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Variation of morphological characters of Oriental spruce (*Picea orientalis*) in Turkey

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Oriental spruce (*Picea orientalis* L. Link) is one of the most considering species distributed along Colchis sector of Euro-Siberian geophytological region the world. The tree taxon is mostly used in reforestation in the Northeast Black Sea Region of Turkey. However, a few data is available about its intra-specific variation and adaptability. To study the pattern of natural variation of Oriental spruce, 25 populations taken from natural stands in Turkey were compared based on phenotypic variation of cone, seed and wing morphology, and two geographic parameters (altitude and watershed). ANOVA showed that the morphological characters differed in the populations. Also, the cluster modelling performed on morphological characters suggested that geographic parameters (watershed and altitude) exhibited different groups.

Key words: *Picea orientalis*, geographic variation, morphological characters, Turkey

Introduction

Oriental spruce (*Picea orientalis* (L.) Link.), one of the forty spruce species in the world, is widespread in the Northeast Black Sea Region, its backward section and inner part of this region as well. The species covers about 350 000 ha in this region. The mixed and pure oriental spruce stands begin just west of the Melet River and extend along to the southern section of Caucasian Mountains in Georgia. The forests are also found in the backward section of the Eastern Black Sea region especially within the Coruh and Harsit watersheds along the north facing slopes. In vertical direction it begins at the coastal zone and continues as high as 2400 m altitude (Atalay, 1984; Saatcioglu, 1976).

Oriental spruce is an important species for reforestation in the Black Sea region of Turkey. It is of critical importance from both ecological and silvicultural perspective. However, there are few studies on genetic and geographical variation of these taxa. Atalay (1984) studied the seed transfer of Oriental spruce, whereas the paper by Gezer (1976) dealt with the morphogenetic characteristics of the seedlings. Atasoy (1996) and Urgenc (1965) investigated the variation of seeds, cones and seedlings. In addition, Turna (1996) determinated genetic structure of Oriental spruce populations using isozyme analysis. However, all these studies lack information about the geographical variation based on detailed morphometric variables and analyses.

The objective of this study was to investigate the variation within and between Oriental spruce populations in Turkey using morphological characters. As well, this study aims to extend the knowl-

Table 1. Description of the populations studied

No	Populations	Watershed* – Altitude**	Mean Altitude (m)	Latitude (North)	Longitude (East)
1	Ordu – Cambası-1	1-2	1200	40° 43′ 20″	37° 57′ 15″
2	Ordu – Cambası-2	1-3	1500	40° 42′ 39″	37° 55′ 38″
3	Ordu – Cambası-3	1-4	1800	40° 38′ 58″	37° 56′ 16″
4	Giresun – Dereli-1	2-2	1200	40° 35′ 50″	38° 27′ 15″
5	Giresun – Dereli-2	2-3	1500	40° 34′ 48″	38° 27′ 00″
6	Giresun – Dereli-3	2-4	1800	40° 33′ 45″	38° 26′ 15″
7	Trabzon – Karadag-1	3-3	1500	40° 56′ 37″	39° 24′ 00″
8	Trabzon – Karadag-2	3-4	1800	40° 55′ 38″	39° 22′ 55″
9	Trabzon – Macka-1	4-1	900	40° 48′ 55″	39° 38′ 50″
10	Trabzon – Macka-2	4-2	1200	40° 41′ 45″	39° 28′ 00″
11	Trabzon – Macka-3	4-3	1500	40° 40′ 30″	39° 25′ 45″
12	Trabzon – Macka-4	4-4	1800	40° 40′ 16″	39° 25′ 30″
13	Trabzon – Caykara-1	5-3	1500	40° 34′ 24″	40° 23′ 50″
14	Trabzon – Caykara-2	5-4	1800	40° 34′ 30″	40° 23′ 10″
15	Rize – Ikizdere	6-4	1800	40° 38′ 50″	40° 32′ 12″
16	Rize – Camlıhemsin-1	7-3	1500	40° 52′ 28″	40° 56′ 15″
17	Rize – Camlıhemsin-2	7-4	1800	40° 52′ 20″	40° 56′ 40″
18	Rize – Camlıhemsin-3	7-5	2100	40° 48′ 40″	40° 56′ 45″
19	Torul – Krtn-1	8-2	1200	40° 42′ 45″	39° 12′ 40″
20	Torul – Krtn-2	8-3	1500	40° 43′ 30″	39° 13′ 15″
21	Torul – rmcek-1	9-3	1500	40° 39′ 40″	39° 01′ 10″
22	Torul – rmcek-2	9-4	1800	40° 39′ 45″	39° 00′ 25″
23	Artvin – Atila-1	10-2	1200	41° 07′ 23″	41° 37′ 22″
24	Artvin – Taslıca-2	10-3	1500	41° 08′ 00″	41° 36′ 40″
25	Artvin – Taslıca-3	10-4	1800	41° 08′ 00″	41° 36′ 40″

* Watershed number, ** Altitude number

edge of the geographic patterns of morphological variation of Oriental spruce in Turkey.

Material and methods

Sampling and measurement procedure

This work was carried out in 25 natural populations of Oriental spruce distributed along five altitudinal gradients of 10 watersheds in Turkey. Sample trees were chosen from the populations using randomised sampling design. The distance between consecutive watersheds is about 50 kilometres and each sample was selected from every 300-meter altitudinal zone. The principal geographic characteristics of all the populations are summarized in Table 1.

The populations are numbered sequentially from west to north. Tree collection areas are laid down from west through east of northeast Black Sea Region in which the western border of Oriental spruce is situated at Melet River (Ordu-Cambası, No, 1, 2, 3). The eastern border is Rize-Camlıhemsin (No, 16, 17, 18) and the southern border lies along the north facing slopes of Coruh and Harsit River watershed (Torul and Artvin, No, 19, 20, 21, 22, 23, 24 and 25). These populations represent large proportion of distribution areas. Relevant map showing location of the populations is given in Figure 1.

The material collection was carried out to serve a large research program on Oriental spruce including studies on genetic diversity and eco-physiological studies. The methods for sampling of individual trees and measurements of morphological characters were taken from the previous studies, such as Maley & Parker, 1993; Koral et al., 1995; Lee et al., 1998; Matziris, 1998; Turna, 1996; Turna, 2002; Boulli et al., 2001.

For each population a systematic sampling approach was used. A mean 100-meter distance was allocated for each sample tree. A total of 20 sample trees and 15–20 healthy cones from the last year crop and upper part of each tree crown collected from each sample tree were used. A total of 500 trees were sampled. Thus, to differentiate the 25 natural oriental spruce populations for a morphometric analysis, a total of 12 measurements were made as follows:

As to cone morphology, the five traits were measured on each cone using 10 cones per tree: i) cone length (CL), ii) closed cone width (CW), iii) cone length to width ratio (CL/CW), closed cone forms, iv) cone stem forms (CSF), (cylinder and conic) and v) point of cone apex (CPS), (sharp pointed, bending and obtuse).

As to seed morphology, the 10 winged seeds were measured. The seeds were chosen randomly from a composite sample of several cones from the same tree. The wing was removed and both seed and wing were

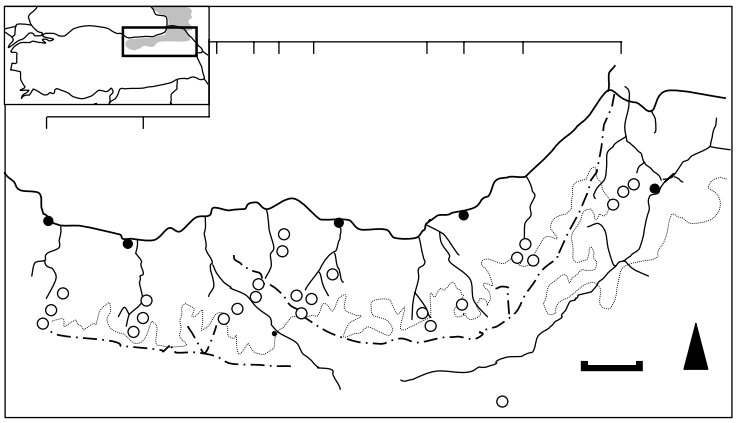

Fig. 1. Map of Oriental spruce natural distributions indicating the sampled localities.

measured. Seven seed and wing traits were quantified: i) seed length (SL), ii) seed width (SW), iii) seed length to width ratio (SL/SW), iv) wing length (WL), v) wing width (WW), vi) wing length to width (WL/WW) and vii) wing shape (WS) (scimitar-obtuse, scimitar-oval, oblong-obtuse and oblong-oval).

Data analysis

Analysis of morphological variation was based on the measurements of 12 characters related to cones, seeds and wings. Variations among and within populations were analysed using ANOVA-one way (Zar, 1984). Correlation between pairs of morphological characters and altitude, latitude and longitude was evaluated using Pearson's correlation coefficient (Snedecor & Cohran, 1968). We also examined overall variations of morphological characters among populations using Principal Component Analyses (PCA) performed on transformed mean matrix. The altitude, watershed and other morphological characters were analysed as supplementary variables. Populations were classified hierarchically using chi-square distance. Statistical analysis was carried out using SPSS 11.0 (SPSS for windows, release 11.0).

Results

The overall mean values of all characters measured, their standard deviations, F and significance levels are presented in Table 2. In general, high levels of all morphological variation were found for all the 25 natural populations. The analysis of variance revealed significant differences between populations based on all morphological characters.

Morphological traits for determining cone size (length, width and length to width ratio) and cone form (cone stem form, point of cone apex) were found to be more variable (Tab. 2). Among populations the cone length varied from 5.554 cm (popn. No. 10) to 7.262 cm (popn. No. 7) and its mean value was 6.425 cm, cone width varied from 1.429 cm (popn. No. 3) to 1.955 cm (popn. No. 9) and its mean value was 1.592 cm. The cone length to width ratio varied from 3.291 (popn. No. 9) to 4.501 (popn. No. 2) and its mean value was 4.061 cm.

Seed length varied from 3.836 mm (popn. No. 10) to 4.528 mm (popn. No. 1) and its mean value was 4.175 mm, the seed width varied from 2.310 mm (popn. No. 14) to 2.816 mm (popn. No. 1), and its mean value was 2.541 mm. The seed length to width ration varied from 1.552 mm (popn. No. 24) to 1.846 (popn. No. 14), and its mean value was 1.654 mm. The longest and the largest seeds came from the west of Trabzon populations (popn. No. 1, 2, 3, 4, 5, 6, 7, 8).

The four wing related traits corresponding to length, width, length to width ratio and wing form, differed significantly among populations (Tab. 2), The four wing values varied respectively from 9.954 mm (popn. No. 10) to 13.873 mm (popn. No. 1), 5.161 mm (popn. No. 9) to 6.349 mm (popn. No. 1), 1.896 (popn. No. 10) to 2.238 mm (popn. No. 5), and 2.050 (popn. No. 12) to 3,850 (popn. No. 25), and their mean values of four wings traits were 11.778 mm, 5.640 mm, 2.099 mm and 2.928 respectively. Both longest and largest wings belong to the west of Trabzon populations (popn. No. 1, 2, 3, 4, 5, 6, 7, 8).

Figure 2 indicates population groups based on morphological characters, resulting from the cluster analysis. According to this figure, five different main groups were formed. The first group included two sub groups (1.1 and 1.2) and the same was true in the second group, which included two sub groups (2.1 and 2.2) as well. Groups 3 and 4 included only one population and the other

Table 2. Measurements (mean ± standard deviation, F and significancy) of morphological characters determined for 25 natural populations of Oriental spruce in Turkey

No	CL (cm)	CW (cm)	CL/CW	SL	SW	SL/SW	WL	WW	WL/WW	CSF	CPS	WS
1*	7.047	1.730	4.093	4.528	2.816	1.622	13.873	6.349	2.193	2.000	2.550	2.550
	±3.404	±0.918	±0.329	±0.145	±0.181	±0.095	±0.892	±0.234	±0.126	±0.000	±0.510	±1.099
2	6.924	1.549	4.501	4.518	2.755	1.646	12.873	6.075	2.126	2.000	2.450	2.250
	±9,342	±1.539	±0.648	±0.370	±0.153	±0.075	±1.232	±0.330	±0.176	±0.000	±0.686	±1.372
3	5.927	1.429	4.154	4.254	2.687	1.591	11.958	5.696	2.111	2.000	2.300	2.550
	6,224	±0.379	±0.414	±0.261	±0.088	±0.113	±0.911	±0.209	±0.185	±0.000	±0.923	±1.191
4	6.729	1.650	4.090	4.504	2.667	1.691	12.924	5.905	2.204	1.750	2.350	2.700
	±4,214	±1.056	±0.223	±0.295	±0.064	±0.094	±0.855	±0.365	±0.205	±0.444	±0.745	±1.174
5	6.504	1.652	3.938	4.430	2.652	1.685	12.702	5.754	2.238	1.700	1.900	2.850
	±5.589	±1.090	±0.207	±0.298	±0.130	±0.138	±0.845	±0.543	±0.264	±0.470	±0.852	±1.226
6	7.192	1.715	4.210	4.520	2.743	1.656	13.232	6.020	2.210	1.650	2.250	3.250
	±3.660	±1.229	±0.285	±0.202	±0.086	±0.081	±0.756	±0.320	±0.120	±0.489	±0.851	±1.070
7	7.262	1.643	4.442	4.458	2.511	1.787	12.700	5.909	2.169	1.600	2.300	3.150
	±5.357	±1.310	±0.393	±0.267	±0.095	±0.117	±0.821	±0.390	±0.155	±0.503	±0.923	±1.089
8	6.608	1.596	4.152	4.244	2.576	1.655	11.862	5.713	2.095	2.000	1.550	3.550
	±5.946	±0.868	±0.405	±0.209	±0.123	±0.091	±0.570	±0.415	±0.163	±0.000	±0.887	±0.887
9	6.272	1.955	3.291	3.930	2.473	1.609	10.563	5.161	2.059	1.050	2.500	3.150
	±7.800	±3.385	±0.661	±0.285	±0.168	±0.096	±0.943	±0.409	±0.083	±0.224	±0.761	±0.813
10	5.554	1.584	3.520	3.836	2.470	1.560	9.954	5.308	1.896	1.600	2.450	2.200
	±5.095	±1.316	±0.252	±0.302	±0.142	±0.089	±0.815	±0.510	±0.216	±0.503	±0.887	±1.322
11	6.615	1.674	3.956	4.146	2.507	1.664	11.581	5.592	2.080	2.000	2.050	3.300
	±6.805	±0.955	±0.286	±0.253	±0.129	±0.083	±0.907	±0.319	±0.152	±0.000	±0.759	±0.923
12	6.526	1.708	3.834	4.201	2.452	1.723	11.650	5.700	2.056	1.900	2.500	2.050
	±6.898	±0.844	±0.436	±0.203	±0.132	±0.088	±0.833	±0.355	±0.182	±0.308	±0.827	±1.099
13	6.568	1.607	4.098	4.121	2.413	1.723	11.641	5.626	2.080	2.000	1.850	2.200
	±7.946	±1.403	±0.380	±0.277	±0.128	±0.125	±1.268	±0.464	±0.193	±0.000	±0.745	±1.322
14	6.167	1.523	4.053	4.223	2.310	1.846	11.576	5.545	2.097	2.000	1.950	2.400
	±7.649	±1.150	±0.384	±0.255	±0.180	±0.171	±1.210	±0.283	±0.189	±0.000	±0.887	±1.353
15	5.985	1.448	4.184	4.051	2.482	1.645	11.376	5.334	2.145	1.600	1.950	3.700
	±8.248	±1.920	±0.466	±0.244	±0.146	±0.063	±1.029	±0.366	±0.139	±0.503	±0.759	±0.923
16	6.198	1.608	3.862	4.051	2.435	1.672	11.265	5.557	2.041	1.950	1.850	2.750
	±6.844	±1.102	±0.339	±0.205	±0.108	±0.076	±0.808	±0.402	±0.174	±0.224	±0.933	±0.786
17	6.048	1.515	4.003	3.956	2.326	1.714	10.917	5.459	2.010	1.900	1.400	2.400
	±6.546	±1.085	±0.388	±0.243	±0.166	±0.092	±0.867	±0.401	±0.116	±0.308	±0.821	±1.314
18	5.941	1.537	3.879	4.118	2.475	1.676	11.334	5.585	2.047	1.900	1.300	2.600
	±5.108	±0.870	±0.363	±0.236	±0.182	±0.109	±0.966	±0.387	±0.224	±0.308	±0.657	±0.883
19	6.348	1.529	4.158	3.924	2.496	1.578	10.843	5.355	2.038	1.700	1.550	3.150
	±6.244	±1.079	±0.314	±0.346	±0.171	±0.107	±0.892	±0.343	±0.179	±0.470	±0.887	±1.040
20	6.339	1.638	3.881	4.144	2.677	1.554	11.618	5.591	2.093	1.650	1.600	3.400
	±4.813	±1.207	±0.254	±0.213	±0.091	±0.073	±0.916	±0.424	±0.192	±0.489	±0.754	±0.681
21	6.760	1.561	4.335	4.083	2.412	1.699	12.201	5.571	2.202	1.900	2.050	3.650
	±6.887	±0.919	±0.335	±0.301	±0.131	±0.095	±1.209	±0.305	±0.231	±0.308	±0.999	±0.489
22	6.496	1.516	4.299	4.081	2.450	1.680	11.807	5.544	2.143	1.850	1.950	3.500
	±4.699	±1.097	±0.274	±0.207	±0.166	±0.115	±0.911	±0.298	±0.198	±0.366	±0.945	±0.513
23	6.561	1.487	4.415	4.092	2.636	1.559	11.430	5.695	2.019	2.000	1.800	2.950
	±7.996	±0.838	±0.463	±0.187	±0.134	±0.059	±0.804	±0.276	±0.150	±0.000	±0.768	±1.146
24	6.250	1.506	4.144	3.971	2.569	1.552	11.225	5.461	2.063	2.000	1.700	3.100
	±8.033	±1.089	±0.346	±0.306	±0.157	±0.082	±1.244	±0.407	±0.159	±0.000	±0.865	±1.294
25	5.815	1.443	4.029	3.990	2.538	1.580	11.355	5.499	2.071	2.000	1.050	3.850
	±8.551	±1.298	±0.440	±0.327	±0.197	±0.091	±1.096	±0.383	±0.102	±0.000	±0.224	±0.366
Mean	*6.425*	*1.592*	*4.061*	*4.175*	*2.541*	*1.654*	*11.778*	*5.640*	*2.099*	*1.828*	*1.966*	*2.928*
	±7.673	±1.698	±0.461	±0.329	±0.190	±0.121	±1.276	±0.446	±0.188	±0.378	±0.887	±1.150
F ratio	*8.453*	*15.208*	*9.682*	*12.694*	*17.453*	*10.936*	*16.951*	*9.818*	*3.871*	*10.004*	*5.162*	*5.006*
P	*0,000*	*0,000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*

CL: Cone length (cm), CW: Cone width (cm), CL/CW: Cone length to width ratio, SL: Seed length (mm), SW: Seed width (mm), SL/SW: Seed length to width ratio, WL: Wing length (mm), WW: Wing width (mm), WL/WW: Wing length to width ratio, CSF: Cone seed form, CPS: Cone apex form, WS: Wing shape; *: Population numbers same as in Table-1

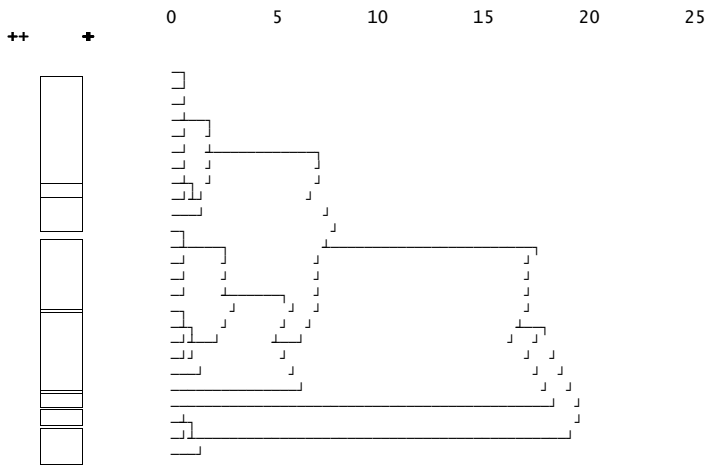

Fig. 2. Hierarchical cluster of 25 natural populations of Oriental spruce performed on the basis of morphological characters.

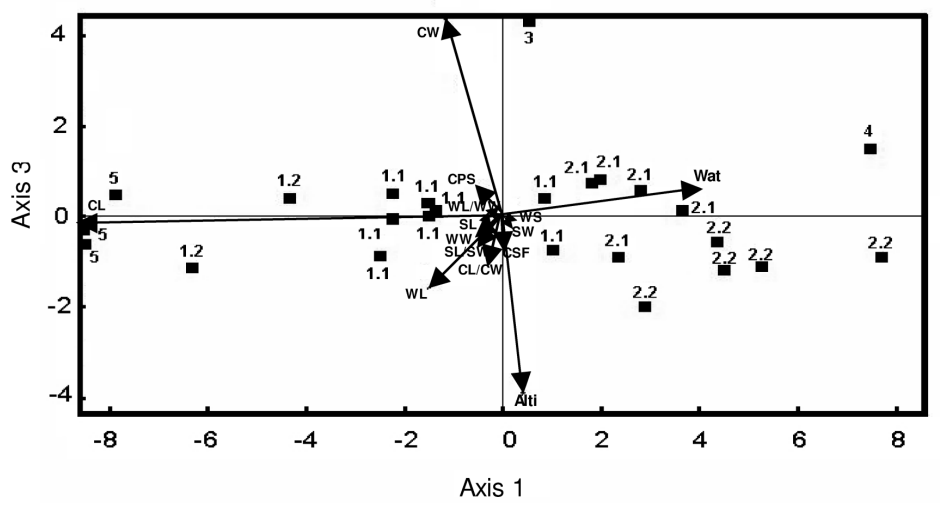

Fig. 3. Projections of Oriental spruce populations and geographic parameters on the plans formed by the principal component analyses performed on the basis of morphological characters.

group had several populations.

Relationships between all morphological traits, altitude and watershed parameters were expressed in a correlation matrix in Table 3. According to this table, cone length correlated positively with eleven morphological characters (r between 0.028 and 0.795), but altitude negatively correlated with watershed. Of these, the differences in SL, WL, WW and WL/WW characters were significant at $p < 0.01$. Cone width correlated positively with seed and wing characters (r between 0.102 and 0.239), and CPS (r equal to 0.531) except wing shape. Seed length correlated positively with all morphological characters except wing shape (r between 0.148 and 0.700). Also, it correlated positively with altitude but negatively with watershed. Seed width correlated with cone and wing characters (r between 0.046 and 0.700) and it correlated negatively with SL/SW, altitude and watershed (Tab. 3).

The wing characters positively correlated with all seed and cone characters used in this study (r ranged from 0.149 to 0.939). Cone length to width ratio and all wing characters exhibited positive correlation with altitude. In addition, seed length, and seed length to width ratio exhibited

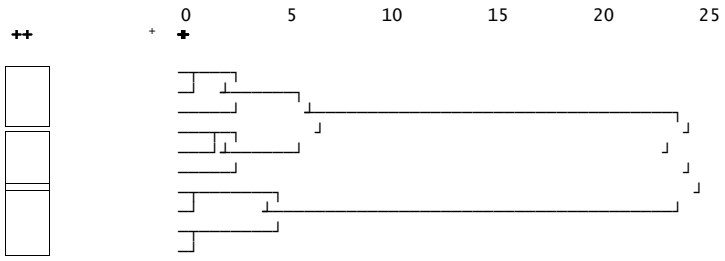

Fig. 4. Hierarchical clustering of populations of Oriental spruce along the 10 watersheds performed on the basis of morphological characters.

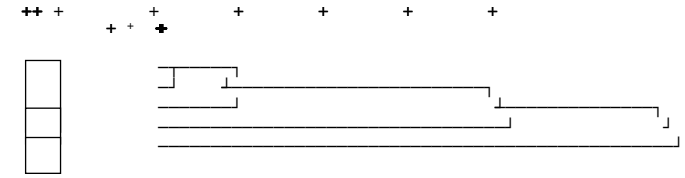

Fig. 5. Hierarchical cluster of 5-altitude stage of Oriental spruce performed on the basis of morphological characters.

also positive correlations width altitude (r equal to 0.066 and 0.357, respectively) and negative correlation with the watershed (r equal to -0.710 and -0.539 respectively). Contrary to watershed parameters exhibiting negative correlation with all morphological characters, the cone length to width ratio, cone stem form and altitude exhibited positive correlation respectively (r equal to 0.068, 0.141 and 0.100).

To assess the effects of the morphological characters on the cluster groups, principal component analysis (PCA) based on the 12 morphological characters and the two geographic parameters was implemented (Fig. 3). This analysis showed the gradient of morphological characters on the axis 1 and 3, explaining 40% and 23% of the total variation, respectively. Watershed was positively correlated with population groups of 2.1, 2.2 and 4. On the other hand, groups 1.1, 1.2 and 5 were negatively associated with cone length. According to the same figure, the effects of altitude and cone width were insignificantly correlated in forming the cluster groups.

In order to determine if the variability of morphological characters based on watersheds is distinct, the cluster analysis was conducted (Fig. 4). According to this figure, hierarchical clustering process leads to two majors groups, one with two minor groups and the other with one minor group. Watershed 1 (Ordu), 2 (Giresun), 3 (Trabzon-Karadag) and 9 (Torul-rümcek), from west of Trabzon to the west border of Oriental spruce, showed also grouping affinities. The first group included two minor group, one of which included watershed number 4, (Trabzon-Macka), 5 (Trabzon-Caykara) and 8 (Torul-Kürtün), the other minor group included 6 (Rize-Ikizdere), 7 (Rize-Camlıhemsin) and 10 (Artvin). Similarly, hierarchical cluster analysis of 5-altitude stage led to 3 different groups, (Fig. 5). The first group included altitude No. 2 (mean 1200 meter), altitude No. 3 (mean 1500 meter) and altitude No. 4 (mean 1800 meter). Altitude No. 1 (mean 900 meter) and 5 (mean 2100 meter) were in different groups.

Discussion

Since the morphometric variation in several tree species in Turkey has been a relatively less studied issue, it should be given a high priority in forest breeding and selection system (Isik & Kara, 1997).

Earlier studies on variation in morphological and genetic characters have revealed the existence of considerable variation in form and growth characteristics of this species (Atasoy, 1996; Urgenc, 1965; Gezer, 1976). Similar findings were also found in other forest species (Calamassi et al., 1988; Isik, 1986; Conkle et al., 1988). Donahue & Upton (1996) stated that the southern populations are morphologically different from the northern ones, and that the southern population have more variation. Variation in most of these characteristics appeared to be related mostly to altitude and climatic factors.

The results of this study reflecting some geo-

Table 3. Pearson coefficient of correlation between pairs of geographic parameters and morphological characters of Oriental spruce populations

	CL	CW	CL/CW	SL	SW	SL/SW	WL	WW	WL/WW	CSF	CPS	WS	Alti.
CL	1												
CW	0.425*	1											
CL/CW	0.530*	−0.532**	1										
SL	0.749**	0.239	0.447*	1									
SW	0.441*	0.150	0.266	0.654**	1								
SL/SW	0.318	0.102	0.178	0.356	−0.472*	1							
WL	0.795**	0.182	0.546**	0.939**	0.659**	0.280	1						
WW	0.745**	0.149	0.512**	0.911**	0.700**	0.197	0.924**	1					
WL/WW	0.670**	0.174	0.463*	0.759**	0.442*	0.338	0.858**	0.599**	1				
CSF	0.028	−0.591**	0.520**	0.148	0.040	0.121	0.225	0.368	−0.018	1			
CPS	0.419*	0.531**	−0.085	0.445*	0.307	0.140	0.368	0.377	0.253	−0.309	1		
WS	0.073	−0.106	0.203	−0.166	0.046	−0.260	0.002	−0.230	0.306	−0.198	−0.387	1	
Alti.	−0.190	−0.500*	0.258	0.066	−0.227	0.357	0.057	0.031	0.095	0.443*	−0.436*	0.074	1
Wat.	−0.383	−0.439*	0.068	−0.710**	−0.458*	−0.263	−0.539**	−0.569**	−0.373	0.141	−0.678**	0.430*	0.100

* Correlation is significant at 0.05 levels. ** Correlation is significant at 0.01 levels. *** Abbreviation of variable are listed in Table 2

graphical parameters (altitude, watershed) clearly showed that ecological differentiation along gradients of various watersheds is the major driving force behind cone, seed and wing variation. By comparing seed, cone and wing sizes in different sampled areas, representing different environmental conditions, some general understanding about the effects of environmental factors on watershed and altitude can be obtained. Considering the clustering groups of Oriental spruce, it was observed that distribution of the groups was significant. Namely, a clear geographic pattern typified by altitude and watershed grouping is revealed in this study. Adjacent populations that presented close relationships among ecological features tended to cluster into the same group. In addition, Pearson's coefficient correlations and PCA analyses are in agreement with the general tendency of relationships between most of the characters and altitude and watershed.

This study showed that the populations are not homogeneous with regard to the characteristics of cone, seed and wing. The reason of the fact that the grouping and differences existed among the studied populations in terms of morphological characters may explain that there were different origins or varieties, forming the Oriental spruce stands. Previous studies support this statement. For example, KAYACIK (1960) showed that the Oriental spruce stands include diverse morphological features such as the growth habits, root system and cone colour. Similar results showed that genetic diversity exists within and among the populations of Oriental spruce with respect to seeds and seedling characteristics (ATASOY, 1996; GEZER, 1976; URGENC, 1965).

This study exhibited higher adaptation plasticity and higher stability of the species under varying environmental conditions. When the morphological characters were evaluated by altitudinal zones, the anthropological effects in the first (mean 900 m a.s.l.) and fifth (mean 2100 a.s.l.) altitudinal zones were observed. However, the 2^{nd}, 3^{rd} and 4^{th} altitudinal zones represent the optimal distributed habitats of Oriental spruce stands. With this respect, the natural distribution area of *P. orientalis* in Turkey is divided geographically into five main breeding zones according to the climatic and ecological characters. ATALAY (1984) also proposed the seed transfer regioning for this taxon in which the longest vertical distance should be realized in a total of 350 m. This study not only supported his findings, but also provided the evidence for flexibility among the altitudes.

This study suggests that forestry practices

in the Oriental spruce stands, such as selection of seed sources and determination of seed transfer zones, should strongly emphasize the consideration of elevation gradients in this region. In this species for which genetic tests have not been performed, important differences have been found among populations from different geographic areas.

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References

ATALAY, I. 1984. Regioning of the seed transfer of Oriental spruce (*Picea orientalis* L.) in Turkey. Forest General Directorate, Forest Tree Seeds and Breeding Research Directorate, Publication No. 2, Ankara, 67 pp.

ATASOY, H. 1996. Studies on the genetic diversity within and among the populations of Oriental spruce (*Picea orientalis* L. LINK) by the characteristics of seeds and seedlings. Turkish Forestry Research Institute, Technical Bulletin No. 261, Trabzon, 86 pp.

BOULLI, A., BAAZIZ, M. & HIRIT, O. M. 2001. Polymorphism of natural populations of *Pinus halepensis* MILL. in Morocco as revealed by morphological characters. Euphytica **119:** 309–316

CALAMASSI, R., PUGLISI, S. & VENDRAMNI, G. 1988. Genetic variation in morphological and anatomical needle characteristics in *Pinus brutia* TEN. Silvae Gen. **37:** 169–252.

CONKLE, M. T., SCHILLER, G. & GRUNWALD, C. 1988. Electrophoretic analysis of diversity and phylogeny of *Pinus brutia* and closely related taxa. Systematic Botany **13:** 411–424.

DONAHUE, J. K. & UPTON, J. L. 1996. Geographic variation in leaf, cone and seed morphology of *Pinus greggii* in native forests. For. Ecol. Man. **82:** 145–157.

GEZER, A., 1976. Researches on the morphogenetic characteristics of the seedlings of Oriental spruce (*Picea orientalis* L.). Turkish Forest Research Institute, Technical Bulletin, No. 92, Trabzon, 176 pp.

ISIK, K. 1986. Altitudinal variation in *Pinus brutia* TEN.: Seed and seedling characteristics. Silvae Gen. **35:** 58–67.

ISIK, K. & KARA, N. 1997. Altitudinal variation in *Pinus brutia* TEN. and its implication in genetic conservation and seed transfers in Southern Turkey. Silvae Gen. **46:** 113–120.

KAYACIK, H. 1960. Doğu Ladini (*Picea orientalis* L.) In Coğrafi Yayılışı. Review of the Faculty of Forestry, University of Istanbul, Series B, **2:** 25–32.

KORAL, L., MADMONY, A., RIOV, Y. & SCHILLER, G. 1995. *Pinus halepensis* × *Pinus brutia* subsp. *brutia* hybrids? Identification using morphological and biochemical traits. Silvea Gen. **44:** 186–190.

LEE, S., CHOI, W. Y., NORBU, L. & PRADHAM, R. 1998. Genetic diversity and structure of blue pine (*Pinus wallichiana* JACK.) in Bhutan. For. Eco. Man. **105:** 45–53.

MALEY, M. L. & PARKER, W. H. 1993. Phenotypic variation in cone and needle characters of *Pinus banksiana* (Jack Pine) in Northwestern Ontario. Can. J. Bot. **71:** 43–51.

MATZIRIS, D. 1998. Genetic variation in cone and seed characteristics in a clonal seed orchard of Aleppo pine grown in Greece. Silvae Gen. **47:** 37–41.

SNEDECOR, G. & COHRAN, W. 1968. Statistical methods. The Iowa State Univ. Press, Ames, Iowa, USA, 593 pp.

SAATCIOGLU, F. 1976. Silvikültür I (Silvikültürün Biyolojik Esasları ve Prensipleri), University of Istanbul, Faculty of Forestry, Publication No: 2187/22, pp. 175–182.

TURNA, I. 1996. Determination of genetic structure of Oriental spruce (*Picea orientalis* L. LINK) populations using isozyme analysis. Karadeniz Technical Univ. Graduate School, Phd Thesis, 120 pp.

TURNA, I. & YAHYAOGLU, Z. 2002. Allozyme variation in some populations of Oriental spruce (*Picea orientalis* L. LINK.) in Turkey. Pb. Univ. Res. Bull. (Sci.) **52:** 119–125.

URGENC, S. 1965. Doğu Ladini Kozalak ve Tohumu Üzerine Araştırmalar, Forest Service, Turkey Publication No. 417/40, 143 pp.

ZAR, J. H. 1984. Biostatistical analysis. Second Edition, Prentice Hal, Inc., Englewood Cliffs, New Jersey, 717 pp.

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