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Full Length Research Paper

Genetic variation in growth traits and morphological characteristics of eastern cottonwood (*Populus deltoides* Bartr.) hybrids at nursery stage

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Eastern cottonwood (*Populus deltoides* Bartr.) clones obtained from intraspecific and interspecific crosses were tested at İzmit nursery in Turkey. Growth traits and various morphological characteristics were assessed after two growing seasons. Significant clonal differences were observed regarding height, diameter, volume index and survival rate. Ten intraspecific crosses had significantly better growth performances than control clones "Samsun" and "I-214" based on volume index values, but most of the clones showed poor survival rates in comparing control clones. High heritability values were found for the clone means of tree dimensions and survival rate, ranging from 0.51 to 0.65. Factor analysis was applied for 13 components and 71.46% of total variance was explained by the first five components. Volume index was determined as the most important variable in component 1. Groups of the clones were separated by discriminant functions and five highest groups were indicated with the most effective variable volume index.

Key words: Eastern cottonwood, hybrid clone, genetic variation, growth trait, morphological characteristic, heritability, tree dimensions.

INTRODUCTION

Poplars are important fast growing species in Turkey and various clones of native black poplar (*Populus nigra* L.) species are widely used in plantations in central and eastern Anatolia. On the other hand, eastern cottonwood (*Populus deltoides* Bartr.) and *Populus* x *euramericana* (*P. deltoides* x *P. nigra*) clones have been considered among the most productive clones for wood and fiber industry in temperate regions. Black poplar species (*P. nigra* and *P. deltoides*) have significant economic and genetic value due to its wide geographic adaptation and fast growth for breeding and producing new hybrid clones. Therefore, a program was initiated in 1985 to conserve and improve black poplar genetic resources in Turkey (Tunçtaner, 1993; Toplu, 1996; Tunçtaner, 1998).

The economic importance of poplar cultivation in Turkey has been considerably developed by importing some germplasm (seed and cutting) of eastern cottonwood and its hybrids. Some valuable information was obtained from clonal tests of *Populus deltoides* and *Populus x euramericana* in temperate regions of Turkey (Tunçtaner et al., 1998; 2004). *P. deltoides* and its hybrids are economically important as a source of wood and fiber in the world. Intensively, managed hybrid poplar is a promising source of wood fiber given the high yields and relatively short growing cycles. Forest product companies are interested in finding new industrial uses for hybrid poplar. Engineering properties have been measured for clear wood specimens and oriented strandboard (OSB) panels and product opportunities have been explored (Peters et al., 1999).

In accordance with the multi-purpose use of hybrid poplar wood, breeding strategies have been developed and implemented to measure, capture, recombine and exploit the genetic variation of these poplars in many countries (Mohrdiek et al., 1979; Teissier and Cros, 1984; Tunçtaner, 1988; Michel et al., 1989; Bisoffi, 1992; Benea and Muntean, 1996; Gözükırmızı et al., 1996; Foster et

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al., 1998; Tunçtaner, 2002 ; Pliura et al., 2007).The objective of this study is to explain the genetic variation within intraspecific and interspecific crosses of *P. deltoides* and make a preliminary selection of the promising clones for further research studies.

MATERIALS AND METHODS

88 hybrid poplar clones obtained from the intraspecific and inter-specific crosses of eastern cottonwood and black poplar (Tunçtaner et al., 1992) and two control clones (*P. x euramericana* "I-214", *P. deltoides* "Samsun") were used as research material in this study. The list of the clones is given in Table 1. The experiment was established at the nursery in İzmit with the cuttings of 90 clones. Randomised block design with three replications was used and each clone was represented with 10 cuttings in each replication.

At the end of two-year rotation period; survival rates of the clones were calculated. Heights (H, cm) and diameters (D, mm) of saplings were measured. Volume index (VI, dm^3) was calculated by the following equation:

$$VI = (D/2)^2 \times H \times 3.1416$$

Some methods and indices were used for determination of following morphological characteristics of the clones (Tunçtane,r 2002; Işık and Toplu,2004).

$$\text{Branch index (BI)} = \frac{\text{Total height } (H_t) - \text{Height of third branch from top } (H_3)}{\text{Total height } (H_t)}$$

BI = 0 (the worst), 1 (the best)

Stem straightness (SS):

1: Better than I - 214 (straight)
2: Similar to I - 214 (slightly curve)
3: Worse than I -214 (very curve or fork).

Length of leaves in relation to maximum width (LMW) = $\frac{L}{W}$ x 100

1: < 90%
2: 90 - 99%
3: 100 - 109%
4: 110 - 119%
5: ≥ 120%.

Angle between the medial vein and the second lower lateral vein (ANG):

1: < 50°
2: 50 - 59°
3: 60 - 69°
4: 70 - 79°
5: 80 - 89°
6: >90°.

Shape of leaf base (SLB):

1: Cuneiform
2: Rounded cuneiform
3: Sinnate cuneiform
4: Straight
5: Straight sinnate
6: Slightly cordate
7: Moderately cordate
8: Very cordate.

Leaf tip (LT):

1: Pointed
2: Short acuminate
3: Acuminate
4: Long acuminate.

Colour of petiole (CP):

1: Completely green
2: Upper side pink or slightly red
3: Upper side wholly or almost wholly red
4: Wholly pink
5: Wholly red
6: Green but upper part side partly red.

Medial vein colour (MVC):

1: Green
2: Flesh (pink)
3: Red
4: Green with red marking at the base
5: Partly red.

Length of the petiole in relation to the length of the medial vein (LP):

1: < 40 %
2: 40 - 45 %
3: 46 - 50 %
4: 51 - 55 %
5: 56 - 60 %
6: 61 - 65 %
7: 66 - 70 %
8: > 70 %

Statistical analysis

Analysis of variance (ANOVA) was applied for comparisons of survival rate (%), height, diameter and volume indices of the clones. Duncan's multiple range test was used for ranking of the clones. Broad-sense heritabilities of clonal means were calculated using the following equation:

$$H^2 = Vc / Vc + Ve$$

Where Vc: Genetic variance due to clonal differences
Ve: Phenotypic variance

In explaining the genetic variance for growth and morphological characteristics of the clones to determine the most effective components and to create groups of the clones on the basis of these components, factor and discriminant analysis as multi-dimension statistical techniques were applied. To achieve this, version 9.0 of the statistical package for social science (SPSS) was used. Names, units and labels of the variables are given in Table 2.

RESULTS AND DISCUSSION

Significant differences were found between the clones at0.001 levels for the characters of survival rate, height,

Table 1. *P. deltoides* hybrids tested in the experiment at İzmit nursery.

Order	Clones	Crossings	Origin	Order	Clones	Crossings	Origin
1	D001	P.delt. x P. delt.	İzmit	46	D046	P.delt. x P. delt.	İzmit
2	D002	P.delt. x P. delt.	İzmit	47	D047	P.delt. x P. delt.	İzmit
3	D003	P.delt. x P. delt.	İzmit	48	D048	P.delt. x P. delt.	İzmit
4	D004	P.delt. x P. delt.	İzmit	49	D049	P.delt. x P. delt.	İzmit
5	D005	P.delt. x P. delt.	İzmit	50	D050	P.delt. x P. delt.	İzmit
6	D006	P.delt. x P. delt.	İzmit	51	D051	P.delt. x P. delt.	İzmit
7	D007	P.delt. x P. delt.	İzmit	52	D052	P.delt. x P. delt.	İzmit
8	D008	P.delt. x P. delt.	İzmit	53	D053	P.delt. x P. delt.	İzmit
9	D009	P.delt. x P. delt.	İzmit	54	D054	P.delt. x P. delt.	İzmit
10	D010	P.delt. x P. delt.	İzmit	55	D055	P.delt. x P. delt.	İzmit
11	D011	P.delt. x P. delt.	İzmit	56	D056	P.delt. x P. delt.	İzmit
12	D012	P.delt. x P. delt.	İzmit	57	D057	P.delt. x P. delt.	İzmit
13	D013	P.delt. x P. delt.	İzmit	58	D058	P.delt. x P. delt.	İzmit
14	D014	P.delt. x P. delt.	İzmit	59	D059	P.delt. x P. delt.	İzmit
15	D015	P.delt. x P. delt.	İzmit	60	D060	P.delt. x P. delt.	İzmit
16	D016	P.delt. x P. delt.	İzmit	61	D061	P.delt. x P. delt.	İzmit
17	D017	P.delt. x P. delt.	İzmit	62	D062	P.delt. x P. delt.	İzmit
18	D018	P.delt. x P. delt.	İzmit	63	D063	P.delt. x P. delt.	İzmit
19	D019	P.delt. x P. delt.	İzmit	64	D064	P.delt. x P. delt.	İzmit
20	D020	P.delt. x P. delt.	İzmit	65	D065	P.delt. x P. delt.	İzmit
21	D021	P.delt. x P. delt.	İzmit	66	D066	P.delt. x P. delt.	İzmit
22	D022	P.delt. x P. delt.	İzmit	67	D067	P.delt. x P. delt.	İzmit
23	D023	P.delt. x P. delt.	İzmit	68	D068	P.delt. x P. delt.	İzmit
24	D024	P.delt. x P. delt.	İzmit	69	D069	P.delt. x P. delt.	İzmit
25	D025	P.delt. x P. delt.	İzmit	70	D070	P.delt. x P. delt.	İzmit
26	D026	P.delt. x P. delt.	İzmit	71	D071	P.delt. x P. delt.	İzmit
27	D027	P.delt. x P. delt.	İzmit	72	D072	P.delt. x P. delt.	İzmit
28	D028	P.delt. x P. delt.	İzmit	73	D074	P.delt. x P. delt.	İzmit
29	D029	P.delt. x P. delt.	İzmit	74	D075	P.delt. x P. delt.	İzmit
30	D030	P.delt. x P. delt.	İzmit	75	D076	P.delt. x P. delt.	İzmit
31	D031	P.delt. x P. delt.	İzmit	76	D077	P.delt. x P. delt.	İzmit
32	D032	P.delt. x P. delt.	İzmit	77	D078	P.delt. x P. delt.	İzmit
33	D033	P.delt. x P. delt.	İzmit	78	D079	P.delt. x P. delt.	İzmit
34	D034	P.delt. x P. delt.	İzmit	79	D080	P.delt. x P. delt.	İzmit
35	D035	P.delt. x P. delt.	İzmit	80	D081	P.delt. x P. delt.	İzmit
36	D036	P.delt. x P. delt.	İzmit	81	D082	P.delt. x P. delt	İzmit
37	D037	P.delt. x P. delt.	İzmit	82	D083	P.delt. x P. delt.	İzmit
38	D038	P.delt. x P. delt.	İzmit	83	D084	P.delt. x P. delt.	İzmit
39	D039	P.delt. x P. delt.	İzmit	84	E085	P.delt. x P.nigra	İzmit
40	D040	P.delt. x P. delt.	İzmit	85	E086	P.delt. x P.nigra	İzmit
41	D041	P.delt. x P. delt.	İzmit	86	E087	P.delt. x P.nigra	İzmit
42	D042	P.delt. x P. delt.	İzmit	87	E088	P.delt. x P.nigra	İzmit
43	D043	P.delt. x P. delt.	İzmit	88	E089	P.delt. x P.nigra	İzmit
44	D044	P.delt. x P. delt.	İzmit	89	I-214	P. x euramericana	Italy
45	D045	P.delt. x P. delt.	İzmit	90	Samsun	P. deltoides	Italy

diameter and volume index (Table 3). Variance components and heritability values of the clones were also included in this table. Rank orders of the clones for characters showed that mean values varied between 31.3 - 61.3 mm for diameter, 4.8 - 7.5 m for height, 16.3 - 97.6% for survival and 3.6 - 21.4 for volume index (Table 4).

The top ten *P. deltoides* clones obtained from intra-

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

Variables	Units	Labels
Diameter	mm	DMM
Height	cm	HCM
Survival	%	SPR
Volume index	dm^3	$VIDM^3$
Branchness index	Index (0 - 1)	BI
Stem straightness	Index (1 - 3)	SS
Length/width	Index (1 - 5)	LMW
Angle between veins	Index (1 - 6)	ANG
Shape of leaf base	Index (1 - 8)	SLB
Leaf tip	Index (1 - 4)	LT
Colour of petiole	Index (1 - 5)	CP
Medial vein colour	Index (1 - 4)	MVC
Lenght of petiole	Index (1 - 8)	LP

Table 3. Results of ANOVA, variance components and heritability values of the clones.

Characters	Source	DF	F	% Vc	H^2
Diameter	Blocks	2		4.2	
	Clones	89	9.96***	58.4	0.61
	Error	178	3.12***	37.4	
	Total	269			
Height	Blocks	2		3.2	
	Clones	89	7.99***	60.5	0.62
	Error	178	3.34***	36.3	
	Total	269			
Survival	Blocks	2		4.1	
	Clones	89	7.81***	49.1	0.51
	Error	178	2.09***	46.8	
	Total	269			
Volume index	Blocks	2		3.9	
	Clones	89	10.63***	62.6	0.65
	Error	178	3.74***	33.5	
	Total	269			

***: 0.001 level significant.

specific crossings (D 044, D 066, D 010, D 011, D 055, D 064, D 002, D 014, D 061 and D 060) showed better growth performances than control clones Samsun (at 11th order) and I-214 (at 55th order) regarding their volume index values. Index values of control clones were found 15.67 for Samsun and 10.53 for I-214. Heritability value of the clones for volume index (H2:0.65) was also found in reasonably high level. Superior growth performances of eastern cottonwood clones at nursery and plantation stages were stated in Turkey and some other countries (Teissier and Cros, 1984; Tunçtaner, 1988; Padro and Hernandez, 1989; Tunçtaner, 1991; Huang et al., 1992; Tunçtaner et al., 2004). Therefore, intensive studies have been made on selection of interspecific and intraspecific crossbreds of this species for multi-purpose wood production (Gaget et al., 1984; Rajora and Zsuffa, 1984; Guzina et al., 1992; Huang et al., 1992; Tunçtaner, 2002; Robison et al., 2006; Marron et al., 2007).

74.6% of the interspecific and 59.9% of intraspecific clones survived at the end of the second growing season. The survival rates of the control clones, Samsun and I-214 were 95.5% and 91.2%, respectively. Only one clone (D 021) showed better survival rate (97.6%) than control clones. Rooting ability of stem cuttings is a very important criterion in selecting clones for commercial culture of poplar species. Poor survival rates of *P. deltoides* comparing *P. nigra* and *P. x euramericana* were reported (Cornu, 1972; Zsuffa, 1976; Jokela, 1984; Tunçtaner, 1988). Variation in rooting ability of *P. deltoides* associated with geographic origins, families and individual clones within families were also reported (Ying and Bagley, 1977; Nelson and Tauer, 1986; Coyle et al., 2006).

Morphological characteristics of the clones were determined by index values (Table 5).

Factor analysis was applied to the data concerning growth and some morphological characteristics of the clones. The correlation matrix, obtained by calculating the correlation coefficients between 13 variables, was used as a first input of factor analysis. In factor analysis, total variance was explained for 13 components and the first 5 components having larger proportion than 1.0 in total variance were extracted (Kaiser Criterion). Proportion of variance of the first 5 components in the total variance is 71.46 % (Table 6).Then, unrotated component matrix was obtained using principal component model and in order to get a more reliable matrix for scientific explanation, the matrix rotated by varimax rotation method was produced (Table 7).

In the first component, four variables ($VIDM^3$, DMM, HCM and SS) 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 “$VIDM^3$” which had shown the maximum correlation (0.959). Using the same method, the component 2 was named as “Morphology” and represented by “ANG”. The component 3 was named as “Leaf Characteristics” and represented by “LMW”. The component 4 was named as “Branch” and represented by “BI”. The component 5 was named as “Colour” and represented by “CP”. Consequently, the 13 variables have been decreased to 5 components with the loss of 29% information. According to the results of factor analysis, clones were separated into a priori 5 groups depending on the most important variable “$VIDM^3$” in the component 1 (Table 8).

Table 4. Rank of the growth values of the clones.

Diameter (mm)	Height (cm)	Survival (%)	Volume index (dm^3)	Diameter (mm)	Height (cm)	Survival (%)	Volume index (dm^3)
(44) 61.3	(66) 750.0	(21) 81.1	(44) 21.4	(18) 47.0	(30) 631.6	(39) 54.7	(42) 11.0
(66) 58.3	(12) 734.3	(90) 77.7	(66) 20.7	(23) 47.0	(26) 630.6	(27) 53.8	(57) 10.9
(55) 57.3	(63) 719.3	(63) 75.0	(10) 17.7	(32) 46.6	(43) 630.3	(76) 53.8	(16) 10.9
(10) 57.0	(61) 715.3	(89) 72.7	(11) 17.6	(15) 46.3	(35) 630.0	(05) 53.8	(20) 10.8
(11) 56.3	(08) 708.0	(71) 72.2	(55) 17.0	(57) 46.3	(71) 630.0	(73) 53.8	(39) 10.8
(64) 54.6	(07) 706.0	(20) 71.5	(64) 16.5	(39) 46.0	(46) 627.6	(75) 53.8	(18) 10.7
(90) 54.6	(62) 705.0	(65) 70.0	(02) 16.1	(16) 45.6	(55) 627.6	(34) 53.3	(32) 10.7
(14) 54.3	(11) 698.3	(03) 68.8	(14) 16.1	(46) 45.6	(73) 626.6	(41) 53.1	(65) 10.7
(60) 54.3	(10) 696.6	(08) 68.0	(61) 16.1	(54) 45.6	(24) 626.0	(78) 53.1	(23) 10.6
(02) 54.0	(14) 692.0	(14) 66.1	(60) 16.0	(36) 45.3	(54) 624.3	(24) 52.8	(89) 10.5
(61) 53.6	(13) 689.3	(36) 66.1	(90) 15.6	(65) 45.3	(53) 624.0	(10) 52.7	(40) 10.4
(13) 53.3	(02) 688.6	(15) 64.6	(63) 15.6	(83) 45.3	(37) 622.0	(80) 51.1	(36) 10.3
(63) 53.3	(44) 687.6	(25) 63.9	(13) 15.5	(17) 45.0	(34) 621.0	(44) 51.1	(72) 10.2
(68) 52.3	(15) 687.0	(45) 63.9	(62) 15.5	(20) 45.0	(83) 621.0	(60) 51.1	(83) 10.1
(41) 52.0	(01) 677.0	(12) 63.8	(07) 15.1	(89) 45.0	(42) 620.3	(87) 50.8	(54) 10.0
(47) 52.0	(64) 676.6	(48) 63.4	(59) 14.4	(40) 44.6	(72) 613.0	(81) 48.9	(46) 9.9
(62) 52.0	(60) 675.3	(79) 63.4	(68) 14.4	(30) 44.3	(32) 612.6	(33) 48.8	(28) 9.8
(06) 51.6	(09) 674.0	(37) 62.7	(41) 14.3	(25) 43.6	(47) 612.0	(22) 48.0	(25) 9.7
(07) 51.6	(45) 673.3	(09) 62.7	(12) 14.1	(28) 43.6	(49) 610.6	(29) 47.2	(17) 9.5
(52) 51.6	(05) 671.0	(53) 62.7	(06) 13.9	(49) 43.6	(52) 610.6	(69) 47.0	(49) 9.4
(59) 51.3	(65) 671.0	(70) 61.9	(09) 13.8	(85) 43.6	(56) 610.3	(61) 46.9	(30) 9.3
(74) 51.3	(40) 669.3	(07) 61.2	(08) 13.7	(78) 43.3	(21) 609.0	(67) 46.9	(48) 9.2
(05) 50.6	(90) 666.0	(23) 61.2	(05) 13.6	(48) 43.0	(23) 608.0	(74) 46.9	(56) 8.9
(29) 50.6	(06) 661.3	(26) 61.2	(74) 13.6	(56) 43.0	(81) 606.3	(58) 46.9	(03) 8.8
(04) 50.3	(36) 661.3	(16) 60.0	(29) 13.5	(33) 42.3	(04) 605.6	(32) 45.0	(78) 8.7
(34) 50.0	(89) 660.0	(13) 59.7	(52) 13.4	(38) 42.0	(33) 605.0	(77) 45.0	(33) 8.3
(43) 50.0	(20) 659.3	(19) 59.7	(82) 13.4	(72) 41.6	(70) 604.3	(85) 44.7	(69) 8.3
(82) 50.0	(41) 657.6	(88) 59.7	(01) 13.1	(03) 40.6	(67) 604.0	(49) 42.7	(71) 8.1
(08) 49.6	(29) 655.0	(83) 59.2	(34) 13.0	(73) 40.6	(84) 601.3	(56) 42.7	(73) 8.1
(09) 49.6	(75) 655.0	(30) 59.0	(47) 12.9	(50) 40.3	(18) 600.6	(86) 42.7	(85) 8.1
(12) 49.6	(68) 654.3	(06) 58.0	(43) 12.5	(69) 40.3	(38) 600.3	(38) 41.0	(38) 8.1
(79) 49.6	(58) 648.3	(31) 58.0	(79) 12.4	(70) 40.3	(50) 599.6	(35) 41.0	(51) 7.5
(01) 49.3	(16) 646.6	(82) 57.7	(45) 12.3	(51) 40.0	(51) 598.3	(62) 41.0	(21) 7.4
(75) 49.3	(59) 644.3	(04) 57.7	(58) 12.3	(71) 40.0	(31) 584.0	(18) 40.7	(50) 7.4
(19) 49.0	(74) 643.0	(50) 57.7	(37) 12.3	(84) 40.0	(80) 582.3	(68) 38.8	(70) 7.2
(42) 49.0	(69) 640.6	(11) 56.9	(04) 12.2	(86) 39.6	(17) 580.0	(43) 38.8	(84) 7.2
(26) 48.6	(03) 640.0	(40) 56.9	(75) 12.1	(21) 39.3	(88) 577.3	(28) 38.0	(31) 7.1
(37) 48.6	(22) 640.0	(57) 56.9	(35) 12.0	(31) 39.0	(78) 574.6	(51) 37.2	(86) 6.6
(35) 48.3	(25) 640.0	(52) 56.7	(19) 12.0	(27) 38.3	(27) 570.3	(64) 37.2	(76) 6.2
(45) 48.3	(39) 636.6	(66) 56.7	(26) 11.9	(76) 38.3	(76) 557.3	(46) 36.6	(88) 6.2
(58) 48.3	(48) 636.0	(84) 55.8	(15) 11.6	(77) 37.3	(28) 549.3	(54) 34.9	(27) 6.1
(22) 47.6	(82) 636.0	(01) 55.7	(22) 11.5	(80) 37.0	(85) 540.6	(42) 30.7	(77) 6.1
(24) 47.6	(19) 635.0	(02) 55.3	(24) 11.5	(88) 37.0	(86) 536.6	(59) 30.2	(80) 6.0
(53) 47.6	(79) 634.3	(17) 54.9	(81) 11.2	(67) 35.6	(77) 534.0	(55) 30.2	(67) 5.6
(81) 47.3	(57) 633.3	(72) 54.9	(53) 11.1	(87) 31.3	(87) 486.0	(47) 23.8	(87) 3.6

The numbers in brackets represent the order of the clones in Table 1.

Discriminant analysis was performed on the basis of 5 effecive components determined by factor analysis. Four discriminant functions were obtained to separate the groups from each other. Standardized discriminant

Table 5. Mean index values of the clone types and control clones.

Clone type	Morphological characteristics								
	BI	SS	LMW	ANG	SLB	LT	CP	MVC	LP
Intraspecific crosses	0.4	2.1	2.8	3.9	5.6	3.5	1.5	3.0	5.4
Interspecific crosses	0.5	2.2	3.0	2.8	5.2	3.6	1.2	3.4	5.6
I-214	0.6	2.0	3.0	2.0	4.0	3.0	2.0	4.0	6.0
Samsun	0.4	2.6	2.0	4.0	7.0	4.0	2.0	4.0	6.0

Table 6. Total variance explained for the components.

Components	Initial Eigenvalues			Extraction Sum of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	3.635	27.963	27.963	3.635	27.963	27.963
2	1.984	15.262	43.224	1.984	15.262	43.224
3	1.387	10.699	53.893	1.387	10.669	53.893
4	1.278	9.834	63.727	1.278	9.864	63.727
5	1.005	7.730	71.457	1.005	7.730	71.457
6	0.871	6.701	78.158			
7	0.823	6.332	84.490			
8	0.627	4.823	89.313			
9	0.494	3.798	93.112			
10	0.449	3.453	96.565			
11	0.299	2.297	98.862			
12	0.129	0.994	99.856			
13	1.870E-02	0.144	100.000			

Extraction method: Principal component analysis.

Table 7. Rotated component matrix.

Variables	Components				
	1	2	3	4	5
$VIDM^3$	0.959				
DMM	0.938				
HCM	0.934				
ANG		0.800			
SLB		0.792			
SPR		-0.602			
SS	0.383	0.434			
LMW			0.858		
LP			-0.600	0.481	
BI				0.813	
LT			0.421	0.585	
CP					0.923
MVC		0.485			0.556

Extraction Method: Principal component analysis.
Rotation Method : Varimax with Kaiser normalization.

Table 8. The groups and number of the clones.

Groups	Volume index (dm^3)	Number of the clones
Group 1	21.40 - 20.73	2
Group 2	17.77 - 14.17	17
Group 3	13.97 - 11.03	27
Group 4	10.93 - 8.10	30
Group 5	7.50 - 3.67	14

Table 9. Standardized canonical discriminant function coefficients.

Variables	Functions			
	1	2	3	4
$VIDM^3$	1.010	0.300	-0.650	-0.042
ANG	-0.013	0.348	0.659	0.202
LMW	-0.093	0.725	0.356	0.568
BI	-0.008	-0.640		0.199
CP	-0.050	0.021		0.692

function coefficients are given in (Table 9) and statistical parameters of these functions are given in (Table 10). It is clearly understood that the most important discriminant function is function 1, when the (Tables 9 and 10) are taken into consideration. The results of the classification

Table 10. Some statistical parameters of discriminant functions.

Functions	Eigenvalues	% of variance	Cumulative %	Canonical correlation
1	12.177[a]	98.0	98.0	0.961
2	0.188[a]	1.5	99.5	0.398
3	0.049[a]	0.4	99.9	0.217
4	0.007[a]	0.1	100.0	0.085

a: First 4 canonical discriminant functions were used in the analysis.

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

Groups	Predicted group membership					Total
Original count	1	2	3	4	5	
1	2	0	0	0	0	2
2	0	16	1	0	0	17
3	0	0	27	0	0	27
4	0	0	0	29	1	30
5	0	0	0	0	14	14
%						
1	100.0	0.0	0.0	0.0	0.0	100.0
2	0.0	94.1	5.9	0.0	0.0	100.0
3	0.0	0.0	100.0	0.0	0.0	100.0
4	0.0	0.0	0.0	96.7	3.3	100.0
5	0.0	0.0	0.0	100.0	100.0	100.0

of the clones concerning the predicted groups determined by discriminant analysis are given in (Table 11). It can be stated that the classification of the clones into 5 groups based on the most important variable "VIDM^3" was correctly made on 97.8% confidence. In the original grouped cases the highest success was achieved in group 1, 3 and 5 with 100%. The success in group 2 and 4 are 94.1 and 96.7%, respectively. According to the results of this analysis the clone D 041 in group 2 was transferred to group 3 and the clone D 038 in group 4 was transferred to group 5.

Conclusion

Genetic variation on growth trends and some morphological characteristics of the intraspecific and interspecific crosses of *P. deltoides* was taken into consideration for preliminary selection of the best clones at nursery stage. Significant differences in tree dimensions and survival were found between the clones. Intraspecific crosses generally showed better growth traits than interspecific crosses. Large genetic variation in growth and morphology was found among the clones. Factor analysis was applied for 13 components. Total variance was explained for these components and 71.46% of total variance was represented by the first five components (growth, morphology, leaf characteristics, branch and colour). Volume index (VIDM^3) in the component 1 was determined as the most important variable.

Discriminant analysis was processed with 5 effective components derived by factor analysis. Groups of the clones were separated by discriminant functions and 5 highest groups were determined with the most effective variable volume index. 17 intraspecific crossings (D044, D066, D010, D011, D055, D064, D002, D014, D061, D060, D063, D013, D062, D007, D059, D068 and D041) and control clone "Samsun" in the first and second groups are the most productive clones to be considered for further research studies regarding their growth trends and some morphological characteristics. Great emphasis should also be given to rooting abilities of these clones for commercial production in nursery.

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