

## The Impact of Site Index on Wood Density and Fiber Biometry of Populus Deltoids Clones

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**Abstract:** The variability of wood density and fiber biometry was determined in four 12-year-old populus deltoids clones grown under two different site conditions in Iran. The values of wood density and fiber length, fiber diameter and fiber wall thickness were obtained and variance analyses were performed considering site and clone as the sources of variation. Components of genetic and phenotypic variations were determined to calculate heritability in its broad sense. The results indicated that site and clone had significant effect on wood density and fiber biometry. The pattern variation of properties showed that the clone 77/51 corresponded to the higher wood density and fiber biometry range in both sites, but the clone 45/51 had the lowest. Also, the wood density of populus deltoids from Safra-baste site in Guilan was higher than that it Shast-kolateh site in Gorgan. For each clone, the mean values of wood density, fiber length and fiber diameter and fiber wall thickness varied between 305.7 - 367.1 kg m<sup>-3</sup>, 0.96 - 1.29 mm, 24 - 28.46 μm and 5.02 - 6.25 μm respectively. Heritability values demonstrate a stronger genetic control in wood density compared to fiber biometry.

**Key words:** Populus deltoids • Clones • Site • Wood density • Fiber length • Fiber diameter • Fiber wall thickness • Heritability

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### INTRODUCTION

The poplars (populus spp.) are a diverse group of plants that have become an economically important part of forestry in the world [1]. They represent the fastest growing trees in the temperate regions and produce wood that is widely used by the forest industry. Considering that wood supplies in the future may become scarce, wood production from poplar plantation could play a larger role as raw material for domestic and industrial uses [2].

The genetic programmers, concerning populus deltoids, investigate how to maintain their wide ranges of adaptability to different environmental conditions, while simultaneously improving wood quality, specifically wood density and fiber length. Wood basic density is considered as one of the most important features in genetic improvement programmers [3] and is one of the most often studied wood quality traits [4-6]. It is a

complex feature influenced by cell wall thickness, the proportion of the different kinds of tissues and the percentages of lignin, cellulose and extractives [7]. Both wood density and fiber length determine whether the quality of raw material is suitable for a specific use in the paper industry. Fiber length also has impacts on paper characteristics, such as strength, optical properties and surface quality.

Several researchers [6-10]. have demonstrated that genetic make up can influence fiber characteristics and specific gravity of the tree. Both of these properties can influence the quantity as well as the quality of the pulp. Knowledge of the genetic and environmental variation present in forest stands allows the development of adequate strategies for the selection of superior genotypes. The objective of this article was to determine the variability of wood density and fiber biometry in four populus deltoids clones, growing under two different site conditions.

Table 1: The characteristics of site location and populus deltoids trees

Site	Type of climate	Direction	Altitude (m)	Mean Annual Temperature (°C)	Annual Rainfall (mm)	Type of Clay
Safra-baste	Mediterrance	37° 17' N 55° 45' E	50	17.5	1186	siltylome
Shast-kolateh	Mediterrance	36° 45' N 54° 24' E	300	19	525	spodosols

**MATERIALS AND METHODS**

The materials for this study came from a populus deltoids clone trial by the Iranian Research Institute of Forest and Rangelands in north of Iran. The trial is located in two sites. The characteristics of site location and populus deltoids trees are listed in Table 1.

The trials comprised 4 clones at the both sites (Table 2) and clones were planted in row plots containing four trees at 3.5 × 3.5 m spacing at Safra-baste site and 3 × 3 m at Shast-kolateh site. The physical and biometrical characteristics of five poplar aged 12 years in each clone, with stem diameter in the stands was 24 cm and 18 cm, mean stand height 12 m and 10.53 for Safra-baste and Shast-kolateh sites respectively. The populus deltoids trees were cut for the study in October 2004.

Less than two hours after the harvest, the trees were bucked at three meter intervals and 4-cm-wide slabs were cut through the cross sections of the separated pieces. The slabs were taken directly to the freezer, to avoid losing their moisture content. Consequently, the two sample disks were taken at breast height (1.30 m). One was used to determine density and the other to carry out fiber biometry measurements. Wood density was examined according to ASTM-D143 [11], calculating the ratio between dry weight of the sample and saturated volume in complete discs; after removal of their bark, twenty replicate samples were tested for each treatment level.

Wood maceration fiber length, fiber diameter and fiber wall thickness was performed with Franklin’s reagent [12]. The value of fiber biometry (measuring a minimum 100 fibers in one specimen for each clone) is expressed by Olympus microscope with image analyzer.

The statistical analysis was conducted using SPSS programming method in conjunction with analysis of variance (ANOVA) techniques; Duncan multiply range test (DMRT) was used to test the statistical significance at α = 0.05 level. After the analysis of variance of the data, components of phenotypic and genetic variance were determined in order to calculate the heritability in the broad sense for both sites using the following equation:

$$h_2 = \frac{V_g}{V_p} = \frac{V_g}{V_g + V_{ga} + V_e}$$

Where:  $h_2$  = heritability in the broad sense,  $V_g$  = genetic variance,  $V_p$  = phenotypic variance,  $V_{ga}$  = variance of the interaction of genotypes with the environments,  $V_e$  = variance of error.

The following model was employed (genotypes were considered as fixed effects and sites as randomized effects):

$$Y_{ijk} = \mu + C_i + S_j + CS_{ij} + e_{ijk}$$

Where:  $Y_{ijk}$  = phenotypic value,  $\mu$  = general mean value,  $C_i$  = effect of clone,  $S_j$  = effect of site,  $CS_{ij}$  = effect of the interaction of clone and site.  $e_{ijk}$  = experimental error associated to the  $k^{th}$  tree of clone  $i$  in the site  $j$

**RESULTS AND DISCUSSION**

The results of an ANOVA indicated that the site and clone had significant effect on wood density ( $p < 0.05$ ). Also the interaction between site and clone had significant difference (Tables 3). The pattern of variation of the wood density as a function of clone and site has been shown in Table 5. As shown in Table 5, clone 77/51 corresponds to the higher wood density range in both sites, but the clone 45/51 had the lowest wood density. Also, the wood density of populus deltoids from Safra-baste site in Guilan higher than Shast-kolateh site in Gorgan. The wood density values were found between 305.7 kg m<sup>-3</sup> and 367.1 kg m<sup>-3</sup> in this study.

The results of an ANOVA indicated that the site and clone had significant effect on fiber biometry ( $p < 0.05$ ). Also the interaction between site and clone had significant difference (Tables 4). The pattern of variation of the fiber biometry (fiber length, fiber diameter and fiber wall thickness) as a function of clone and site has been shown in Table 5. As shown in Table 5, clone 77/51 corresponds to the higher fiber length; fiber diameter and fiber wall thickness range in both sites, but the clone 45/51 had the lowest fiber biometry. Also, the fiber

Table 2: Clones identification

Clones	Origin
I-69/55	P. deltoids Marsh
I-45/51	P. deltoids var. Missouriensis
I-72/58	P. deltoids var. Missouriensis
I-77/51	P. deltoids Marsh

Table 3: Analysis of variance for wood density in both sites

Source of Variation	DF	SS	MS	F
Sites	1	1.274	1.274	28.95*
Clones	3	2.597	0.866	19.68*
Sites × Clones	3	2.012	0.671	15.25*
Error	152	6.743	0.044	-
Total	159	12.626	-	-

\*- Significantly difference at 95% confident level

Table 4: Analysis of variance for fiber biometry in both sites

Source of Variation	DF	SS	MS	F
Sites	1	2.641	2.641	293.44*
Clones	3	4.104	1.368	152*
Sites × Clones	3	4.215	1.405	156.11*
Error	792	7.882	0.009	-
Total	799	18.752	-	-

\*- Significantly difference at 95% confident level

biometry (fiber length, fiber diameter and fiber wall thickness) of populus deltoids from Safra-baste site in Guilan was higher than that it Shast-kolateh site in Gorgan. The fiber length, fiber diameter and fiber wall thickness values were found between 0.96-1.29 mm, 24-28.46 μm and 5.02-6.25 μm respectively, in this study.

Heritability in the broad sense is defined as the ratio of total genetic variance to phenotypic variance. The most important function of this parameter is its predictive role. Since this study considers four clones only, the results should be interpreted with

caution due to the small sample size. An estimate of  $h_2 = 0.72$  was obtained for wood density and 0.63 for fiber length, 0.67 for fiber diameter and 0.61 for fiber wall-thickness of populus deltoids.

Significant site effects for wood density have been previously reported by Garcia and Suarez and Zhang *et al.* Peszlen did not detect differences for density in three clones of the genus Populus planted in two sites in Hungary. The range of variation between clones agrees with that observed in previous studies carried out in the country [15-17]. For pulp and paper production, species with higher lengths are preferred since a better fiber net is achieved, resulting in a higher resistance of the paper. This is the reason why clones with fibers longer than one millimeter are like all clones in both sites, except clone I-45/51 in shast-kolateh Gorgan. It is interesting that clone I-77/51 is the only clone that overcomes the millimeter limit at both sites in agreement with values reported by Garcia Volonté and Monteoliva *et al.*

In other studies, Peszlen found a heritability of 0.51 for density in three Populus clones planted in Hungary. Yanchuk *et al.* determined heritability of 0.35 for density and 0.43 for fiber length in populations of Populus tremuloides. They emphasized that both these traits were under a moderate genetic control. In view of the multi-purpose role of Populus species, the possibilities of increasing the cultivation area for providing raw material for the paper industry requires a deeper knowledge of their genetics. Previous papers [20-22], reported significant interclonal genetic variation in wood density and other properties of poplars or its hybrids. This indicated that more favorable environmental conditions facilitated the revelation of clone difference in wood physical and structural properties. A rather similar extent of interhybrid and interclonal variation indicated that both hybrid and clone selection should be combined in tree breeding programs to yield a synergistic enhancement of growth site and wood properties.

Table 5: Clone × Site comparison of wood densities and fiber biometry

Density (kg m <sup>-3</sup> )			Fiber length (mm)			Fiber diameter (μm)			Fiber wall thickness(μm)		
Clone	Guilan*	Gorgan*	Clone	Guilan	Gorgan	Clone	Guilan	Gorgan	Clone	Guilan	Gorgan
69/55	347.4b	317.6b	69/55	1.17a	1.12a	69/55	26.24b	24.32b	69/55	6.14ab	5.34ab
45/51	316.9c	305.7c	45/51	1.03b	0.96b	45/51	25.18c	24b	45/51	5.94b	5.02b
72/58	344.6b	326.2b	72/58	1.08ab	1.04b	72/58	25.67bc	24.09b	72/58	6.02b	5.13b
77/51	367.1a	359.2a	77/51	1.29a	1.19a	77/51	28.46a	25.64a	77/51	6.25a	5.73a

Noted: \*Guilan as represented Safra-baste site, Gorgan as represented Shast-kolateh site.

Results with different letters are significantly different (Duncan test).

**The Following Conclusions Were Obtained from this Research:**

- An analysis of variance indicates that the site and clone had significant effect on fiber biometry; also the interaction between site and clone had significant difference
- The pattern variation of properties showed that the clone 77/51 corresponded to the higher wood density and fiber biometry range in both sites, but the clone 45/51 had the lowest
- The wood density of populus deltoids from Safrabaste site in Guilan was higher than that it Shastkolateh site in Gorgan.
- Heritability values demonstrate a stronger genetic control in wood density compared to fiber biometry.

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