Primary Selection of Willow Clones for Multi-Purpose Use in Short Rotation Plantation

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Abstract

In this study, growth performances and wood properties of various willow (*Salix* L.) clones were investigated. 53 clones were selected from natural tree-like willow populations occuring in the Black Sea, Marmara, Trace, Central Anatolia and South-east Anatolia regions. Genetic characteristics of the willow clones and poplar clone I-214, such as diameter, height, volume, volume increment, basic density, dry matter and holocellulose production, caloric value, ash content, nitrogen and protein values were determined using the data obtained from the experiment at İzmit nursery. The values representing the genetic characteristics of the clones analysed by factor analysis and discriminant analysis were applied for grouping of the clones based on the most effective variables. Selection of the willow clones to be used for further research studies were made.

Key words: willow, clone, variation, selection, analyses of variance, factor and discriminant analyses.

Introduction

It is estimated that the gap between supply and demand of industrial wood in Turkey will become 6.7 million cubic meter in 2010 (OGM, 1988). Therefore the emphasis has been given to the establishment of industrial plantations with fast growing species in order to meet the wood shortage (ÜRGENÇ 1982; ODABAŞI and BOYDAK, 1984; TUNÇTANER, 1990).

Poplar and willow are the principle fast growing species in Turkey and their potential growing area has been extended by the GAP project carried out in the south-east Anatolia region (BOYDAK, 1986; BAŞAL and SÖZEN, 1986). Industrial plantations with the selected clones of these species will play very important role to support the wood production in Turkey.

Willows do not have significant value in many countries. But in Turkey natural and cultures of tree-like willow species have economic importance, as in the case of poplars, to obtain clear, soft and light timber in a short period of time. They occur on the great variety of edaphic and hydrological conditions in the regions of bottomlands. Therefore, studies on genotypic differences between the clones of tree-like willows are highly important for the plantations to be established on marginal sites which are less suited to growing poplars.

Tree-like willows are well suited to the establisment of special purpose plantations. They are generally planted in short-rotation plantations for biomass production and the raw material produced from these plantations are used for pulp, reconstituted wood products, chemicals, energy and animal feed (ANDERSON, 1977; AROLA and MIYATA, 1981; BONDUELLE, 1979; ERICSSON, 1984).

It was reported that the genus *Salix* in Turkey was grouped by SKVORTSOV into two sub-genera, eleven sections and twenty three species of which only a few have populations growing to tree-formed and so being of any economic value (DAVIS, 1982). Tree-formed willow species in Turkey are *S. alba*, *S. fragilis*, *S. excelsa* and *S. acmophylla* (YALTIRIK, 1988; GÖKMEN, 1977; KAYACIK, 1963). Selection of clones from these species and their hybrids, will make a great contribution to the wood supply obtained from special-purpose plantations.

Materials and Methods

53 clones were selected from the natural tree-like willow populations occuring in the Black Sea, Marmara, Trace, Central Anatolia and South-east Anatolia regions. Locations of the selected individuals, temporary clone numbers and their species are given in *Table 1*. Cutting materials were collected from these individuals and multiplied at an experimental nursery in İzmit.

An experiment was established at the İzmit nursery with 53 willow clones and poplar clone *P. x euramericana* (I-214), were included for comparision. 30 cm long cuttings were planted in row-plots representing clones and repeated in three blocks. 48 cuttings were planted for each clone. Spacing was 180 cm between the rows and 50 cm between the cuttings.

At the end of the second year variations of some genetic characteristics of the clones, diameter, height, volume and mean annual volume increment, basic density, dry matter, holocellulose production, calorie value, ash content, nitrogen and protein values were investigated. In this investigation methods explained by different scientist were considered (ZSUFFA, 1976; BIRLER et al., 1978; RANDAL, 1976; HINCHLEY, 1976; TANK, 1980; BOZKURT, 1979; CIVAOĞLU, 1963; KAÇAR, 1972; KESKIN, 1981; TUNÇTANER, 1988).

Analysis of variance (ANOVA) was applied to the data obtained from the height and diameter measurements of the clones in three blocks. ANOVA was also used for comparisons of the volume productions of clones per hectare. Volume productions of the clones (m^3/ha) were calculated using the data of tree volumes obtained from stem analyses of three sample trees for each clone and number of the trees per hectare. DUNCAN's Multiple Range Test was used for the grouping of the clones incase significant differences appeared between the volumes of the clones. Variations and the mean values of some wood characteristics of the clones were also determined.

In explaning the genetic variance to determine the most effective components and to create groups of clones on the basis of these components, factor analysis and discriminant analysis as multi-dimension statistical techniques were applied. To achieve this, Version 9.0 of Statistical Package for Social Sciences (SPSS) was used. Names, units and labels of the variables are given in *Table 2*.

Results and Discussion

The results of ANOVA for diameter and height measurements of the clones showed significant differences at 0.001 confidence level (F = 11.99***, 24.99***). Diameter growth varied between 4.7 cm (clone 8408) and 1.9 cm (clone 8602). Heights of

Table 1. – Locations, species and clone numbers of the selected willow trees.

Order	Clone	Species	Origin (Region)	Order	Clone	Species	Origin (Region)
1	6202	*S.excelsa*	Akyazı (M)	28	62/14	*S.alba*	Akyazı (M)
2	6205	*S.excelsa*	Akyazı (M)	29	82/11	*S.alba*	Kırşehir (CA)
3	6208	*S.excelsa*	Akyazı (M)	30	83/16	*S.alba*	Kızılcahamam (CA)
4	6209	*S.excelsa*	Akyazı (M)	31	84/2	*S.alba*	Edirne (T)
5	6210	*S.excelsa*	Akyazı (M)	32	84/4	*S.alba*	İpsala (T)
6	6412	*S.excelsa*	İzmit (M)	33	84/5	*S.alba*	İpsala (T)
7	8313	*S.excelsa*	Kırşchir (CA)	34	84/7	*S.alba*	Akyazı (M)
8	8401	*S.excelsa*	Edirne (T)	35	84/12	*S.alba*	Akyazı (M)
9	8406	*S.excelsa*	Akyazı (M)	36	84/15	*S.alba*	Karasu (M)
10	8408	*S.excelsa*	Akyazı (M)	37	84/17	*S.alba*	Karasu (M)
11	8409	*S.excelsa*	Akyazı (M)	38	84/18	*S.alba*	Karasu (M)
12	8410	*S.excelsa*	Akyazı (M)	39	84/21	*S.alba*	Çarşamba (BS)
13	8411	*S.excelsa*	Akyazı (M)	40	84/22	*S.alba*	Çarşamba (BS)
14	8413	*S.excelsa*	Akyazı (M)	41	84/31	*S.alba*	Çarşamba (BS)
15	8414	*S.excelsa*	Karasu (M)	42	85/1	*S.alba*	Demirköy (T)
16	8416	*S.excelsa*	Karasu (M)	43	85/2	*S.alba*	Demirköy (T)
17	8419	*S.excelsa*	Çarşamba (BS)	44	86/1	*S.alba*	K.Maraş (SEA)
18	8420	*S.excelsa*	Çarşamba (BS)	45	86/2	*S.alba*	K.Maraş (SEA)
19	8423	*S.excelsa*	Çarşamba (BS)	46	86/3	*S.alba*	Mardin (SEA)
20	8424	*S.excelsa*	Çarşamba (BS)	47	86/4	*S.alba*	Mardin (SEA)
21	8425	*S.excelsa*	Çarşamba (BS)	48	86/5	*S.alba*	Mardin (SEA)
22	8426	*S.excelsa*	Çarşamba (BS)	49	86/6	*S.alba*	Gaziantep (SEA)
23	8427	*S.excelsa*	Çarşamba (BS)	50	83/17	*S.alba*	Kızılcahamam (CA)
24	8428	*S.excelsa*	Çarşamba (BS)	51	86/9	*S.acmophylla*	Malatya (SEA)
25	8429	*S.excelsa*	Çarşamba (BS)	52	86/7	*S.acmophylla*	Gaziantep (SEA)
26	8430	*S.excelsa*	Çarşamba (BS)	53	86/8	*S.acmophylla*	Adıyaman (SEA)
27	6212	*S.excelsa*	Akyazı (M)	54	I-214	*P.x euram.*	Italy

Regions: Black Sea (BS), Marmara (M), Trace (T), Central Anatolia (CA), South-east Anatolia (SEA).

Table 2. – Names, units and labels of the variables.

VARIABLES	UNITS	LABELS
Diameter (Dbh)	Cm	DBH
Height	M	HEIGHT
Volume	m^3/ha	VOL
Annual Mean Vol. Inc.	m^3/ha/y	INC
Basic Density	g/cm^3	BDEN
Ovendry Weight	t/ha	OVDRW
Holocelulose Percentage	%	HOLCELP
Holocelulose Amount	t/ha	HOLCELT
Gross Calorific Value	G	GRCAL
Net Calorific Value	G	NETCAL
Ash Percentage	%	ASH
Nitrogen Percentage of (Air Dry)	%	NPADWE
Nitrogen Percentage of (Oven Dry)	%	NPODWE
Protein Percentage	%	PROTEIN

the clones varied between 6.7 m (clone 8211) and 2.3 m (clone 8620). Poplar clone I-214 had a mean diameter of 4.5 cm and a mean height of 6.3 m. Some of the willow clones showed better growth performances than poplar clone I-214. Similiar results were obtained in Yugoslavia. KYRSTINIC (1979) reported that selected willow clones had shown better growth than the *P. x euramerican* hybrids.

ANOVA was applied for the volume productions of the clones per hectare calculated for three sample trees belonging to the clones. According to the result of ANOVA, significant differences at 0.001 level were found between the clones (F = 19.18***). DUNCAN test was used for the grouping of clones and the results were given in *Table 3*. As it can be seen in *Table 3*, the mean volumes of the clones per hectare varied between 67,2 m^3 (clone 8408) and 3,3 m^3 (clone 8602). This value amounted to 56,1 m^3/ha for the poplar clone I-214. Overall mean volume of the clones was 35,42 m^3/ha with the standard deviation of 17,24. Some statistical parameters of the tested clones regarding their taxonomical relations are given in *Table 4*. The mean value of *S. excelsa* clones for volume production per hectare was higher than the means of the other species in the test site. The tested willow clones were also classified into regions (*Table 1*) and species with the mean values and standard deviations given in *Table 5*. As it can be seen in *Table 5*, *S. alba* clones originated from the Black Sea region had the maximum mean volume production in the trial site with the mean volume of 49,7 m^3/ha. *S. excelsa* clones from the Black Sea region have also shown higher volume productions in the trial site than other clones originated from other regions.

According to the results of the DUNCAN test the clone 8408 originating from the Marmara region showed the highest volume production at the test site. The other willow clones in this group are generally from the Marmara and Black Sea regions and they have shown considerable higher volume productions at the test site. The top five willow clones also showed better growth performances than the poplar clone I-214. Volume productions of the willow clones in the first group varied between 67.2 m^3 and 49.9 m^3 at the test site. Similar results were obtained in Yugoslavia for the volume productions of selected *S. alba* clones at the end of two year rotation periods (WASIELEWSKI, 1982; KRSTINIC, 1984).

Table 3. – Comparision of the means of volumes of the clones per hectare by DUNCAN test at 0,01 level.

Species	Origin	Clone No	Volume (m^3/ha)
S. excelsa	Akyazı	8408	67,2
S. excelsa	Çarşamba	8428	66,1
S. excelsa	Akyazı	8409	62,2
S. excelsa	Çarşamba	8429	61,6
S. alba	Kırşehir	8211	60,5
P. x eur.	Italy	I-214	56,1
S. alba	Çarşamba	8422	54,9
S. excelsa	Çarşamba	8424	54,4
S. excelsa	Akyazı	8406	53,8
S. alba	Çarşamba	8421	53,3
S. excelsa	Akyazı	6212	52,7
S. excelsa	Çarşamba	8427	52,7
S. excelsa	Edirne	8401	50,5
S. alba	Akyazı	8407	49,9
S. excelsa	Çarşamba	8419	49,9 p: 0,01
S. excelsa	Akyazı	6208	48,8
S. excelsa	Akyazı	8413	48,8
S. alba	Karasu	8417	47,2
S. excelsa	Akyazı	6209	46,1
S. excelsa	Akyazı	6210	44,9
S. excelsa	İzmit	6412	44,4
S. excelsa	Çarşamba	8430	43,8
S. excelsa	Çarşamba	8423	41,1
S. alba	Çarşamba	8431	41,1
S. excelsa	Çarşamba	8420	38,3
S. excelsa	Çarşamba	8425	37,7
S. excelsa	Karasu	8414	36,6
S. excelsa	Akyazı	6205	35,0
S. alba	Karasu	8415	34,4
S. alba	Edirne	8402	34,4
S. excelsa	Akyazı	6202	28,3
S.acmophylla	Malatya	8609	27,7
S. excelsa	Akyazı	8410	26,6
S.acmophylla	Adıyaman	8608	26,6
S. alba	İpsala	8404	24,9
S. alba	Akyazı	6214	22,2
S. alba	Akyazı	8412	21,6
S. excelsa	Karasu	8416	21,6
S. excelsa	Kırşehir	8313	21,6
S. alba	Mardin	8604	21,1
S. alba	Mardin	8603	20,5
S. alba	Kızılcahamam	8316	20,0
S. alba	Demirköy	8501	20,0
S. excelsa	Çarşamba	8426	19,4
S.acmophylla	Gaziantep	8607	19,4
S. alba	Demirköy	8502	17,2
S. alba	Gaziantep	8606	16,6
S. alba	Mardin	8605	13,8
S. excelsa	Akyazı	8411	13,3
S. alba	İpsala	8405	13,3
S. alba	Karasu	8418	12,2
S. alba	K.Maraş	8601	9,4
S. alba	Kızılcahamam	8317	3,8
S. alba	K.Maraş	8602	3,3

Mean: 35.42 Standard deviation: 17.24

Basic density values of the willow clones vary between 0.409 and 0.299 g/cm^3. The mean density is 0.350 g/cm^3. In Yugoslavia, mean basic density of *S. alba* cultivars was found to be 0.331 g/cm^3 (ANON., 1986). In Italy, this value for willow wood was reported as 0.360 g/cm^3 (FAO, 1979). Basic density value for poplar clone I-214 was found to be 0.270 g/cm^3. In Italy, it

Table 4. – Mean volume production of the clones regarding their species.

Species	No of Clones	Mean	sd
S. excelsa	27	43,2	14,48
S. alba	23	26,7	16,86
S. acmophylla	3	24,5	4,51

Table 5. – Mean volume production/ha by classification of the willow clones into the regions and species.

SPECIES	REGIONS														
	Marmara			Black Sea			Trace			Central Anatolia			Southeast Anatolia		
	n	$\bar{x}$	sd	n	$\bar{x}$	sd	n	$\bar{x}$	sd	n	$\bar{x}$	sd	n	$\bar{x}$	sd
S.excelsa	15	42,02	15,03	10	46,5	13,49	1	50,50	-	1	21,60	-	-	-	-
S.alba	6	31,25	15,16	3	49,7	7,54	5	21,96	8,13	3	28,10	29,20	6	14,11	6,85
S.acmophylla	-	-	-	-	-	-	-	-	-	-	-	-	3	24,56	4,51
General	21	39,94	15,51	13	47,25	12,17	6	26,71	13,73	4	26,47	24,06	9	17,6	7,85

Table 6. – Correlation coefficients of the variables.

	DBH	HEIGTH	VOL	INC	BDEN	OVDRW	HOLCELP	HOLCELT	GRCAL	NETCAL	ASH	NPADWE	NPODWE	PROTEIN
DBH	1.00	0.92**	0.94**	0.94**	-0.10	0.92**	-0.16	0.92**	-0.31*	-0.29*	-0.19	0.10	0.09	-0.09
HEIGTH		1.00	0.94**	0.94**	0.03	0.94**	-0.12	0.95**	-0.28*	-0.23	-0.16	0.14	0.13	-0.11
VOL			1.00	1.00**	-0.04	0.98**	-0.16	0.97**	-0.29*	-0.24	-0.08	0.09	0.07	-0.12
INC				1.00	-0.04	0.98**	-0.16	0.97**	-0.29*	-0.24	-0.08	0.09	0.08	-0.12
BDEN					1.00	0.14	-0.01	0.13	0.13	0.01	-0.20	-0.26	-0.25	0.13
OVDRW						1.00	-0.18	0.99**	-0.26*	-0.25	-0.22	0.04	0.03	-0.10
HOLCELP							1.00	-0.11	0.40**	0.34*	-0.11	0.13	0.12	0.05
HOLCELT								1.00	-0.24	-0.22	-0.13	0.05	0.04	-0.10
GRCAL									1.00	0.78**	-0.22	-0.11	-0.10	0.18
NETCAL										1.00	-0.09	-0.06	-0.06	0.19
ASH											1.00	0.01	0.01	0.05
NPADWE												1.00	0.99**	0.01
NPODWE													1.00	-0.08
PROTEIN														1.00

* Correlation is significant at the 0.05 level
** Correlation is significant at the 0.01 level

Table 7. – Total varianc explained for the components.

Components	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative%	Total	% of Variance	Cumulative%
1	6,099	43,566	43,566	6,099	43,566	43,566
2	2,186	15,617	59,183	2,186	15,617	59,183
3	1,954	13,960	73,143	1,954	13,960	73,143
4	1,041	7,433	80,576	1,041	7,433	80,576
5	1,027	7,338	87,915	1,027	7,338	87,915
6	0,722	5,158	93,073			
7	0,648	4,630	97,702			
8	0,192	1,372	99,074			
9	6,761E-02	0,483	99,557			
10	5,135E-02	0,367	99,924			
11	5,924E-03	4,232E-02	99,966			
12	4,275E-03	3,054E-02	99,997			
13	4,858E-04	3,470E-03	100,000			
14	2,780E-07	1,986E-06	100,000			

Extraction Method : Principal Component Analysis.

was reported that the basic density values of I-214 varied between 0.280 and 0.320 g/cm^3 (SEKAWIN, 1977). In France, it was found to be 0.279 g/ cm^3 (BARNEOUD et al., 1982).

Dry matter of the clones varied from 1.3 t (clone 8602) to 23.0 t (clone 8211) per hectare. This was 15.1 t/ha for poplar clone I-214. Similar results were obtained from an experiment in New Zealand. The best clone of *S. matsudana x alba* hybrids produced a dry matter of 22.6 t/ha at the end of a two year rotation period (HATHAWAY and KRAAYENOORD, 1979). STOTT (1984) reported that annual dry wood production of willow

Table 8. – Rotated component matrix[a].

Components	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative%	Total	% of Variance	Cumulative%
1	6,099	43,566	43,566	6,099	43,566	43,566
2	2,186	15,617	59,183	2,186	15,617	59,183
3	1,954	13,960	73,143	1,954	13,960	73,143
4	1,041	7,433	80,576	1,041	7,433	80,576
5	1,027	7,338	87,915	1,027	7,338	87,915
6	0,722	5,158	93,073			
7	0,648	4,630	97,702			
8	0,192	1,372	99,074			
9	6,761E-02	0,483	99,557			
10	5,135E-02	0,367	99,924			
11	5,924E-03	4,232E-02	99,966			
12	4,275E-03	3,054E-02	99,997			
13	4,858E-04	3,470E-03	100,000			
14	2,780E-07	1,986E-06	100,000			

Extraction Method: Principal Component Analysis
Rotation Method: Varimax with Kaiser Normalization
a. Rotation converged in 7 iterations.

plantations was 15 t, 16–32 t and 10–20 t per ha in England, Sweden and Canada respectively.

Gross calorific values of all the willow clones varied from 3439 cal/g (clone 8429) to 4644 cal/g (clone 8502). The mean calorific value was found as 4266 cal/g. Net calorific values of the clones varied from 3362 cal/g to 4548 cal/g. The mean calorific value was found as 4193 cal/g. Gross and net calorific values for poplar clone I-214 was found to be 4264 cal/g and 4051 cal/g respectively. In Yugoslavia calorific value of *S. alba* was found to be 4264 cal/g. GAMBLES/ZSUFFA (1984) reported that the calorific values of two year old hybrid poplar clones varied between 4347 and 4945 cal/g. In Sweden calorific values of one and two year old sprouts of 33 willow clones were found to be 4699 and 4849 cal/g respectively (AGER et al., 1986).

Ash content of the willow clones varied between 0.40% (clone 8402) and 0.97% (clone 8602). The mean ash content was 0.69%. This value was calculated as 0.77% for I-214. In Yugoslavia, ash content of *S. alba* and I-214 were found to be 0.54% and 0.75% respectively (Anon., 1986).

Protein contents of the willow clones varied from 5.3% (clone 8422) to 19.3% (clone 8605). The mean protein content was calculated as 10.8%. Protein content of I-214 was calculated as 14.5%. It was reported that leaves of the willows and hybrid poplars contained a protein content of 10% and 11.9% in their leaves respectively (KANSU, 1964). Poplar and willow leaves are considerably rich in protein content as compared to clover and they can be considered as suitable sources of fodder (VIART, 1980; GAMBLES and ZSUFFA, 1984; SIEBERT, 1979).

The data obtained from growth performances and some wood characteristics of the clones were processed by factor analysis. The correlation matrices of the 14 variables given in *Table 6* are the first input for factor analysis.

At the end of factor analysis total variance is explained in *Table 7*. In the table the first 5 components having larger

Table 9. – Standardized canonical discriminant function coefficients.

Variables	Function		
	1	2	3
VOL	1,062	0,000	0,038
BDEN	-0,180	0,403	-0,453
GRCAL	-0,037	-0,099	0,192
NPADWE	-0,375	1,013	-0,076
PROTEIN	0,064	0,121	0,925

Table 10. – Some statistical parameters of discriminant function.

Function	Eigenvalue	% of Variance	Cumulative %	Canonical Correlation
1	14,444[a]	99,1	99,1	0,967
2	0,091[a]	0,6	99,8	0,289
3	0,035[a]	0,2	100,0	0,184

a. First 3 canonical discriminant function were used in the analysis.

Table 11. – The results of classification made for grouping of the clones.

Group		Predicted Group Membership				Total
		1	2	3	4	
Original Count	1	15	0	0	0	15
	2	1	14	0	0	15
	3	0	0	16	1	17
	4	0	0	0	7	7
%	1	100,0	0,0	0,0	0,0	100,0
	2	6,7	93,3	0,0	0,0	100,0
	3	0,0	0,0	94,1	5,9	100,0
	4	0,0	0,0	0,0	100,0	100,0

a. % 96,3 of original grouped cases correctly classified.

Table 12. – Casewise statistics for grouping of the clones.

Case Number	Actual Group	Highest Group Predicted Group	Case Number	Actual Group	Highest Group Predicted Group
1	4	4	28	3	3
2	4	4	29	1	1
3	3	3	30	1	1
4	2	2	31	2	2
5	4	4	32	1	1
6	3	3	33	2	2
7	3	4**	34	3	3
8	2	2	35	3	3
9	2	1**	36	2	2
10	3	3	37	2	2
11	2	2	38	2	2
12	3	3	39	1	1
13	4	4	40	2	2
14	1	1	41	3	3
15	4	4	42	2	2
16	2	2	43	2	2
17	2	2	44	3	3
18	1	1	45	1	1
19	3	3	46	1	1
20	1	1	47	3	3
21	3	3	48	3	3
22	3	3	49	1	1
23	1	1	50	1	1
24	4	4	51	1	1
25	2	2	52	3	3
26	3	3	53	1	1
27	4	4	54	1	1

For the original data, squared Mahalanobis distance is based on canonical functions.
For the cross-validated data, squared Mahalanobis distance is based on observations.

proportion than 1 in the total variance are determined (KAISER criterion). Proportion of variance of the first 5 components to total variance is 87.915%.

In factor analysis in the first stage, unrotated component matrix was obtained using principal component model. Later in order to get a more reliable matrix for scientific explanation, the matrix rotated by Varimax Rotation Method was produced (*Table 8*).

In the first component the first 6 variables (VOL, INC, HOLCELT, OVDRW, HEIGHT, DBH) showing high correlations were grouped. These variables have close relations with the growth of the clones. Therefore the component 1 was named as "Growth" component and it was represented with the variable "VOL" which had shown the maximum correlation (0.987). Using the same method the component 2 was named as "Calori" and represented by "GRCAL". Component 3 was named as "Nitrogen Content" and represented with "NPADWE". Component 4 was named as "Burning" and the variable "BDEN" was selected as representative since it had shown positive correlation. Component 5 was named as "Protein" and represented with "PROTEIN". Consequently the 14 variables have been decreased to 5 components with only the loss of 12.1% of information.

According to the results of factor analysis, clones were separated into 4 groups, depending on the most important variable, "VOL" in the component 1, groups are as follows:

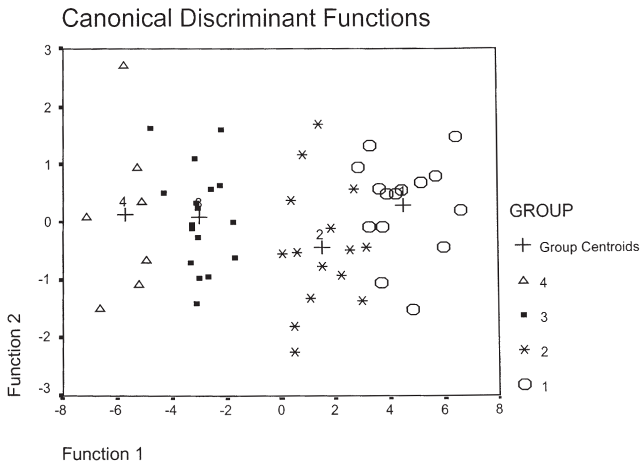

Figure 1. – Grouping of the clones on the basis of discriminant functions 1 and 2.

Groups	*Volume m^3/ha*	*Number of the clone*
Group 1	67.2 – 49.9	15
Group 2	49.8 – 34.4	15
Group 3	34.3 – 16.6	17
Group 4	16.5 – 0.0	7

Discriminant analysis was performed on the basis of 5 effective components determined by factor analysis. According to the results of discriminant analysis three discriminant functions were obtained to separate the groups from each other. Standardized discriminant function coefficients are given in *Table 9*. Also statistical parameters of discriminant functions are shown in *Table 10*.

It has been clearly shown that the most important discriminant function is function 1 when the tables 9 and 10 are taken into consideration. The plotting of the clones and group centroides on discriminant functions 1 and 2 are shown in *Figure 1*.

The results of the classification concerning the predicted groups determined on the basis of 5 effective variables explained by factor analysis are given in *Table 11*.

It can be stated that the classification of the clones into 4 groups based on the most important variable "VOL" was correctly made on 96.3% confidence. In the original grouped cases the highest success was achieved in group l and 4 with 100%. Allocation of the clones to different groups is shown in *Table 12*. In the original cases the clones 8410 (case number 7) and 8413 (case number 9) were in group 3 and group 2, but later they were transferred to group 4 and group 1 respectively.

Conclusion

The growth performances of the clones and some of their wood characteristics are taken into consideration for multipurpose selection of willow clones. For this purpose the emphasis was given to the volume production of the clones since they were the close relations between volume and dry matter content of wood.

Significant differences were found among the clones for volume productions per hectare. The groups of the clones were determined by DUNCAN test at 0.01 significant level (*Table 3*). The clones in the first group had considerably higher volume production as compared with the overall mean (35.42 m^3/ha). *S. excelsa* clones showed much better growth performances than the other species with a mean volume of 43.2 m^3/ha (*Table 4*) and 4 *S. excelsa* clones ranked on top of the all tested clones (*Table 3*). Evaluation of the clones concerning their regions, determined by location (*Table 1*) were expressed in *Table 5*. The most satisfactory clones at the test site originated from the Black Sea region.

According to the factor analysis volume was determined as the most important variable among the variables in component 1 (*Table 8*). Discriminant analysis was processed with 5 effective components derived by factor analysis (*Table 9*). Groups of the clones were separated by discriminant functions and the highest groups were determined with the most effective variable volume (*Table 10*, *Figure 1*, *Table 11* and *12*).

The group 1 determined by discriminant analysis contain 16 clones with the transfer of clone 8413 from group 2 whereas the first group determined by DUNCAN test at 0.01 significant level contain 15 clones with the same order.

15 willow clones in the group 1 are the most important clones to be considered for further research studies regarding their growth performances and some other wood characteristics for the ecological conditions represented by the test site at İzmit. Priority should be given to the following clones which have greater volume production than the poplar clone I-214.

Species	*Origin*	*Region*	*Clone No*
Salix excelsa	Akyazı	Marmara	8408
Salix excelsa	Çarşamba	BlackSea	8428
Salix excelsa	Akyazı	Marmara	8409
Salix excelsa	Çarşamba	Black Sea	8429
Salix alba	Kırşehir	Central Anatolia	8211

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Fertility Variation and Gene Diversity in Clonal Seed Orchards of Pinus brutia, Pinus nigra and Pinus sylvestris in Turkey

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Summary

Clonal variation in the production of female and male strobili was studied in seed orchards of *Pinus brutia* in southern, and those of *P. nigra* and *P. sylvestris* in northern Turkey. Large differences in female and male fertility among clones were found. The most abundant quartile of clones in *P. brutia*, *P. nigra* and *P. sylvestris* seed orchards produced 44.1%, 40.5%, 33.9% and 37.8% of total female, and 76.1%, 62.6%, 36.7% and 34.1% in total male strobilus production, respectively. There were positive correlations between female and male strobilus production in all seed orchards. The status numbers (N_s) were calculated as 19.3 (64% of census number) and 23.2 (66%) in two *P. brutia* seed orchards, 29.2 (94%) in a *P. nigra* seed orchard and 25.7 (92%) in a *P. sylvestris* seed orchard. Male fertility variation was larger than female fertility variation in *P. brutia* and *P. nigra* seed orchards, while it was an opposite situation in the *P. sylvestris* seed orchard. The effect of fertility variation was discussed for the establishment of new seed orchards and the management of current orchards in Turkey.

Key words: Pinus brutia, *Pinus nigra*, *Pinus sylvestris*, seed orchard, fertility variation, status number, gene diversity.

Introduction

A seed orchard is an important seed source for forest plantation, and it keeps generally high genetic diversity compared to natural forests where orchard parents were selected (SAVOLAINEN and KÄRKKÄINEN, 1992). *Pinus brutia* TEN., *P. nigra* ARNOLD. and *P. sylvestris* L. are among most important native *Pinus* species in Turkey, and they occupy about 3.7 (26.4%), 2.5 (17.9%) and 0.7 (5.0%) million ha of the total 14 million ha of high forest area in Turkey, respectively (CALISKAN, 1998).

Large clonal differences in female and male fertility have been reported in seed orchards (KJAER, 1996; KANG and LINDGREN, 1998; NIKKANEN and RUOTSALAINEN, 2000), in natural populations (BILA and LINDGREN, 1998), and in plantation areas (BILA *et al.*, 1999). Research on cone and seed properties, phenology, and pollen production in seed orchards have also been studied (YAZDANI and LINDGREN, 1991; MATZIRIS, 1993, 1997, 1998; FRIES, 1994; YAZDANI *et al.*, 1995; KESKIN, 1999). Such fertility variation will cause rapid accumulation of group coancestry and potential inbreeding in the following generation (BILA, 2000; KANG, 2001). To monitor and determine the genetic diversity of seed crops, some genetic parameters such as genetic relatedness, inbreeding, and gene diversity should be calculated.

Effective population size and status number have been widely used to express accumulated inbreeding, random genetic drift and group coancestry (CROW and KIMURA, 1970; LINDGREN *et al.*, 1996; KJAER and WELLENDORF, 1997). A key difference between effective population size and status number is how to describe the loss of gene diversity (inbreeding and group-coancestry). The former expresses it as dynamic over generations, while the latter does as static in each generation separately (LINDGREN and MULLIN, 1998). Seed orchards are generally used only for one generation. So, the status number is a good tool for monitoring gene diversity of orchard crops.

The purpose of this study is to evaluate fertility variation among orchard parents and its effect on gene diversity of seed (i.e., status number), and to provide genetic information to guide the "National Tree Breeding and Seed Production Programme for Turkey (KOSKI and ANTOLA, 1993)". New seed orchards in Turkey will be established vegetatively with grafts after progeny tests according to the programme.

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