

Comparison of 22 Taurus Cedar (*Cedrus libani* A. Rich.) Origins by Seedling Morphological Distance

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Abstract : In this study, seeds were collected from 22 seed stands of Taurus cedar (*Cedrus libani* A. Rich.), and these seeds were sown at the Black Sea Technical University Nursery in 1995. The main morphological characteristics of 2+0 year old seedlings were measured in 1997. Values of seedling morphological distance were calculated using the Penrose formula to compare the origins in terms of morphological characteristics. According to the Penrose formula, when the values of morphological distance (P_{ij}) approach zero, the similarity between origins increases. Consequently, the most similar origins were Mugla-Arpacık and Isparta-Belceğiz2 ($P_{18,22}=0.040$), while the most different origins were Mersin-Aslanköy and Isparta-Belceğiz1 ($P_{3,11}=13.890$). Therefore, the Penrose formula should be used in the preparation of forest gene maps, and also, in the studies of fixing geographical variations and seed transfer regions.

Key Words : *Cedrus libani*, Origin, Seedling, Morphological characteristics, Penrose formula

22 Toros Sediri (*Cedrus libani* A. Rich.) Orijinin Fidan Morfolojik Mesafe Değerleri ile Karşılaştırılması

Özet : Bu çalışma, 22 Toros Sediri (*Cedrus libani* A. Rich.) tohum meşçeresinden elde edilen ve 1995 yılında Karadeniz Teknik Üniversitesi Orman Fakültesi Fidanlığına 1995 yılında ekilen tohumlardan üretilen 2+0 yaşlı fidanlar üzerinde gerçekleştirilmiştir. Fidanlarda 1997 yılında yapılan temel morfolojik özelliklere ait ölçüm değerleri kullanılarak, orijinler arası benzerlik ve farklılıklar Penrose formülü yardımıyla belirlenmeye çalışılmıştır. Penrose formülüne göre elde edilen morfolojik mesafe değeri sıfıra yaklaştıkça, orijinlerin birbirine benzerliği de artmaktadır. Hesaplanan morfolojik mesafe değerlerine göre birbirine en benzer orijinler Muğla-Arpacık ve Isparta-Belceğiz2 ($P_{18,22}=0.040$) orijinleri olarak bulunurken, birbirinden en farklı orijinlerin ise Mersin-Aslanköy ve Isparta-Belceğiz1 ($P_{3,11}=13.890$) orijinleri olduğu ortaya çıkmıştır. Dolayısıyla bu formül, orman gen haritalarının çıkarılmasında, genetik ve coğrafik varyasyon çalışmalarında ve tohum transfer rejyonlarının belirlenmesinde kullanılabilir.

Anahtar Sözcükler : Toros sediri, Orijin, Fidan, Morfolojik özellik, Penrose formül

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Introduction

The Taurus cedar (*Cedrus libani* A. Rich.) mainly grows in Taurus Mountains, Turkey, except for small stands in North Lebanon and Syria (1). Outside its continuous range, it also occurs in the Sultan Mountains, Deresinek valley, and the vicinity of Emirdag (2), Niksar and Erbaa (3), as natural small stands and groups. In Turkey, there are 99,325 hectares of pure Taurus cedar forests and 67,850 hectares of this area are normal high forest and 31,475 hectares represent destroyed high forest (4).

The Taurus cedar shows also good development outside its natural range areas as it has a high adaptation capability. Because of this characteristic it is used in plantations outside its natural range. According to the data obtained, in Turkey 61,611 hectares have been planted in total between the years 1983 and 1989 (5).

In establishing a seed source appropriate for a plantation area genetic assessment of the species is needed.

In this study, collection of seeds from 22 seed stands of Taurus cedar in Turkey allows a study of genetic similarity and differences between origins.

Materials and Methods

Materials

In this study, 2+0 year old seedlings, which were produced from seeds from 22 seed stands obtained from the Forest Trees and Seeds Research Office, were used. General informations about these seed stands are given in Table 1.

Methods

Fixing Seedling Characteristics

On January 5th 1995, seeds from the first 18 origins of the 22 seed stands, and on March 1995 seeds from the remaining 4 origins were sown into seedbeds 120 cm wide by the drill sowing method 1 cm deep, in 5 rows with 3 repetitions. Each repetition was 2m long and approximately 300 seeds were sown in each row. As a covering median a mixture of 40 % sand + 60 % humus was used.

At the end of the second year, seedling height (H) was measured for 100 seedlings from each origin with a 0.1 cm accuracy. Also, 30 lifted seedlings from each origin were cleaned by washing in the Seed and Physiology Laboratory in the Silviculture Department of the Faculty of Forestry of Black Sea Technical University and on these seedlings root-collar diameter (RCD) with a 0.01 mm accuracy, fresh weight of root and stem (RFW, SFW) with 0.01 g accuracy, and length of longest subterminal branch (LBL) with a 0.5 cm accuracy were measured. In addition, on these seedlings, the numbers of the subterminal branches (LBN) longer than 1 cm and

Table 1. Origins of *Cedrus libani* used in the study.

Origin No	Forest District	Forest Range	Area of Seed Stand (Ha)	Latitude (N°)	Longitude (E°)	Altitude (m)
1	Antalya	Akdag	107.0	36°38'42"	30°15'54"	1750
2	Antalya	Sevindik	68.3	36°31'39"	29°44'09"	1500
3	Mersin	Aslankoy	75.0	37°00'00"	34°14'00"	1000
4	Isparta	Kapidag	301.3	38°05'23"	30°42'20"	1600
5	Mersin	Abanoz-2	74.0	36°19'05"	32°58'38"	1350
6	Antalya	Aykiricay	94.5	36°27'01"	30°10'46"	1300
7	Antalya	Y.Alakir	201.5	36°36'53"	30°23'17"	1350
8	Denizli	Konak	107.0	37°17'20"	29°04'50"	1530
9	Amasya	Niksar	286.5	40°47'30"	36°34'40"	1100
10	K.Maras	Elmadag	106.0	37°37'03"	36°28'08"	1550
11	Isparta	Belceviz-1	229.5	37°52'46"	31°17'57"	1610
12	Antalya	Karacay	141.5	36°23'53"	29°26'25"	1550
13	Adana	Pozanti	176.0	37°30'32"	34°57'38"	1325
14	Eskisehir	Sultandagi	290.0	38°32'02"	31°09'07"	1400
15	Antalya	Ciglikara	41.0	36°33'25"	29°48'00"	1850
16	Mersin	Abanoz-1	244.0	36°20'15"	32°56'15"	1430
17	Isparta	Dirmil	40.5	36°55'08"	29°29'17"	1650
18	Mugla	Arpacik	249.0	36°49'52"	29°14'00"	1360
19	Konya	Gokyurt	631.0	37°49'39"	32°02'00"	1500
20	Konya	Ermenek-1	71.5	36°32'07"	32°46'38"	1750
21	Konya	Ermenek-2	47.0	36°30'43"	32°44'05"	1710
22	Isparta	Belceviz-2	59.0	37°50'02"	32°18'04"	1550

the number of buds (BN) on the terminal sprout were determined. The same seedlings were dried in a drying oven at 105 °C for 24 hours and dry weights of root and stem (RDW, SDW) were determined with a 0.01 g accuracy. By adding the value of the fresh weight of root and stem, the fresh weight of the plant (FW) and by adding the value of dry weight of root and stem, the dry weight (DW) of the plant were determined.

Statistical Procedure

The Statgraphics statistical program was used for calculations. Because average values are in different units, using the formula $Zik = (Xik - Xk) / Sk$, the values were standardized and became unitless (6-8).

In this formula:

Zik ; the standardized value of k^{th} characteristic of i^{th} origin,

Xik ; the average original value of k^{th} characteristic of i^{th} origin,

Xk ; the average value over all origins obtained from the original values of k^{th} characteristics,

Sk ; standard deviation of the origins for the k^{th} characteristic.

On the other hand, in the Penrose formula:

$$P_{ij} = \sum_{k=1}^p \frac{(\mu_{ki} - \mu_{kj})^2}{P \cdot V_k}$$

P_{ij} ; distance value between origins i^{th} and j^{th} ,

P ; number of studied characteristics,

μ_{ki} ; standardized average value of the k^{th} characteristics of the i^{th} origin,

μ_{kj} ; standardized average value of k^{th} characteristics of j^{th} origin,

V_k ; the value of k^{th} characteristic on the main diagonal of the variance-covariance matrix.

These distance values for seedling characteristics of origins are combined and the results are evaluated accordingly. When values approach zero, the similarity between origins increases (8).

Results

Original values for the average seedling height, root-collar diameter, fresh and dry weight of seedling, the number and the length of subterminal branches and the number of the buds on the terminal sprout in each origin are given in Table 2.

Average plant heights vary between 12.58 and 23.33 cm, average root-collar diameters between 2.28 and 4.18 mm, average root fresh weights between 1.16 and 4.93 g, average stem fresh weights are between 1.82 and 9.91 g and average seedling fresh weights are between 2.98 and 14.84 g. Also, average root dry weights vary between 0.45 and 1.77 g, average stem dry weights between 0.68 and 3.87 g and average seedling dry weight between 1.12 and 5.64 g. Subterminal branch lengths were found to vary between 1.63 and 5.90 cm, the amount of subterminal branches between 1.17 and 6.11 and number of buds between 1.73 and 2.37 on average. General average values for origins are also given in Table 2.

Standardized values obtained from the original measuring values are given in Table 3, and the variance-covariance matrix obtained from the standardized values are in Table 4. Calculating the morphological distance values, the values of the characteristics from the main diagonal of the variance-covariance matrix are used.

Seedling morphological distance values were calculated using the values given in Tables 3 and 4 with the Penrose formula and the results obtained are given in Table 5.

According to the researched characteristics the origins of Mugla-Arpacik and Isparta-Belcegi2 with a unit value of 0.040 ($P_{18,22}$) are the most similar to each other, and the origins of Mersin-Aslankoy and Isparta-Belcegi1 with a unit value 13.890 ($P_{3,11}$) are the most different from each other. Also when one examines Table 5 one can see that although the distance

Table 2. Mean original values for origins of the different seedling characteristics.

Origin No	Seedling characteristics										
	H (cm)	RCD (mm)	RFW (g)	SFW (g)	FW (g)	RWD (g)	SDW (g)	DW (g)	LBL (cm)	LBN	BN
1	14.68	2.93	2.05	3.01	5.06	0.78	1.00	1.90	2.23	1.73	1.93
2	14.84	2.46	1.59	2.54	4.13	0.57	0.92	1.49	2.08	1.30	1.93
3	16.97	3.28	2.50	4.30	6.80	0.99	1.64	2.52	4.48	2.73	2.34
4	17.13	2.95	2.31	3.06	5.37	0.75	1.08	1.83	2.96	2.20	2.33
5	15.63	2.76	2.43	3.37	5.80	1.01	1.33	2.34	3.65	2.73	2.17
6	14.89	2.85	1.90	3.50	5.40	0.77	1.31	2.08	2.18	2.20	1.93
7	16.21	3.58	3.20	5.05	8.25	1.17	1.82	2.98	4.79	3.17	2.33
8	18.74	4.18	4.27	7.43	11.69	1.47	2.83	4.30	4.65	4.30	2.20
9	18.99	3.52	3.03	4.82	7.85	1.26	2.01	3.27	5.30	4.37	2.07
10	17.40	3.75	3.40	6.09	9.49	1.39	2.17	3.55	5.55	4.13	2.37
11	23.33	3.99	4.93	9.91	14.84	1.77	3.87	5.64	5.90	6.10	2.10
12	12.58	2.28	1.16	1.82	2.98	0.45	0.68	1.12	1.63	1.17	1.73
13	14.25	3.46	3.50	3.85	7.36	0.61	1.45	2.57	2.86	1.70	2.17
14	17.86	2.98	2.10	3.88	5.98	0.88	1.47	2.35	3.40	2.97	2.13
15	15.02	2.96	2.17	3.55	5.72	0.81	1.33	2.14	3.08	2.33	1.97
16	19.31	3.53	2.95	5.48	8.43	1.12	1.98	3.00	4.37	4.10	2.00
17	15.99	2.69	1.90	3.02	4.92	0.79	1.09	1.88	1.72	1.40	2.00
18	15.85	3.47	2.97	4.72	7.68	0.93	1.68	2.61	3.72	2.60	2.03
19	16.98	3.00	2.28	3.46	5.74	1.04	1.44	2.48	3.68	2.53	1.93
20	16.60	3.38	2.46	4.25	6.71	1.18	1.27	2.91	4.95	2.63	2.37
21	17.57	3.87	2.19	6.92	10.11	1.35	2.42	3.75	6.38	4.43	1.93
22	15.33	3.43	2.07	4.21	6.28	1.04	1.82	2.86	3.90	2.50	2.17
General	16.63	3.24	2.65	4.46	7.11	1.03	1.66	2.71	3.79	2.88	2.10

from Mersin-Aslankoy origin to Konya-Ermenek1 origin is 0.180 unit ($P_{3,20}$), it is 13.890 unit ($P_{3,11}$) to Isparta-Belcegez1 origin. So the similarity between Mersin-Aslankoy origin and Konya-Ermenek1 origin is 77.17 times ($P_{3,11}=13.890 / P_{3,20}=0.180$) greater than the similarity between Mersin-Aslankoy origin and Isparta-Belcegez1 origin.

Discussion

As shown in Table 5, seedling morphological distance values calculated with the Penrose formula, range between 0.040 ($P_{18,22}$) and 13.890 ($P_{3,11}$).

Table 3. Mean standardized values of origins for different seedling characteristics.

Origin No	Seedling Characteristics										
	H	RCD	RFW	SFW	FW	RDW	SDW	DW	LBL	LBN	BN
1	-0.882	-0.629	-0.639	-0.795	-0.775	-0.708	-0.935	-0.814	-1.139	-0.950	-0.942
2	-0.810	-1.579	-1.166	-1.052	-1.125	-1.366	-1.048	-1.227	-1.248	-1.273	-0.942
3	0.147	0.079	-0.123	-0.090	-0.120	-0.050	-0.034	-0.389	0.500	-0.119	1.373
4	0.219	-0.588	-0.341	-0.768	-0.658	-0.802	-0.822	-0.885	-0.607	-0.546	1.317
5	-0.455	-0.972	-0.203	-0.598	-0.496	0.013	-0.470	-0.371	-0.105	-0.119	4.132
6	-0.787	-0.790	-0.811	-0.527	-0.647	-0.740	-0.499	-0.633	-1.175	-0.546	-0.942
7	-0.195	0.685	0.680	0.319	0.427	0.514	0.220	0.274	0.726	0.024	1.317
8	0.942	1.898	1.906	1.619	1.722	1.455	1.642	1.605	0.624	1.149	0.583
9	1.054	0.564	0.485	0.194	0.276	0.796	0.487	0.567	1.097	1.205	-0.151
10	0.340	1.029	0.909	0.887	0.894	1.204	0.712	0.849	1.279	1.012	1.542
11	3.003	1.514	2.663	2.974	2.909	2.395	3.106	2.955	1.534	2.602	0.018
12	-1.825	-1.943	-1.659	-1.445	-1.559	-1.743	-1.386	-1.600	-1.576	-1.378	-2.071
13	-1.075	0.443	1.024	-0.336	0.091	-1.241	-0.301	-0.388	-0.680	-0.950	0.413
14	0.546	-0.527	-0.582	-0.320	-0.429	-0.395	-0.273	-0.361	-0.287	0.075	0.187
15	0.729	-0.578	-0.501	-0.500	-0.526	-0.614	-0.470	-0.572	-0.520	-0.441	-0.716
16	1.198	0.184	0.393	0.554	0.494	0.358	0.445	0.295	0.420	0.987	-0.547
17	-0.293	-1.114	-0.811	-0.789	-0.828	-0.677	-0.808	-0.834	-1.510	-1.192	-0.547
18	-0.356	0.463	0.416	0.139	0.212	-0.239	0.022	-0.098	-0.054	-0.223	-0.377
19	0.151	-0.487	-0.375	-0.549	-0.519	0.107	-0.316	-0.230	-0.083	-0.280	-0.942
20	-0.019	0.281	-0.169	-0.118	-0.154	0.546	-0.555	0.204	0.842	-0.199	1.542
21	0.416	1.272	-0.478	1.341	1.127	1.079	1.064	1.050	1.884	1.254	-0.942
22	-0.590	0.382	-0.616	-0.140	-0.316	0.107	0.220	0.153	0.077	-0.304	0.413

Table 4. Variance-covariance matrix of standardized values.

	H	RCD	RFW	SFW	FW	RDW	SDW	DW	LBL	LBN	BN
H	0.444	0.172	0.334	0.331	0.326	0.302	0.350	0.342	0.143	0.333	-0.150
RCD		0.284	0.251	0.277	0.282	0.244	0.266	0.275	0.174	0.213	0.063
RFW			0.378	0.350	0.356	0.329	0.359	0.359	0.158	0.301	-0.143
SFW				0.442	0.427	0.338	0.437	0.422	0.211	0.348	-0.048
FW					0.425	0.328	0.427	0.416	0.202	0.332	-0.062
RDW						0.364	0.351	0.356	0.237	0.326	-0.116
SDW							0.457	0.434	0.220	0.362	-0.076
DW								0.433	0.229	0.355	-0.078
LBL									0.301	0.247	-0.045
LBN										0.384	-0.171
BN											0.761

Table 5. Values of morphological distance (P_{ij}).

Origin																					
NO	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
2	0.563	-																			
3	1.079	2.769	-																		
4	0.262	0.993	0.615	-																	
5	2.051	3.097	1.354	1.375	-																
6	0.119	0.694	0.836	0.293	1.879	-															
7	0.614	1.582	0.305	0.324	1.252	0.296	-														
8	1.694	0.549	4.631	2.121	4.502	1.947	3.002	-													
9	0.286	1.077	1.034	0.628	2.818	0.289	0.759	2.597	-												
10	0.254	0.293	1.548	0.393	1.996	0.271	0.733	1.357	0.714	-											
11	7.507	5.244	13.890	9.268	13.591	8.629	11.563	3.550	8.994	7.351	-										
12	1.879	0.659	5.247	2.692	4.348	2.172	3.539	0.771	2.844	1.378	3.393	-									
13	0.484	1.185	1.078	0.668	2.674	0.368	0.667	2.451	0.225	0.761	9.060	2.864	-								
14	0.722	1.864	0.402	0.484	2.028	0.479	0.252	3.048	0.623	1.201	11.338	4.122	0.544	-							
15	0.282	1.196	0.453	0.180	1.656	0.184	0.209	2.388	0.340	0.641	9.770	3.031	0.333	0.129	-						
16	0.435	1.687	0.642	0.541	2.090	0.494	0.651	2.999	0.320	1.093	9.865	3.565	0.389	0.369	0.207	-					
17	0.230	0.391	1.590	0.567	2.714	0.284	0.864	1.531	0.486	0.221	7.523	1.831	0.831	1.010	0.659	0.995	-				
18	1.081	2.450	0.287	0.693	1.908	0.791	0.338	3.858	0.835	1.581	12.985	5.000	0.734	0.091	0.295	0.451	1.489	-			
19	0.840	2.106	0.249	0.397	1.333	0.678	0.248	3.339	0.946	1.235	12.113	4.428	0.899	0.171	0.239	0.444	1.241	0.128	-		
20	0.737	2.089	0.180	0.365	1.304	0.541	0.185	3.894	0.807	0.980	12.620	4.275	0.857	0.484	0.374	0.695	1.107	0.481	0.372	-	
21	0.506	0.342	2.512	0.937	3.175	0.712	1.574	1.425	1.062	0.323	6.358	1.303	1.519	2.006	1.289	1.717	0.244	2.565	2.109	1.778	-
22	0.926	2.297	0.328	0.667	1.887	0.698	0.359	3.575	0.743	1.508	12.211	4.671	0.651	0.079	0.243	0.320	1.393	0.040	0.137	0.526	2.474

It is interesting that although Isparta-Belceğiz1 and Isparta-Belceğiz 2 origins have similar values in the characteristics of latitude, longitude and elevation (Table 1), they do not have any similarities in the morphological distance values ($P_{11,22}=12.211$). On the other hand origins 1 (Antalya-Akdag), 2 (Antalya-Sevindik), 6 (Antalya-Aykırıçay), 7 (Antalya-Y.Alakir), 12 (Antalya-Karacay) and 15 (Antalya-Ciglikara) have generally similar values.

As was said before, origins can be tested by morphological distance value and similarity between origins can be tested with the help of unit values which are obtained as a result of standardization of morphological characteristics. So this characteristic of the formula is an important advantage over variation analysis. It is possible that with the Penrose formula from morphological characteristics one can guess the genetic structure and one can build forest gene maps, and also compare habitats in genetic and geographical studies. Finding origins that have high establishment capacity and establishment values for origin tests and appraising the seedling morphological distance values will influence the commentary success positively.

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