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The morphological traits of cones and seeds of *Abies alba* in the Middle Sudeten

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Abstract Twenty *Abies alba* trees were selected for restoration purpose of species in the Sudeten. Eleven features of cone and seeds collected from those trees were examined and all of them significantly differed selected trees. Five features, i.e. cone length, cone biggest diameter, length and width of ovuliferous scales, and length of wings with were recommended as having the highest diagnostic value.

Additional key words: variability of cones

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Introduction

Although the morphological traits of *Abies alba* Mill. generative organs have been broadly described in the literature (for example Hegi 1981; Boratyński 1983; Aas et al. 1994) the variability of them within a tree, among trees in populations and among populations have not been sufficiently recognized. It is not known if these features are still appropriate to distinguish populations or specimens within a population. The vegetative propagation of silver fir for the needs of seed orchards as well as progeny tests require simple tools to control the identity of parental trees. The morphological features of generative organs seem to be very appropriate for this purpose, because they do not undergo the natural directional selection. Due to the fact that there were many attempts of silver fir restoration and breeding, and to restore dying populations, more precise knowledge on the morphology of a species could be of practical significance.

European silver fir cones are up to 16 cm long and 3–5 cm thick. Seeds are 7–13 mm long and mass of 1000 seeds attains 50–55 g (Schütt 1991). Tyszkiewicz (1949) mentioned the following data: the cones length 10–17 cm, the cone thickness 3–5 cm, the seeds length 10 mm with 25 mm wing, the mass of 1000 seeds totals 55 g. In Romania the cone sizes were reported as follows: length 7–19.5 cm with an average 12.9 cm, thickness 2.9 – 4.6 cm with an average 3.6 cm (Nanu 1977). In the West Croatia the cones length varied from 5.5 cm to 18.5 cm, and the cones diameters from 2,5 cm to 5,0 cm. The variation of seeds were reported as follows: length of seeds 7.5–12.5 mm, width of seeds 3.2–6.8 mm, seeds thickness 1.8–4.5 mm, wings length 12.5–28.5 mm, wings width 6.5–16.5 mm Gudeski (1966). According to Boratyński (1983) the cones length totals 10–15 cm, the diameter 3–5 cm, the width of seed scale 2.5–3.0 cm, the seeds length 7–9 mm. Suszka (1983) reported slightly different measures: the cone length 10–18 cm, the diameter 3–5 cm, the seeds length 8–13 mm, the wing length sometimes exceeds 25 mm, the mass of 1000 seeds 55 g. Kočiová (1974) reported from Slovakia the absolute variability range

of cone length from 7.6 to 19.9 cm, and the average variability range for populations from 12.6 to 14.9 cm while the cones diameters varied from 3.0 to 5.2 cm, and their population averages from 3.8 to 4.2 cm. The author pointed out the high heritability of these features. Provenance heritability (14 populations) was (depending on assessment method): for the cones length – from h^2=0.68 to h^2=0.89, for the cones diameters – from h^2=0.71 to h^2=0.91, and for the seeds mass h^2=0.77 (Kočiová 1974). Ballian and Čabaravdić (2005) used a variability of cones and seeds morphological features to identify the silver firs populations in Bosnia. Average values of the features examined by them amounted: the cones length:- 118.05±4.58 mm, the cones diameter – 35.57±0.77 mm, the relation of diameter to the length – 0.31, the wing length– 24.79±0.46 mm, the wing width – 12.22±0.18 mm, the seed length – 11.72±0.18 mm, the ovuliferous scale length – 27.93±4.64 mm, the ovuliferous scale width – 27.12±3.87 mm. The majority of analyzed features (14 out of 16 diversified considerably the populations. During the process of shoots collection used for grafting of selected trees, their cones were also collected and underwent the morphological analyses.

Our aim was to study the variation of cone and seed features in silver fir individual trees selected in Sudetes as maternal trees for vegetative propagation.

Materials and methods

The fir-cones were collected from 20 sample trees, originating from three forest districts: Zdroje (6 trees), Jugów (1 tree) and Bystrzyca Kłodzka (13 trees). According to seed regionalization in Poland, these forest districts are locvated in 702 seed microregion. Geographically it is the area of middle Sudeten Mountains.

After cone collection, cone dimensions, cone scales and seeds were measured, and the values of proportional features were calculated. Scales and seeds were acquired from the middle part of a cone. The following traits were obtained for each tree:

1. Cone length (L)
2. The largest cone diameter (D)
3. D/L ratio
4. The ovuliferous scales length (OSL)
5. The ovuliferous scales width (OSW)
6. OSW/OSL ratio
7. The length of seed wing (LSW)
8. The width of seed wing (WSW)
9. WSW/LSW ratio
10. The length of seed (LS)
11. LS/LSW ratio

The results were subjected to one-way analysis of variance, including F test and the variance component assessment. The model of analysis was follows:

$$y_{ij}=\mu+a_i+e_{ij}$$

where μ is a arithmetic mean, a_i is a effect of tree, and e_j is a effect of variable within a tree (error).

The descriptive statistics, including the arithmetic mean, the coefficient of variability (V) and the half-interval of confidence (m or ±) were also provided.

The sample size, necessary for specyfing the mean with 5% accuracy in the obtained variance was calculated according to the formula:

$$n=\frac{\sigma^2\cdot t_{0,05}^2}{m^2}$$

where n is a sample size, σ^2 is a variance, m is half- interval of confidence, $t_{0,05}$ is a critical value for Student distribution for $n–1$ degrees of freedom and α=0.05 significance level.

Results

Description of variability in cone sizes is presented in Table 1. The average cone diameter measured 3.5072±0.0423 cm, with values ranging from 3.0778 to 4.1583, for individual trees, and the range of observations within trees from 2.7 cm to 4.8 cm. The average cones lengths amounted 12.9025±0.3010 cm, among trees from 10.2750 to 17.0083 and the individual observation fluctuated from 7.8 to 20.0 cm. The ratio of diameter to length is on average 0.2768±0.0049, and differed within trees from 0.2137 to 0.3439 and within observations from 0.19 to 0.41. Each of these features significant diversified the examined trees (Table 2). The ratio of cone diameter to length did discriminate trees not better than cones sizes. Over 72% of general variance in cone diameters and lengths was ascribed to variability between trees.

The description of ovuliferous scales is presented in Table 3. Length of ovuliferous scales was on average 21.63±0.29 mm. For trees this value was from 18.72 to 26.51. The observation ranged from 15.07 to 29.80. The width of ovuliferous scales was on average 27.03±0.33. In individual trees amounted from 22.62 to 34.45. The observations varied from 17.60 to 37.83. The ovuliferous scales proved to be wider than their length. The ratio was 1.2605±0.0143. The values for trees fluctuated from 1.04 to 1.41. The absolute values ranged from 0.95 to 1.73. The sizes of ovuliferous scales diversified trees more than the cones sizes (Table 4). The variability between trees represents 97% of overall variation in case of scales length and 98% of variance in case of scales width (Table 4). The ratio of these two features does not have stronger discriminating strength than either of them.

The seed sizes is described in Table 5. The average length of seed with a wing was 22.34±0.37 mm, and

Table 1. The features of cones size

Tree number	Number of collected cones	Largest diameter of cones (D)				Length of cones (L)				D/L			
		Mean (cm)	V %	±	For m=5% n=	Mean (cm)	V %	±	For m=5% n=	Mean cm	V %	±	For m=5% n=
6006	13	3.7462	3.8707	0.0869	2.80	13.8538	8.4313	0.6999	13.27	0.2719	7.7645	0.0126	11.25
6009	14	3.2643	5.3206	0.0996	5.21	12.7571	14.3513	1.0495	37.90	0.2593	10.7996	0.0161	21.46
6010	5	4.0600	4.8014	0.2241	6.09	15.6200	12.1841	2.1879	39.24	0.2621	9.4272	0.0284	23.49
6013	12	4.1583	3.8990	0.1020	2.89	17.0083	10.8222	1.1577	22.24	0.2467	9.5631	0.0148	17.37
6021	5	4.1000	10.6315	0.5011	29.87	13.9000	5.0871	0.8129	6.84	0.2953	10.8301	0.0368	31.00
6024	5	3.6200	2.3112	0.0962	1.41	11.5800	5.2315	0.6964	7.23	0.3133	5.5095	0.0198	8.02
6038	14	3.6143	4.3215	0.0895	3.44	12.8357	6.4070	0.4714	7.55	0.2822	5.3301	0.0086	5.23
6040	15	3.4333	3.7602	0.0710	2.57	13.0800	11.0155	0.7929	22.05	0.2653	10.7993	0.0158	21.19
6042	12	3.4833	4.7146	0.1033	4.22	15.4167	8.5510	0.8292	13.88	0.2269	6.8594	0.0098	8.93
6044	6	3.4000	2.6307	0.0893	1.66	12.0500	4.2234	0.5084	4.27	0.2825	3.9983	0.0113	3.83
6046	12	3.6250	6.4562	0.1472	7.91	11.8167	6.9489	0.5165	9.17	0.3070	2.9168	0.0056	1.62
6050	6	3.7500	3.6757	0.1377	3.24	12.3833	6.1588	0.7619	9.08	0.3037	6.8667	0.0208	11.29
6123	17	3.2235	4.3222	0.0713	3.33	10.8294	8.7588	0.4854	13.66	0.2990	6.1117	0.0094	6.65
6124	14	3.6214	5.2144	0.1082	5.00	15.3286	7.5406	0.6626	10.46	0.2373	8.2739	0.0113	12.60
6125	13	3.3923	4.0743	0.0828	3.10	12.3538	11.4933	0.8508	24.66	0.2771	8.8906	0.0148	14.76
6127	16	3.5125	4.3952	0.0818	3.47	10.2750	9.4593	0.5151	16.08	0.3439	7.5869	0.0138	10.35
6131	18	3.0778	5.1741	0.0789	4.73	10.5889	11.1595	0.5852	21.99	0.2931	8.4214	0.0122	12.52
6132	17	3.2765	4.6449	0.0779	3.84	11.9412	8.9122	0.5446	14.14	0.2757	6.7578	0.0095	8.13
6134	9	3.5222	6.4707	0.1719	8.57	16.5444	9.1022	1.1355	16.96	0.2137	6.6042	0.0106	8.93
Total	223	3.5072	9.1433	0.0423	12.99	12.9025	17.6792	0.3010	48.55	0.2768	13.5233	0.0049	28.41

± – confidence semiinterval

Table 2. Analysis of variance of cones dimensions

Source of variation	DF	Diameter D		Length L		D/L	
		Significance level α	σ^2/σ_T^2	Significance level α	σ^2/σ_T^2	Significance level α	σ^2/σ_T^2
Between trees	18	4.29×10^{-49}	0.7238	1.04×10^{-48}	0.7213	1.14×10^{-42}	0.6784
Within trees (error)	204	–	0.2762	–	0.2787	–	0.3216
Total	222	–	1.0000	–	1.0000	–	1.0000

varied among trees from 17.46 to 29.21 mm, and in the absolute values from 15.30 to 36.76 mm. The mean seed-wing width was 11.64±0.13 mm, the averages for tress were from 10.48 to 13.76 mm, and the absolute values from 8.58 to 16.34 mm. The length of seeds amounted on average 8.85±0.15 mm. The averages for trees fluctuated from 7.55 to 10.95 mm. The absolute values ranged from 5.00 mm to13.99 mm.

Ratios of seed traits and their variability are presented in Table 6. The ratio of the seed-wing width to the wing length amounted 0.5321±0.0100, and varied among trees from 0.4241 to 0.6288. The extreme observation values totaled 0.3337 and 0.8450. The ratio of the seed length to the seed-wing length totaled on average 0.4000±0.0048, the averages for trees fluctuated from 0.3444 to 0.4452, and absolute values from 0.2549 to 0.5404.

Both the seed and seed-wings measures and their ratios diversified the individual trees significantly. The most diversifying feature was the length of seed-wing: the between tree variability is responsible for more than 64% of the general variance (Table 7). The wing width, seed length and the proportional features relatively weak, but significantly, diversify individual trees. As far as these features are concerned their variation within a tree proved to be higher than the variance between trees (Table 7).

The examined features are not mutually independent. Correlation coefficients among average values for trees are presented Table 8. Twenty nine out of 55 calculated coefficients proved to be statistically significant.

The published data and own observations of variability of cones and seeds features are compared in Table 9.

Table 3. Ovuliferous scales dimensions

Tree number	No of scales	Length of scales (OSL)				Width of scales (OSW)				OSW/OSL			
		Mean (mm)	V %	±	For m=5% n=	Mean (mm)	V %	±	For m=5% n=	Mean	V %	±	For m=5% n=
6005	24	25.45	9.6450	1.0341	15.85	33.34	6.2458	0.8774	6.65	1.3177	7.7190	0.0429	10.15
6006	22	21.16	11.6534	1.0904	23.36	27.09	5.2575	0.6297	4.76	1.2938	10.6372	0.0609	19.47
6009	28	25.69	5.9726	0.5940	5.99	26.76	5.4666	0.5664	5.02	1.0430	4.5899	0.0185	3.54
6010	23	26.51	6.0451	0.6913	6.26	32.24	5.4894	0.7635	5.16	1.2190	6.3940	0.0336	7.00
6013	16	24.67	8.0925	1.0570	11.77	34.45	5.9448	1.0855	6.35	1.4006	5.5601	0.0413	5.56
6021	22	20.35	10.5992	0.9538	19.33	26.81	7.0934	0.8409	8.66	1.3260	8.5795	0.0503	12.66
6024	21	20.05	8.2994	0.7552	11.92	23.58	8.8769	0.9499	13.63	1.1846	12.9062	0.0694	28.82
6038	20	19.73	11.5016	1.0582	23.02	26.46	5.9998	0.7404	6.27	1.3588	13.0494	0.0827	29.64
6040	14	19.29	8.5551	0.9460	13.47	25.23	8.5141	1.2312	13.34	1.3151	11.1514	0.0841	22.88
6042	22	22.06	5.0139	0.4890	4.32	26.12	7.4868	0.8645	9.64	1.1856	7.5851	0.0398	9.90
6044	21	21.62	10.3122	1.0119	18.40	27.60	8.2491	1.0333	11.77	1.2911	14.3483	0.0841	35.61
6046	20	21.60	9.3393	0.9410	15.18	27.29	5.2432	0.6675	4.78	1.2731	9.8007	0.0582	16.72
6050	18	19.74	7.6574	0.7487	10.35	27.69	4.2018	0.5761	3.12	1.4103	8.8998	0.0622	13.98
6123	37	18.72	8.7954	0.5486	12.70	23.74	3.9908	0.3156	2.62	1.2777	9.9366	0.0423	16.21
6124	18	23.01	8.2926	0.9450	12.14	26.69	7.3473	0.9710	9.53	1.1659	9.9540	0.0575	17.49
6125	24	21.37	9.8059	0.8827	16.38	26.61	8.3399	0.9350	11.85	1.2516	9.0605	0.0478	13.99
6127	19	20.63	9.2287	0.9141	14.92	25.58	8.2170	1.0093	11.83	1.2480	10.8017	0.0647	20.45
6131	26	18.85	7.1976	0.5470	8.76	22.62	7.4060	0.6754	9.27	1.2056	10.1001	0.0491	17.24
6132	14	20.12	13.0412	1.5039	31.29	25.02	6.2088	0.8904	7.09	1.2608	12.8840	0.0931	30.54
6134	14	21.97	10.4923	1.3213	20.26	29.19	4.3764	0.7323	3.52	1.3401	9.6066	0.0738	16.98
Total	423	21.63	14.0946	0.2914	30.70	27.03	12.9114	0.3336	25.76	1.2605	11.8694	0.0143	21.77

Table 4. Analysis of variance of cone scales dimensions

Source of variation	DF	Scale length OSL		Scale width OSW		OSW/OSL	
		Significance level α	σ^2/σ_T^2	Significance level α	σ^2/σ_T^2	Significance level α	σ^2/σ_T^2
Between trees	19	8.12×10^{-72}	0.9676	4.91×10^{-110}	0.9830	2.38×10^{-25}	0.8954
Within trees (error)	403	-	0.0324	-	0.0170	-	0.1046
Total	422		1.0000		1.0000		1.0000

Discussion

The cones used for examination were collected in order to obtain seeds for progeny tests. Only a small part of cones could be devoted for morphological examinations. In the similar examinations the controversy about sample size always appears. The formula for the sample size is derived from the formula for the confidence half-interval. The sample size entirely depends on the variance of measured feature and closeness of mean estimation (depends on the square of confidence half – interval). It is pointless to estimate the mean feature values according to assumed number of observations. If we require the confidence half-interval to amount to 5% of an average, we need 13 cones to determine the population average of cone diameter, about 50 cones to determine length, and 31 scales to determine the length of scales. If we require more accuracy in an average determination (shorter e.g. 1% confidence half-interval), the sample size increases significantly. For the cones diameter, the sample size amounts to 321 cones, for length 1200 cones and for scales length 763 scales. To determine the means within a tree usually the smaller samples are required. However, if the observations differ significantly, the variance and required sample size increases. For instance, to determine the cone diameter variability within a tree sometimes 2 cones were needed (e.g. tree 6044, Table 1), but in the other case of another tree 30 cones would be required (tree 6021, Table 1). To determine the cone length from 5 to 40 cones are required, and to determine the scales length from 5 to 32 scales are needed.

The measurements of cones, cone-scales and seeds and their variability fall within the frames described by other authors (Tyszkiewicz 1949; Gudeski 1966;

Table 5. Dimensions of seeds

Tree number	No of seeds	Length of seed wings LSW				Width of seed wings WSW				Length of seeds LS			
		Mean (mm)	V %	±	For m=5% n=	Mean (mm)	V %	±	For m=5% n=	Mean (mm)	V %	±	For m=5% n=
6005	13	25.80	8.5139	1.3164	13.53	13.76	11.2679	0.9291	23.70	10.57	10.8267	0.6856	21.88
6006	21	22.48	11.3572	1.1587	22.31	12.17	12.5570	0.6937	27.28	8.91	15.2256	0.6158	40.10
6009	26	26.02	12.0598	1.2650	24.58	10.87	13.5838	0.5952	31.19	8.95	15.5101	0.5595	40.66
6010	10	26.60	13.5177	2.5334	36.29	12.44	12.4899	1.0948	30.98	10.40	20.8719	1.5291	86.51
6013	25	29.21	10.2372	1.2316	17.78	13.44	8.8119	0.4880	13.17	10.95	11.7897	0.5320	23.58
6021	18	22.14	9.9870	1.0950	17.61	11.69	15.5061	0.8977	42.45	9.17	7.8202	0.3551	10.80
6024	20	20.88	10.8773	1.0592	20.59	12.41	13.4824	0.7803	31.64	7.86	15.1884	0.5571	40.15
6038	20	19.29	9.0509	0.8142	14.26	11.80	9.4859	0.5220	15.66	7.95	16.7922	0.6226	49.08
6040	20	21.87	8.8747	0.9051	13.71	11.30	14.3663	0.7573	35.92	8.99	8.5685	0.3592	12.78
6042	26	21.76	9.6685	0.8482	15.80	10.48	10.9377	0.4619	20.22	8.45	12.6592	0.4314	27.08
6044	13	21.29	8.0397	1.0256	12.07	11.74	13.4221	0.9445	33.63	8.94	7.8785	0.4220	11.59
6046	23	21.29	11.1165	1.0208	21.15	12.59	12.0499	0.6542	24.85	8.27	11.6462	0.4155	23.22
6050	15	20.50	12.3585	1.3945	27.76	11.61	13.5880	0.8682	33.55	7.93	13.7258	0.5991	34.24
6123	20	17.46	8.3776	0.6824	12.22	10.89	10.2231	0.5195	18.19	7.55	10.8885	0.3833	20.64
6124	29	26.06	7.4836	0.7405	9.37	11.52	13.0121	0.5694	28.33	10.04	12.9941	0.4954	28.25
6125	15	19.88	12.8798	1.4091	30.15	11.34	12.5587	0.7839	28.66	7.89	11.8515	0.5145	25.52
6127	25	20.25	7.9640	0.6642	10.76	11.26	12.3008	0.5704	25.67	9.01	11.7249	0.4349	23.32
6131	24	19.58	8.9003	0.7343	13.50	10.51	8.2009	0.3632	11.46	8.36	13.4673	0.4744	30.90
6132	21	21.37	8.2947	0.8046	11.90	10.92	13.2101	0.6549	30.19	8.27	12.2852	0.4613	26.11
6134	6	20.86	4.0135	0.8364	3.86	11.47	14.9278	1.7106	53.37	8.24	17.3451	1.4280	72.05
Total	390	22.34	16.6255	0.3698	42.74	11.64	11.0023	0.1275	18.72	8.85	16.5609	0.1459	42.41

Table 6. Relative features of seeds

Number of tree	Number of seeds	WSW/LSW				LS/LSW			
		Mean	V %	±	For m=5% n=	Mean	V %	±	For m=5% n=
6005	13	0.5346	10.4375	0.0334	20.34	0.4104	9.3887	0.0231	16.46
6006	21	0.5441	18.5976	0.0459	59.83	0.3982	14.2499	0.0257	35.13
6009	26	0.4241	19.4829	0.0333	64.15	0.3444	10.2285	0.0142	17.68
6010	10	0.4729	14.7711	0.0492	43.33	0.3878	9.0279	0.0247	16.19
6013	25	0.4651	13.8422	0.0265	32.51	0.3764	10.4578	0.0162	18.56
6021	18	0.5337	18.9471	0.0501	63.38	0.4159	7.0044	0.0144	8.66
6024	20	0.5985	14.9971	0.0419	39.15	0.3746	9.6632	0.0169	16.25
6038	20	0.6180	14.9804	0.0432	39.06	0.4111	12.0037	0.0230	25.08
6040	20	0.5214	17.7241	0.0431	54.68	0.4132	10.1088	0.0195	17.79
6042	26	0.4850	13.7412	0.0269	31.91	0.3895	11.3186	0.0178	21.65
6044	13	0.5557	16.5329	0.0551	51.03	0.4225	11.4719	0.0290	24.57
6046	23	0.5957	13.9219	0.0358	33.18	0.3904	10.4287	0.0176	18.62
6050	15	0.5753	19.6093	0.0621	69.88	0.3886	11.8242	0.0253	25.41
6123	20	0.6288	13.9812	0.0410	34.02	0.4332	9.8529	0.0199	16.90
6124	29	0.4451	16.0601	0.0272	43.16	0.3849	9.8842	0.0144	16.35
6125	15	0.5788	16.7562	0.0534	51.02	0.4007	13.5965	0.0300	33.59
6127	25	0.5585	13.6427	0.0314	31.58	0.4452	9.7723	0.0179	16.20
6131	24	0.5416	13.2493	0.0302	29.91	0.4269	10.1909	0.0183	17.70
6132	21	0.5148	15.8039	0.0369	43.21	0.3875	9.7206	0.0171	16.35
6134	6	0.5503	14.8523	0.0816	52.83	0.3947	16.0893	0.0634	62.00
Total	390	0.5321	18.9132	0.0100	55.31	0.4000	12.1070	0.0048	22.66

Table 7. Analysis of variance of seeds dimensions and shapes

Source of variation	DF	Length of seed wings LSW		Width of seeds wings WSW		WSW/LSW		Length of seeds LS		LS/LSW	
		Significance level α	σ^2/σ_T^2	Significance level α	σ^2/σ_T^2	Significance level α	σ^2/σ_T^2	Significance level α	σ^2/σ_T^2	Significance level α	σ^2/σ_T^2
Between trees	19	1.33×10^{-72}	0.6454	9.38×10^{-18}	0.2566	6.33×10^{-24}	0.3198	9.91×10^{-32}	0.3893	3.96×10^{-15}	0.2277
Within trees (error)	370	–	0.3546	–	0.7434	–	0.6802	–	0.6107	–	0.7723
Total	389	–	1.0000	–	1.0000	–	1.0000	–	1.0000	–	1.0000

Table 8. The coefficients of linear correlation between examined features. Significant values (at $\alpha=0.05$ level) are bold

Feature	D	L	D/L	OSL	OSW	OSW/OSL	LSW	WSW	WSW/LSW	LS
L	**0.6096**	–								
D/L	–0.0911	**–0.8362**	–							
OSL	0.4211	**0.6245**	**–0.4917**	–						
OSW	**0.7399**	**0.7570**	–0.4354	**0.7430**	–					
OSW/OSL	0.4380	0.1737	0.0803	–0.3534	0.3587	–				
LSW	**0.5648**	**0.6860**	**–0.4829**	**0.8524**	**0.7301**	–0.1811	–			
WSW	**0.7758**	0.3820	0.0460	0.3734	**0.6850**	0.4172	**0.4961**	–		
WSW/LSW	–0.1980	**–0.5772**	**0.5940**	**–0.7394**	–0.4236	**0.4452**	**–0.8468**	0.0276	–	
LS	**0.6158**	**0.6210**	–0.3480	**0.7090**	**0.7150**	–0.0177	**0.8981**	**0.4888**	**–0.7465**	–
LS/LSW	**–0.5327**	–0.3205	0.0525	–0.3792	**–0.5863**	–0.3294	–0.1534	–0.3403	–0.0665	–0.2091

Table 9. The comparison of the variability of silver fir cones and seeds according to various published data and according to own measurements

Feature	Literature data [1]		Data from presented measurement		Species variability	
	Ranges of population means	Absolute ranges	Population means	Absolute ranges	Ranges of population means	Absolute ranges
Length of cones (cm)	11.8–14.9	7.0–19.99	12.90	7.8–20.0	11.8–14.9	7.8–20.0
Diameter of cones (cm)	3.6–4.2	2.5–5.2	3.51	2.7–4.8	3.51–4.20	2.5–5.2
Length of seeds (mm)	11.72	7–13	8.85	5.15–13.99	8.85–11.72	5.15–13.99
Length of wings (mm)	20.256–25.040	12.5–28.5	22.34	17.46–29.21	20.256–25.040	12.50–29.21
Width of wings (mm)	12.22–12.87	8.5–16.5	11.64	8.58–16.34	11.64–12.87	8.58–16.50
Width of cone scale (cm)	2.71	2.5–3.0	2.70	2.26–3.45	2.70–2.71	2.26–3.45
Length of cone scale (cm)	2.79	–	2.16	1.51–2.98	2.16–2.79	1.51–2.98

[1] – Tyszkiewicz 1949, Gudeski 1966, Kočiová 1974, Nanu 1977, Boratyński 1983, Suszka 1983, Schütt 1991, Ballian, Čabaravdić 2005.

Kočiová 1974; Nanu 1977; Boratyński 1983; Suszka 1983; Schütt 1991; Ballian and Čabaravdić 2005), and sometimes over these frames (Table 9).

Coefficients of variability of examined features for average trees were from 9.14% to 18.9% in our study. The least variable trait was the cones diameter, and the most variable was the ratio of wing width to wing length and cone length (Table 1, 3, 5 and 6). These values are important while searching the features that significantly differentiate the individual trees and their clones. For the same purpose were used the analyses of variance with component assessment. All examined features diversified the trees significantly. The greatest diagnostic significance was associated with the traits exhibiting the broadest contribution of between-tree variance component in general variation. These features can be put in order according to the decreasing participation of component between trees: variance: the seed-scale width – 98.30%; seed-scale length – 96.76%; the ratio of the former measurements – 89.54%; cone-diameter – 72.38%; cone length – 72.13%; the ratio of cone diameter to cone length– 67.84%; length of a seed-wing– 64.54%; length of seed – 38.93%; the ratio of wing width to wing length – 31.98%; the seed-wing width – 25.66% and the ratio of the seed length to wing length – 22.77%. The features in which the participation of component within trees variance represents less than 50% correlates significantly with more diversifying features and their determination does not contribute

to the knowledge of individual variability. The length of seed correlates significantly with seven features, the most strongly with the seed-wing length (r=0.8981). The wing width correlates significantly with four features, the most strongly with the cone diameter (r=0.7758). The ratio of the wing width to its length correlates significantly with six features, the most strongly with the wing length (r=-0.8468). The ratio of the seed length to the wing length correlates significantly with two features: the cone diameter (r=–0.5327) and the width of seed scales (r=–0.5863). Therefore, the greatest significance is associated the size of seed scales, cones sizes and the length of wing. None of the ratios between measured traits diversified trees better than the measurements. However, traits ratios can characterize the different populations. For example, in our examinations the seed scales are shorter than wider, but Bosnian firs in examinations by Ballian and Čabaravdić (2005) are longer than wider.

On the basis of completed analyses, to characterize the fir trees the description of the following features of cones and seeds can be recommended: cone length, the largest diameter of cones, length of ovuliferous scales, the width of ovuliferous scales and the length of seed wings.

Conclusions

1. All examined features of cones and seeds diversified significantly the trees of silver fir in the Middle Sudeten.
2. Features with particularly broad participation of variance between trees in the general variance have the highest discriminating strength: length and width of ovuliferous scales, length and diameter of cones, and length of seeds with wings.
3. The features that rose from the ratios (shapes) did not differentiate trees better than features mentioned above.
4. The observed values of mean and absolute values are generally the same in comparison to the literature. However, several differences appeared. The highest value of cone-length was observed – 20 cm. As far as the seeds length is concerned the broader range of values was obtained 5.15–14 mm, in relation to 7–13 mm. We obtained maximum value of length of wings – 29.21 cm. Similarly, in the case of the scales length, literature reports the range of absolute values 2.5–3 cm, while we obtained 2.26–3.45 cm.

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