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VARIABILITY AND ADAPTABILITY OF SELECTED POPLAR (*POPULUS NIGRA*) CLONES, BASED ON STABILITY PARAMETERS AND AMMI MODEL

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Poplars are among the most important wood trees that play a key role for provision of raw material for the cellulose industry. In order to study the genetic diversity, selection and introduction of superior and compatible clones in the west of Iran, this research was carried out. The experiment was set up based on randomized complete block design (RCBD) with three replications in eight years (2007 to 2014) at the Agricultural and Natural Resources Research Center of Kermanshah, Iran. From each clone 25 seedlings were planted with 3 × 3 meter spacing. The studied traits included: diameter at breast height, total height, current annual volume increment and wood volume. The results of mean comparison by Duncan test showed a significant difference between the clones at the level of 5%. The clon 62/154 had the greatest height, diameter, and wood volume. Combined analysis of variance revealed significant effect of Year × Clone interaction for all traits at 5% probability. Based on the cluster analysis, ten clones were grouped into three clusters. The clones 62/149 and 62/154 had the greatest distance of all all clones. Based on the AMMI model, and other stability parameters the clones *P. nigra 56/75*, *P. nigra betulifolia, P. nigra mehregan, P. nigra 63/135, P. nigra 56/72* were selected as the highest productive clones and recommended to cultivation.

Keywords: AMMI model, genetic diversity, *Populus nigra*, stability parameters

INTRODUCTION

The genus Populus (*Populus* spp.) is an important fiber resource for the global pulp and paper production and plays a key role in the cellulose industry. One of the special characters of poplars is their ability of vegetative propagation and fast growth. In addition to the many products from the wood, *Populus* spp. also provide many important environmental functions such as: rehabilitation of degraded lands, protection of soils and water, conservation of biological

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diversity, provision of shelter and shade, and sequestration of carbon in temperate and subtropical regions of the world (TABATABAEI, 1986: BALATINECZ *et al.*, 2001: ZALESNY *et al.*, 2007).

On over 3,600,000 hectares it provides approximately 20 million m^3 of wood and fiber annually. Group of countries supporting large poplar programs include: Argentina, China, France, India, Italy, and Turkey (FAO, 2004). The propagation of poplars by seed is used mostly in breeding programs (BIRANG *et al.*, 1986). The Populus genus (fam. Salicaceae) has six sections and more than 30 species (ECKENWALDER, 1996). Also, the genus of Poplar has a high genetic variation due to its formation and increasing interspecific and inter-population hybridization, and the large dispersion of seeds and pollen (KELARGERY, 2004).

Distance determination is a multivariate statistical method that is calculated based on some measurable characters and is an effective method for determining genetic or genotypic distance in biodiversity evaluations. A great deal of research has been done on the calculation of genetic diversity and its application for the improvement of different plants (FARSHADFAR and FARSHADFAR, 2002; BAUCHAN *et al.*, 1993).

The existence of genotype × environment interactions reduces the ability to estimate the main effects of genotypes (FARSHADFAR, 1998). Awareness of the nature of the interaction between the genotype and the environment helps the breeders to more accurately evaluate the cultivars and select the superior genotypes for high yield and stability (LIN *et al*., 1986; GAUCH, 1988; CORNELIUS and CROSSA, 1999). The researchers used different criteria for recognizing the stability of the cultivars. If the variance of the interaction between the genotype and the environment is significant, then, using one of the many methods of stability analysis to rank stable genotypes is meaningful (FARSHADFAR, 1998). Multivariate statistical methods provide more comprehensive information on the interaction effect and phenotypic variability (VARGAS and CROSSA, 2000). Among these methods, the AMMI model was used to study the effect of the genotype × environment interaction. AMMI model is a combination of analysis of variance and principal component analysis, which is used to analyze stability. Stable genotypes based on this method are determined by biplot diagrams of the first two principal components (CLAY and DOMBEK, 1995; BOTOVIĆ *et al*., 2018).

NAJAFIAN *et al*. (2010), by using AMMI method, determined the stable genotypes in their study and stated that the this method can be used to determine the genotypes of general and specific adaptation for different sites. PEDERSON (1974) suggested comparing genotypes in a small number of locations, but in more than a year. CAMPBELL and LAFEVER (1977) has suggested the increase number of years as opposed to increasing the number of sites.

The multiplicative part of the AMMI model is one of the main components for the analysis of the interaction between the genotype and the environment component (FATAHI 2000; GAUCH and ZOBEL, 1997; YAN *et al*., 2000; AKCURA *et al*., 2005). Having the first two significant PCAs in the AMMI model is the best way to examine the interaction between the genotype and the environment (DANYAIE *et al*., 2011; KAYA *et al*., 2002). In order to better analyze Year × Clone interaction and determine the contribution of clones and years to the interaction, as well as stability, several parameters are used: the average yield of genotypes, CV_i (FRANCIS and CANENBERG, 1978), Wrick ecovalance (W_i^2) (WRICK, 1962), variance stability of Shukla (δ_i^2) (SHUKLA, 1972), the coefficient of determination (R_i^2) (PINTHUS, 1973), and the regression coefficients (b_i) (FINLAY and WILKINSON, 1963), environmental variance (S_i^2) (VARGAS and CROSSA, 2000). NOORI *et al*. (2009; 2013) studied the final adaptation of 18 poplar clones in two stations in Kermanshah province, introduced *P*. × *euramericana cl.* 488, P. × *euramericana cl.* 214, P. × *euramericana cl.* 555 cultivars as superior cultivars.

The aim of this study was to determine the genetic diversity pattern and determine the stability of ten poplar clones based on AMMI model and different stability parameters.

MATERIALS AND METHODS

The experiment was carried out on 10 clones of European black poplar (*Populus nigra* L.) (Table 1) from 2007-2014 at the Mehregan research station of Kermanshah, located on west of Iran at 34º9'N latitude, 47º9'E longitude, at an altitude of 1270 m above sea level. Temperature varied from -20ºC to +45ºC, the means of annual rainfall was 470.7mm. Experiments were conducted in a randomized complete block design (RCBD) with three replications and 3 × 3 meter spacing. The eight-year growth performance was measured.

The height of the plants was measured with the vertex instrument, while basal diameter, diameter at breast height (diameter at a height of 1.50 m), median diameter and tip diameter was measured with caliper and bar diameters. Wood volume was calculated by multiplying by square of diameter with height as its relative index as also used in *Populus* species (BALATINECZ *et al*., 2001; PANDEY *et al*., 1993; WU and STETTLER, 1997).

Irrigation and weed control were done regularly when it was necessary. Each year, at the end of the growing season, the diameter of trees at a height of 1.30 m (diameter at breast height) was measured with caliper with a precision of millimeters. Height of the trees was measured with a Blum Leice micrometer with precision of centimeter. Based on these measurements the wood volume and current annual increment of volume and height were calculated.

Table 1. The list of poplar selected clones

No.	Clones	Source and origin
1	*Populus nigra* L. *cl.* 56/32	Turkey
2	*Populus nigra* L. *cl.* 56/52	Turkey
3	*Populus nigra* L. *cl.* 56/72	Turkey
4	*Populus nigra* L. *cl.* 56.75	Turkey
5	*Populus nigra* L. *cl.* 62.149	Turkey
6	*Populus nigra* L. *cl.* 62.154	Turkey
7	*Populus nigra* L. *cl.* 63/135	Turkey
8	*Populus nigra* L. *cl.* 69/8 *kermanshah*	Iran
9	*Populus nigra* L. *var. betulifolia*	Turkey
10	*Populus nigra* L. *cl. Mehregan*	Iran

Combined analysis of variance was performed for height, diameter, wood volume and annual growth rate of volume and height. Multiple range test was also used (by DMRT, Duncan method). Cluster analysis (based on the UPGMA method) and principal component analysis (PCA) were applied.

The AMMI model was used to analyze the interactions of genotype × environment using the following formula:

$$P_{ijk} = \mu + gi + tj + \sum_{n=1}^{N}(IPCA_n^{Geni})(IPCA_n^{Envj}) + dij + e_{ijk}$$

The AMMI model and the first and second interaction effects of AMMI (PC1, PC2) were used as stability parameters for genotypes and environment.

Euclidean metric has been applied to calculate distance between clones (FARSHADFAR and FARSHADFAR, 2017). Stability parameters has been calculated based on the environmental variation coefficient (CV_i), Wricke ecovalence (W_i^2), Shukla stability variance (δ_i^2), Coefficient of determination (R_i^2), and Finley and Wilkinson regression coefficient (b_i), environmental variance (S_i^2). For statistical computations and plotting, statistical software SPSS, SAS 9.2 and Mintab 15 were used, and for analysis of AMMI, GENSTAT software was used.

RESULTS

Genetic diversity

The results of combined analysis of variance showed significant differences between the growth, diameter at 5% and 1% respectively (Table 2). Effect of factor Year on variation of all the measured traits was significant at 5% level of probability.

Table 2. Mean Square of combined analysis of variance of P. nigra clones

Source of Variations	Height (cm)	Current growth of diameter(cm)	Diameter at breast height (cm)	Current growth of volume (1×1^{-10})	Current growth volume/h (cm^3)	Volume (m^3/h)	Current growth height(cm)
Replication	70.939*	4/923*	134.13*	7639*	9.43*	77569.567**	3.507ns
Clone	7.342^{ns}	0.367*	12.289ns	7145ns	0.882ns	3985.907ns	0.348**
Error1	1.781*	0.1510ns	5.611*	5398ns	0.666ns	1937.52*	0.078ns
Year	743.82*	15.942*	1621.072*	7137**	8.811*	413128.515*	8.38*
Year × Clone	0.582*	0.846*	1.025*	1162**	1.434*	449876*	0.438*
Error2	3.642*	0.507ns	5.534*	1799**	1.221**	10547.194*	0.201ns

*, ** significant at 5% and 1% probability level, respectively

Based on the multiple range test for volume growth, there were seven homogenous groups (Table 3). The greatest overall mean of volume with 17.91 m^3 was found in *P. nigra* 62/154 and the smallest wood volume with 11.71 m^3 was found in *P. nigra* 62/149.

By multiple range test for diameter there were eight homogenous groups. The highest value was found in *P. nigra* 62/154 (12.45 m^3) and the lowest value (10.09 m^3) belonged to clone 62/149. The highest (9.36 m) was clone 62/154 and the shortest (8.24 m) was clone 69/8.

Labels of genetic parameters: Genotypic Coefficient of Variation (GVC), Phenotypic Coefficient of Variation (PVC), Environmental Coefficient of Variation (ECV), Heritability (HB), Genetic Advance (GA) and Genetic Gain (GG).

Table 3. Results of Duncan's multiple range test, and genetic parameters for wood volume, diameter and height of poplar clones

Clone	Wood volume (m^3/ha)	Diameter at breast height (cm)	Height (m)
P. nigra 62/154	17.91283a	12.4547a	9.3632a
P. nigra 56/75	14.68117b	11.2250bc	8.9384bc
P. nigra mehregan	14.3732bc	11.5027b	8.6134c
P. nigra 56/72	14.1244bc	11.3355bc	9.0625b
P. nigra 56/52	13.6811bcd	11.0541c	8.95bc
P. nigra 56/32	13.4659bcd	11.3743bc	8.6744cd
P. nigra 63/135	13.2356cd	10.4977f	8.9058bc
P. nigra betulifolia	12.3694de	10.5947d	8.8411bc
P. nigra 69/8	11.7865e	10.5375e	8.2468e
P. nigra 62/149	11.7281e	10.0864g	8.8152bc
PVC(%)	23.70	8.19	5.98
GVC(%)	11.47	4.24	2.84
ECV(%)	20.74	7.01	5.26
HB(%)	23.43	26.84	22.61
GA(%)	3.46	1.06	0.50
GG(%)	11.44	4.53	2.79

Values with same letter are not significantly different at 5% level of significance, Phenotypic Coefficient of Variation (PVC), Genotypic Coefficient of Variation (GVC), Environmental Coefficient of Variation (ECV), Heritability (HB), Genetic Advance (GA) and Genetic Gain (GG)

The results of cluster analysis based on UPGMA of poplar clones are presented in dendrogram based on all studied traits in Figure 1. Ten clones were grouped in three clusters. Cluster one contains clones *P. nigra* L. *cl.* 62.149, *P. nigra* L. *cl.* 69/8, and *P. nigra* L. *var. betulifolia*. Cluster two contains clones *P. nigra* L. *cl.* 56/32, *P. nigra* L. *cl.* 56/52, *P. nigra* L. *cl.* 56/72, *P. nigra* L. *cl.* 56.75, *P. nigra* L. *cl.* 63/135 and *P. nigra* L. *cl. Mehregan* , and cluster number 3 contains clone *P. nigra* L. *cl.* 62.154.

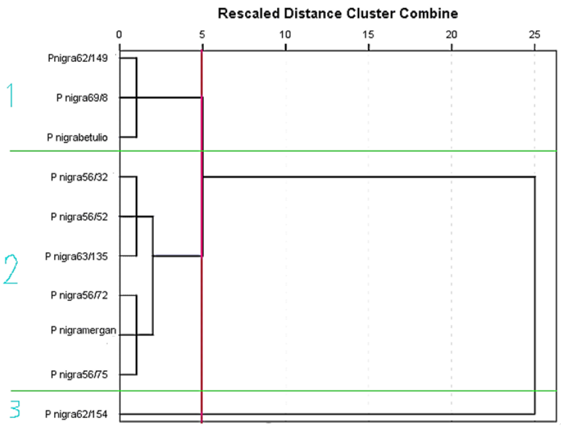

Figure 1. Dendrogram of cluster analysis of 10 *P. nigra* clones

The genotypic distance between the clones is presented in Table 4. The longest genetic distance (38.289) was found between clone 62/154 and clone 62/149, the shortest genetic distance (0.003) was estimted between clone 69/8 and 62/149. The greatest distance was between the first cluster and the third cluster. The intercrossing between members of these two groups, as parents, can be achieved for hybrid vigor in breeding programs.

The genetic parameters were presented in Table 3. Phenotypic coefficient of variation for wood volume was 23.70%, diameter at breast height 8.19%, and tree height was 5.98%. Genotypic coefficient of variation for wood volume was 11.47%, diameter at breast height 4.24%, and tree height 2.84%. Broad sense heritability (Hb) for diameter at breast height 26.84%, wood volume 23.43% and tree height 22.61%. Genetic advance for wood volume was 3.46%, diameter at breast height 1.06%, and tree height 0.50%. Genetic gain for wood volume 11.44, diameter at breast height 4.53%, tree height 2.79%. Phenotypic coefficient of variation is greater than genotypic coefficient of variation for all growth parameters, which varied from 5.98% and 2.84% in tree height to 23.70% percent and 11.47% percent in wood volume.

Table 4. Genotypic distance between examined clones

Case	Clone 56/32	Clone 56/52	Clone 56/72	Clone 56/75	Clone 62/149	Clone 62/154	Clone 63/135	Clone 69/8	Clone betufolia
P. nigra 56/52	0.046								
P. nigra 56/72	0.443	0.195							
P. nigra 56/75	1.447	1.00	0.310						
P. nigra 62/149	3.020	3.814	5.742	8.720					
P. nigra 62/154	19.774	17.906	1.352	1.443	38.249				
P. nigra 63/135	0.053	0.199	0.790	2.090	2.272	2.876			
P. nigra 69/8	2.821	3.590	5.446	8.379	0.003	3.532	2.100		
P. nigra betulifolia	1.202	1.721	3.080	5.344	0.411	3.728	0.750	0.340	
P. nigra mehregan	0.823	0.479	0.062	0.095	6.997	1.528	1.294	6.692	4.015

Stability analysis

The results of analysis of variance of clones' performance using AMMI model are presented in Table 5. There were no significant differences found between the clones for the yield trait. The effect of year, the effect of interaction year × clone and the effect first IPCA have been statistically significant at 5% level, but the effects of second and third principal components were not (Table 6). *P. nigra* L. *cl.* 56/72, *P. nigra* L. *cl.* 56/52, *P. nigra* L. *cl.* 62.154 and *P. nigra* L. *cl.* 62.149 have a large negative values of the first interaction principal component, so they are less stable in terms of the yield, as well as *P. nigra* L. *cl.* 63/135 and *P. nigra* L. *cl.* 69/8 have the highest positive values of IPCA1. The *Populus nigra* L. *var. betulifolia* clone and *P. nigra* L. *cl.* 56.75 have the lowest values of IPCA1, so they are the most stable in terms of wood production.

For better understanding the AMMI model, the biplot has been drawn, based on the first and second principal component (Figure. 2). Based on biplot, it is possible to identify stable clones and classifying the growing years. The analysis of biplot and AMMI model showed that the second and third year had the highest yield, and the first, seventh and eighth year had the lowest performance. Years 2005, 2006, 2008 and 2009 were similar, but year 2007 was significant difference with the other years.

Table 5. Analysis variance of poplar clones based on AMMI Model

Source of variation	DF	SS	MS	F
Treatment (Clone)	9	2.2496	0.2499	0.77ns
Year	7	34.4959	4.9297	15.18*
Year × Clone	63	36.038	0.5727	1.76*
IPCA 1	15	27.7794	1.8519	5.705*
IPCA 2	13	3.9209	0.3016	0.9291ns
IPCA 3	11	2.8182	0.2562	0.7892
noise	158	51.29	0.3246	-
Total	239	132.636	-	-

*,**significant at 5% and 1% probability level, respectively

Table 6. The value of interaction principal component of poplar clones

Clone	IPCA 1	IPCA 2	IPCA 3
P. nigra cl. 56/32	-0.3215	0.1953	-0.5854
P. nigra cl. 56/52	-0.4481	-0.4155	0.2047
P. nigra cl. 56/72	-0.4062	-0.1928	0.1483
P. nigra cl. 56/75	-0.3577	-0.1863	0.5541
P. nigra cl. 62/149	-0.3263	-0.5976	0.0024
P. nigra cl. 62/154	-0.5783	-0.3646	0.0127
P. nigra cl. 63/135	1.1635	-0.0301	0.0277
P. nigra cl. 69/8	0.7405	0.0483	-0.4364
P. nigra .var betulifolia	0.1166	-0.404	0.2086
P. nigra cl. Mehregan	-0.298	-0.4514	-0.1394

Stability parameters of examined traits have been presented in Table 7. Based on the Wricke's ecovalence stability parameter, *P. nigra* L. *var. betulifolia*, *P. nigra* L. *cl. Mehregan*, *P. nigra* L. *cl.* 56/72, *P. nigra* L. *cl.* 62.149 and *P. nigra* L. *cl.* 56.75 were the most stable and the *P. nigra* L. *cl.* 63/135, *P. nigra* L. *cl.* 69/8, and *P. nigra* L. *cl.* 62.154 clones had the lowest stability. Shukla stability variance values also showed that *P. nigra* L. *cl.* 62.149, *P. nigra* L. *var. betulifolia*, *P. nigra* L. *cl. Mehregan*, *P. nigra* L. *cl.* 56/72 and *P. nigra* L. *cl.* 56.75 had the highest stability and *P. nigra* L. *cl.* 63/135 and *P. nigra* L. *cl.* 69/8 had the lowest stability.

Also, regression coefficient based on Finlay and Wilkinson method the *P. nigra* L. *cl.* 62.154, *P. nigra* L. *cl.* 69/8, *P. nigra* L. *cl.* 56.75, *P. nigra* L. *var. betulifolia* and *P. nigra* L. *cl. Mehregan* were close to one, so these clones would have moderate stability under different environmental conditions. The *P. nigra* L. *cl.* 63/135 had a high regression coefficient, so it could be recommended for good environmental conditions. In other words, with improved environmental conditions, this clone will increase yields the most. In contrast, the *P. nigra* L. *cl.* 56/52, *P. nigra* L. *cl.* 56/32 and *P. nigra* L. *cl.* 62.149, had the regression coefficients less than one, so these clones will have stabile economic performance under any environmental conditions. Based on obtained results, these clones could be used for environments with low potential and unfavorable environmental conditions. Based on the deviation from regression line (S_{di}^2) the *P. nigra* L. *var. betulifolia*, *P. nigra* L. *cl.* 56/32, *P. nigra* L. *cl.* 62.149, *P. nigra* L. *cl. Mehregan* and *P. nigra* L. *cl.* 56/72 showed the highest stability in their reaction to different conditions.

Table 7. Stability parameters for examined poplar clones

Clone	Average	R_i^2	S^2_{di}	b_i	σ_i^2	w_i^2	S_i^2	CV_i (%)
P. nigra L. *cl.* 56/32	0.526	0.287	0.039	0.373	0.150	0.849	0.069	261.417
P. nigra L. *cl.* 56/52	0.626	0.372	0.066	0.584	0.152	0.859	0.132	180.850
P. nigra L. *cl.* 56/72	0.587	0.591	0.055	0.828	0.103	0.599	0.167	160.348
P. nigra L. *cl.* 56.75	0.828	0.761	0.062	1.326	0.134	0.759	0.332	92.478
P. nigra L. *cl.* 62.149	0.627	0.399	0.051	0.543	0.133	0.751	0.106	207.829
P. nigra L. *cl.* 62.154	0.748	0.451	0.125	0.947	0.222	1.257	0.286	136.440
P. nigra L. *cl.* 63/135	0.814	0.535	0.335	1.829	0.731	4.136	0.899	52.304
P. nigra L. *cl.* 69/8	0.631	0.587	0.173	1.465	0.350	1.981	0.525	67.907
P. nigra L. *var. betulifolia*	0.583	0.846	0.029	1.177	0.057	0.326	0.235	107.256
P. nigra L. *cl. Mehregan*	0.619	0.654	0.052	0.926	0.093	0.528	0.189	148.546

Coefficient of determination (Ri^2), Deviation from regression line (S^2_{di}), Regression coefficient (bi), Stability variance (σ_i^2), Wricke's ecovalence (Wi^2), Si^2=Environmental variance, CV= Coefficient of variation

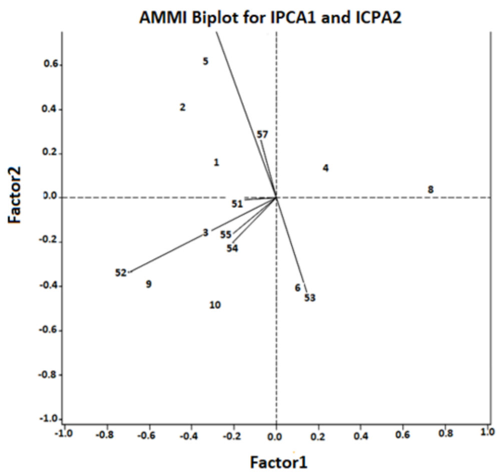

Figure 2. Biplot of the first and second principal components of clones (1-10) and years (51-58)

DISCUSSION

The genetic variation in the plant's genetic resources in a country should be used to develop cultivars adapted to various environmental factors. To achieve this, the use of genotypes and local races as a valuable source of alleles and multi-gene combinations suitable for the particular environments is of the interest of any country (ALLARD, 1996). As seen in this study, the combined analysis of variance, showed the interaction year × clone was significant for all traits. That indicates a difference in response to year variations among poplar clones. DHILLON *et al*., (2010) recorded phenotypic coefficient of variation to be higher than genotypic coefficient of variation in five-year old plantation of poplar clones. In this study, the genetic gain was recorded for wood volume and median diameter (11.44 % and 0.63%, respectively) (Table 4). The result shows the scope for improvement in these traits through breeding programs and selection of clones. Genotypic coefficient of variation for diameter at breast height is higher than that for current annual increment of height, confirming the findings in *P. deltoides* clones recorded subsequently at 5, 6 and 8 years old plantation (NOORI *et al*., 2009). Present study exhibited higher heritability for height (37.53 %) than diameter at breast height (29.55 %) as also recorded by DHILLON *et al*. (2010). RANDALL and COOPER (1973) reported higher heritability for tree height and stem straightness in comparison to other traits in hybrids of poplars.

CHAVAN and KEERTHIKA, (2013) found the PCV (37.18) and GCV (28.89), high heritability value of 0.60 and genetic advance (46.23) for volume index in *Leucaen aleucocephala.* RAMESH (2012) reported genetic gain (30.86%), DBH (18.96), clear bole height (17.19%), angle of branch (17.39), length of branch (19.53) in *P. deltoides* Bartr. SHARMA *et al*. (2011) showed heritability in broad sense for bole straightness (46.36%) and genetic gain of the volume index (67.95%) in tree willow clones, KE-SHENG *et al*. (1996) showed heritability of poplar clones with seven years-old in Shanxi, China for fiber length, fiber width, length, wood specific gravity, tree height and diameter at breast height (DBH) to be 81.9, 73.3, 70.52, 64.3, 68.8 and 70.54%, respectively. PANDEY *et al.* (1993) reported genetic gain for volume (30.86%), DBH (18.96), clear bole height (17.19%), angle of branch (17.39), length of branch (19.53), and in tree height (11.87%). in *P. deltoides*.

Studying and measuring the adaptability and yield stability of cultivars in different environmental conditions is very important in plant breeding programs (COOPER and BYTH, 1996). The diversity of plant species in an environment leads to stability and increases the production capacity of the ecosystem, but it is important that the diversity within species can play an important role in the production of an ecosystem (TILMAN and WEDIN, 1996).

In almost all researches on adaptation of poplar cultivars in Iran have been showed a significant difference between cultivars in studied traits such as diameter, altitude and volume growth (HEMATI and MODIR RAHMATI, 2003; HEMATI *et al*., 2010).

According to the results of cluster analysis in this research, 10 clones were grouped into three clusters. The largest distance was between the first cluster and the third cluster. Cluster analysis is generally used to study the genetic variation of accession in gene banks and to formulate these collections by grouping them through similar traits in common groups, so that the samples of each group can be used as the representatives of the group they belong (FRANCO *et al*., 1997).

The greatest genotypic distance was observed between *P. nigra* 62/154 and *P. nigra* 62/149 (Fig. 4). The smallest distance was between *P. nigra* 69/8 and *P*. nigra 62/149. For the success of breeding programs a breeder needs to know the level of genetic affinity. To determine the genetic differences between the groups, the genotypic distance between them was calculated by Euclidean distance (FARSHADFAR and FARSHADFAR, 2017).

Based on AMMI analysis, the effect of interaction of Year × Clone was significant on the 5% level of probability. The significance of the interaction between the year and the genotype shows that a genotype has not had a similar performance in all years, making it difficult to select the desired genotype and not suggesting any genotype to be used in examined environment (ACIKGOZ *et al*., 2009). GRAFIUS and THOMAS (1971) investigated the interaction between genotype × environment and the evaluation of the yield components. Based on AMMI analysis, the first main component of the interaction was significant at the 5% level. Considering that, only the first principal component of the interaction was significant. So, the best model for this study was IPCA model. Based on the first principal component of the clone 4 and 9, the highest yield stability and clone 7 and 8 with the highest IPCA1 value had the great positive interaction and minimal stability. Clones no. 2, 3, 5 and 6 have a large negative interaction, so they are less stability value. So, it can be stated that the AMMI method is suitable for the stability analysis of the studied clones.

TARAKANOVAS and RUZGAS (2006) introduced AMMI method as an effective method for studying the interaction between genotype and environment, and stated that the results obtained by it can be suitable cultivars for cultivation in different environments or specifies cultivars for cultivation in specific environmental conditions. In general, with regard to stability parameters, the coefficient of environmental variation, Wricke's ecovalence, stability variance, coefficient of determination and regression coefficient, clones 9, 10, and 7 showed the highest stability. Researchers introduced superior genotypes using stability parameters (CHRIS and CLAASSEN, 2012; EBERHART and RUSSEL, 1966; SABAGHNIA *et al*., 2006). The plant breeders are looking for a cultivar that is good not only in terms of these parameters, but also in high performance. The concept of stability in this method is stable rather than dynamic, while in these parameters a poor response rate is given to the environment. HEMATI *et al*. (2010) investigated the stability of 21 closed crown poplar clones in central of Iran that superior clones' *P*. *nigra* 56/72, *P*. *nigra* 72 / 19, *P.nigra* 7/25, *P. nigra betulifolia* were introduced for cultivation. According to the obtained results from the combined analyzes, multiplicative interaction analyzes and stability analysis, it can be stated that the clone *P. nigra* 56/75 and *P. nigra betulifolia* and *P. nigra mehregan* and *P. nigra* 63/135 and *P. nigra* 56/72 are desirable in terms of yield and yield stability and could be introduced for propagation and plantation in the field.

CONCLUSION

Results of this research have suggested that AMMI analysis is a useful method to estimate interaction and stability of poplar clones. The *P. nigra* L. *cl.* 63/135 and *P. nigra* L. *cl.* 69/8 with the highest values of IPCA1 (1.1635 and 0.7405) have a large positive interaction effect, suggesting that they are less stable clones than others. Clones *P. nigra* L. *var. betulifolia* and *P. nigra* L. *cl.* 56.75 have the smallest interaction, according to the first principal components, so they are the most stable in terms of wood production. Combined analysis of variance revealed significant differences for Year × Clone interaction effect for all traits. Based on different stability parameters *P. nigra* L. *var. betulifolia*, *P. nigra* L. *cl. Mehregan,* and *P. nigra* L. *cl.* 63/135 showed the highest stability, but the *Populus nigra 62/154* with 17.91283 m^3/ha produced the greatest amount of wood volume. In this study, the genetic gain was recorded to vary from 11.44 % to 2.79 (for wood volume and Height, respectively). The result shows the scope for improvement in these traits through breeding programs and selection of clones.

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PROMENLJIVOST I ADAPTABILNOST IZABORNIH KLONOVA TOPOLE (*Populus nigra*), ZASNOVANIH NA PARAMETRIMA STABILNOSTI I AMMI MODELU

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Izvod

Topole su jedno od najvažnijih drvnih stabala koja igraju ključnu ulogu u obezbeđivanju sirovina za industriju celuloze. Da bi se proučila genetska raznolikost, selekcija i uvođenje superiornih i kompatibilnih klonova na zapadu Irana, sprovedeno je ovo istraživanje. Eksperiment je postavljen na osnovu randomiziranog kompletnog blok dizajna (RCBD) sa tri ponavljanja u osam godina (2007. do 2014.) u Centru za istraživanje poljoprivrednih i prirodnih resursa u Kermanshahu, Iran. Od svakog klona posađeno je 25 sadnica sa razmakom 3 × 3 metra. Proučene osobine uključuju: prsni prečnik, ukupnu visinu, trenutni godišnji prirast i zapreminu drveta. Rezultati poređenja sredina Duncan-ovim testom pokazali su značajnu razliku između klonova na nivou od 5%. Klon 62/154 imao je najveću visinu, prečnik i zapreminu drveta. Kombinovana analiza varijanse otkrila je značajan efekat interakcije klon x godina za sve osobine sa verovatnoćom od 5%. Na osnovu analize klastera, deset klonova je grupirano u tri klastera. Klonovi 62/149 i 62/154 imali su najveću udaljenost od svih klonova. Na osnovu AMMI modela i ostalih parametara stabilnosti, klonovi *P. nigra 56/75, P. nigra betulifolia, P. nigra mehregan, P. nigra 63/135, P. nigra 56/72* odabrani su kao najproduktivniji klonovi i preporučuje gajenje.

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