1	52	47	1	fsl
Waliszów	304c	12	poor	2,7	5,3	4,1	5,9	19,0	25	25	7	6	37	57	6	sil
Waliszów	317j	9	poor	0,7	4,1	6,4	9,8	16,0	27	21	5	10	37	53	10	sil
Waliszów	315i	8	poor	0,1	1,7	2,9	7,1	19,2	29	24	5	11	31	58	11	sil
Wałbrzych	104g	49	poor	0,7	27,6	17,9	11,8	18,9	12	5	5	1	77	22	1	lcs
Wałbrzych	115d	50	poor	3,5	22,2	12,5	11,3	10,5	10	12	7	11	60	29	11	csl
Wojborz	88a	15	good	12,5	0,4	11,7	17,7	7,7	18	18	9	5	50	45	5	fsl
Zagnańsk	20a	55	good	12,6	0,1	1,0	16,4	28,9	19	15	4	3	59	38	3	fsl
Zdroje	325a	61	good	4,2	19,7	16,2	15,2	13,7	11	9	7	4	69	27	4	sl
Zdroje	140f	64	good	6,0	8,9	10,1	6,5	15,5	20	24	4	5	47	48	5	fsl
Zdroje	325 e1	62	good	0,7	8,1	15,5	15,6	13,2	16	21	3	7	53	40	7	fsl

ation of fir in the Sudety Mountains, especially that the beech has smaller requirements regarding soil moisture, and the average precipitation in the Sudety Mountains is lower than in the Carpathians (Matuszkiewicz 2002).

Fig. 3 presents the share of particular soil texture classes in the total number of samples tested according to stands with better and poorer regeneration. The differences between distributions for good and weak restoration (Fig. 3) are statistically significant

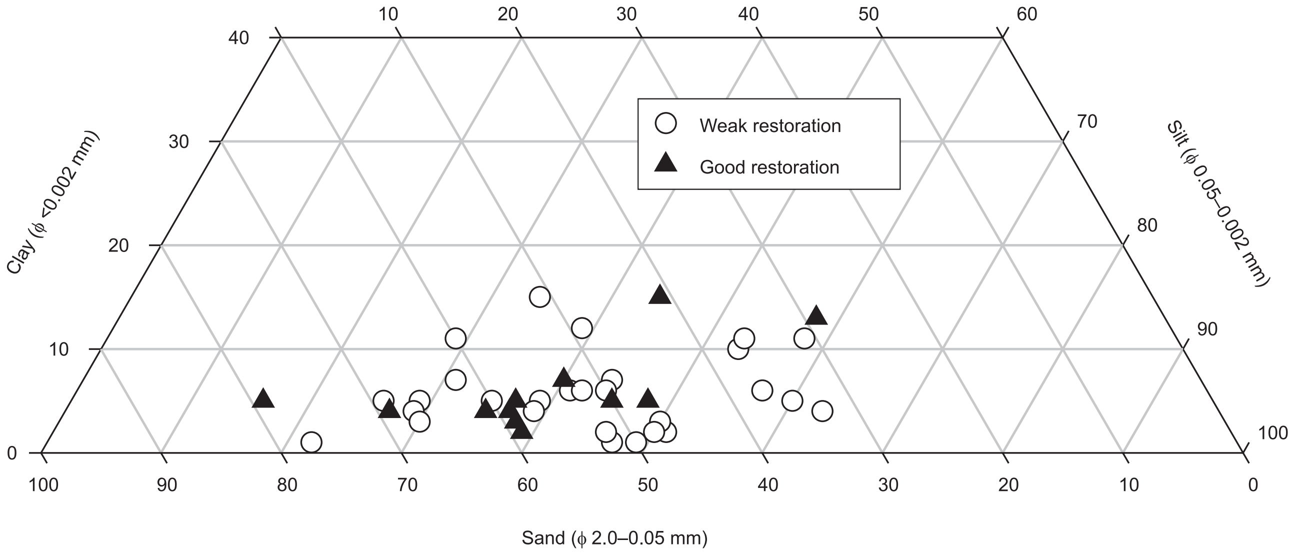

Fig. 2. Diagram of soil texture in examined European silver fir populations

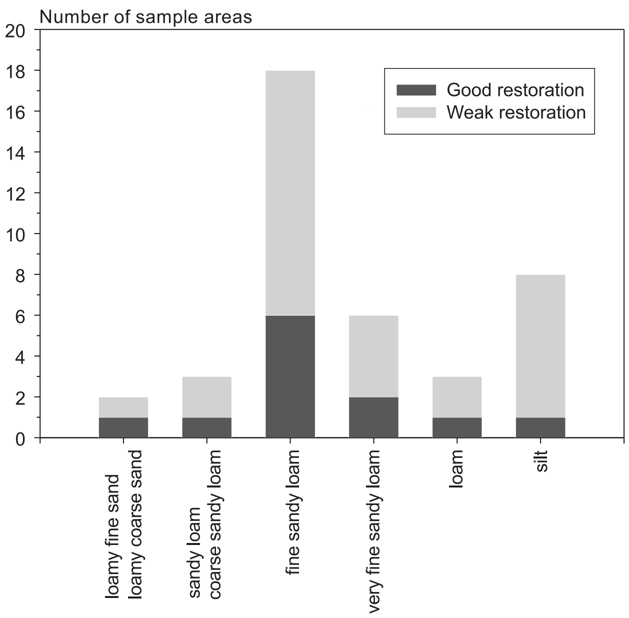

Fig. 3. The share of particular soil texture classes in the total number of samples tested according to stands with good and poor regeneration

(χ^2 test $p \leq 0.05$). When analyzing strictly the relation between the soil texture content of the humose horizon and the regeneration of the fir, a 50% probability of natural regeneration can be expected on soils exhibiting the texture of sandy loams, which contain from 50 to 60% of sand and from 3 to 7% of clay fraction. Attention is also drawn to the occurrence of a large number of silver fir locations on silty soils and, on the other hand, its poor regeneration in such conditions. We did not find any reference in relevant literature to the poorer regeneration of fir on silty soils. To a certain (limited) degree the result obtained by us corresponds to the information contained in the publications of Jaworski (1979b) and Podlaski (2001). Jaworski (l.c.) recorded better survival of fir in mixed montane coniferous forest (medium-textured soils) than in montane acidophilous beech forest (which is usually associated with soils containing more of the clay fraction). According to the quoted author this situation is caused by an unfavorable species composition of the soil microflora in montane acidophilous beech forest, particularly the frequent occurrence of the *Cylindrocarpon destructans* fungus. Podlaski (2001) carrying out research in the Świętokrzyskie Mountains reported poorer fir regeneration on slopes where the soil contains a shallow impermeable layer. According to this author, in such conditions water from rainfall flows rapidly down the slope, and the soil surface layers dry out in short period.

The factors that contributed to the decreased natural regeneration of fir in the aforementioned cases can play a certain role also in the areas investigated by us, however, it appears that these are not the main reasons inhibiting the growth of young firs. The majority of the investigated stands containing silty deposits in the substratum are located in the lower parts of slopes, at foothils zone and within intermountain valleys and basins (mainly the Nysa Kłodzka Basin). Over half of the poorly regenerating tree stands is located outside the steep slopes of the lowest parts of the mountains. The potential plant communities are here usually oak-hornbean forests (Carpinion-betuli alliance), not beech forest (Fagion alliance). As a result of pollution pressure and incorrect management practices, tree stands containing fir in the Sudety Mountains are usually over-opened, not dense. This causes very strong growth of a herbaceous vegetation cover, which in turn hinders the regeneration of firs (Filipiak 2002). This cover is particularly rich in tree stands located at lower altitudes which have the nature of dry-ground forests (Filipiak and Kosiński 2002).

The results and suggestions presented above do not fully explain the causes of problems related to the natural sowing and growth of the young generation of firs on silty deposits, hence, this matter deserves further investigation.

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