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Comparison of Survival and Growth of Different Seed Origins of Eucalyptus camaldulensis in Arid Region of Mehran, Iran

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ABSTRACT

Aims *Eucalyptus camaldulensis* is one of the most productive and best adapted species in the afforestation. The aim of the present study was to investigate the growth and survival rate of *five Eucalyptus camaldulensis* provenances (two from Mazandaran, one from Guilan, one from Ahwaz, and one from Ilam) at the Research Center of Tropical Plants in Mehran, Iran, during 2009-2013.

Materials & Methods The experiment was carried out in Mehran Research Station in Ilam Province with a randomized complete block design and three replications, at 25 plants in each block at a distance of 4×4m. At the end of the growing season, survival, height, circumference at breast height (C.B.H), canopy diameter growth (C.D.G) 147 trees were evaluated.

Findings The result of ANOVA indicated a significant difference between the provenance origins for all traits ($p<0.01$). The survival rate of the studied provenances ranged from 41.7% to 98.3%, whereas Shafarood and Mehran provenances had the highest rate of survival. The mean of annual height growth of five studied provenances varied from 64.57 to 205.29cm. In addition, the characteristics of C.B.H and C.D.G in the selected provenances ranged between 3.60 to 9.44 and 25.51 to 75.26cm, respectively. Among the above mentioned characteristics, Shafarood followed by Ahwaz had the greatest values.

Conclusion The seedlings from the Shafarood origin indicated the highest average in all the studied characteristics. The results provide useful information for choice of *E. camaldulensis* provenances to apply future afforestation in the Mehran region.

Keywords Provenance; Eucalypt; Growth; Dry Regions; Iran

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Introduction

Deforestation and the slow growth of most of the native forest species, combined with the increasing demand for wood and other wood products in Iran highlight the importance of the activities related to afforestation with fast-growing species [1]. In addition, the managers and experts are seeking to increase the success of afforestation, especially in arid and semi-arid regions. In this regard, choice of the right seed source of the species for a given site or region is necessary for achieving maximum productivity both in plantation forestry and agroforestry systems [2]. A large number of studies indicated the relationship between vegetative traits of seeds and seedlings planted in an area by considering the environmental conditions of its origin [3, 4]. Provenance tests are the first steps for future tree improvement programs in order to select the best seedling origins for the related regions [5-7]. The history of adaptive testing of non-indigenous species in the world back to about a century, and most experiments have been carried out on different species of Eucalyptus, which is an Australian native, because the annual volume of Eucalyptus wood produced during (1966-1975) in afforestation 9 times of that of natural forests [7].

Eucalyptus was imported to Iran more than half a century ago and has been planted in the southern regions of this country, and now it covers a vast range of lands in the northern, central, and southern parts of this country [8]. Various species of Eucalyptus were introduced to Iran about 1931 and cultivated in the northern part of this country, but often were destroyed by cold and snow in the years 1948 and 1949 [9, 10]. Among the species planted in Iran, *Eucalyptus camaldulensis* is the most important due to its higher resistance to environmental stress and its rapid growth [11]. In addition, *E. camaldulensis* is considered as one of the most widely distributed tree species for planting in arid and semi-arid lands in tropical and temperate climates, with rainfall from 200mm to 1100mm annually [2]. The success of this species as an exotic is attributed to its superiority to other species in production of wood on infertile and dry sites, its tolerance to drought and high temperature, combined with rapid growth when water is available, deep penetration of roots, tolerance of periodic waterlogging and soil salinity, some degree of frost tolerance, good copping ability, and the usefulness of its wood. Considering all these factors, the evaluation of multiple provenances of this species should be prioritized [3, 10].

Some studies emphasized that seeds and seedlings related to eucalypt species, subspecies and provenances within species may be different based on their germination and growth responses to water stress [12-17]. Results from several trials have shown wide variations among provenances as well as families of *E. camaldulensis* from Australia under a range of geographical locations [18-20]. Moreshet [21] indicated that the Victorian provenance was better adapted to the semi-arid conditions of Southern Occupied Palestine than the Northern Territory provenance. Reddy *et al.* [22] indicated a significant difference in plant height, growth and survival among the four provenances tested. Kumarvelu *et al.* [23] reported better performance of *E. camaldulensis* provenances than *E. tereticornis* in the southern part of India. They found significant differences among provenances of both species. Ginwal *et al.* [2] indicated significant differences between the seed sources at nursery stage for collar diameter and number of leaves. At age 2 years, significant differences between the seed sources were observed for height and field survival. Results indicate that genetic differences exist between the sources of *E. camaldulensis.* None of the traits assessed (viz. height, collar diameter, number of leaves, number of branches, and survival) was found to correlate with any of the geographical coordinates of the site (latitude, longitude, and altitude). Chamshama *et al.* [24] reported significant differences in survival and stem from among provenances. Overall, performance of provenances from northern parts of Australia was found to be superior to those from southern parts and also outside Australia (land races). The study of Mahmood *et al*. [25] indicated significant genetic differences among the seed sources and thus good potential to improve growth of *E. camaldulensis* on marginal soils by selection and breeding.

Due to the success of *E. camaldulensis* species in the southern regions of Ilam Province, some of its cultivars in Iran may be for the development of the Mehran Region more successful and better growth. Thus, the present study aimed to find the most suitable source of *E. camaldulensis* seeds that collected from five areas, to evaluate

the growth of seedlings and determine which locality produced trees of favorable growth and development at the research station of tropical plants in Mehran, Iran.

Materials and Methods

The present study was conducted at the research station of tropical plants in Mehran, Iran, with geographical coordinates of north latitude 46°09'53" and eastern longitude 33°07'20". The station is located in tropical areas of the southern plains of Ilam Province, Iran. Table 1 and Diagram 1 represents meteorological information of the station.

Maximum temperature and relative humidity are regarded as the most important limiting factors in this area. The average long-term annual temperature ranges between 16-46°C and the average annual rainfall is less than 250mm. the average relative humidity, which is less than 50% for about 8 months. The maximum recorded monthly temperature is 38°C and the minimum recorded monthly temperature is 7°C.

This study was based on a research project at the Ilam Agricultural and Natural Resources Research Center, which is a subset of the research project of the Research Institute Forest and Rangeland. Eucalyptus seeds with different source seeds were prepared through this institute. In this study, the one-year-old seedlings of *E. camaldulensis* species were selected from five different origins. Then, 147 trees seedlings were planted at 4×4m spacing in a randomized complete block design with three replications during winter 2009 at Mehran Research Station in Ilam Province (Table 2). Proper irrigation was done in the first year of planting for seedling establishment. The Irrigation was changed according to the degree of air dryness and irrigation was carried out once every seven days in the form of furrow irrigation. Then, Data were collected for the survival rates and vegetative parameters at the end of the growing season during different years. In order to study the soil status of the area, two soil profiles were drilled to different depths of soil, and four soil samples collected from three depths of zero to 30, 30 to 60, and 60 to 90cm soil profile, and finally soil analysis was conducted on these specimens (Table 3). Acidity using a pH meter, soil texture by hydrometric method, soil salinity using electrical conductivity system, organic carbon by the method of burning more, phosphorus absorption by Olsen method and using a spectrophotometer, potassium uptake by ammonium acetate substitution was using a film photometer and organic nitrogen by Kjeldahl method. Before analyzing the data, in order to investigation of the homogeneity and normality of the data, Levene's test and Kolmogorov-Smirnov test were used. The data were analyzed using ANOVA in SAS and the means were compared using Duncan test.

Table 1) The statistics and information related to meteorological station in Mehran during 2004-2014

Index	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
Average temperature (°C)	0.9	27.7	39	36.3	37.2	34.0	26	20.5	13.4	9.9	1.9	16.5
Average maximum temperature (°C)	28.2	35.5	42.5	44.5	45.7	43.1	37.0	27.5	19.9	15.7	17.4	23.4
Average minimum temperature (°C)	13.6	19.9	25.2	28.1	29.0	25.1	20.0	13.2	7.3	3.9	6.8	9.5
Absolute maximum temperature (°C)	39.0	43.8	49.8	52.2	50.4	49.8	45.0	39.2	28.6	25.6	29.8	35.6
Average relative humidity (%)	41	33	21	20	22	24	29	44	53	61	59	44
Average rainfall (mm)	20.4	11.5	0.0	0.0	0.0	8.4	1.1	30.8	23.8	28.2	45.8	19.8
Number of freezing days	0	0	0	0	0	0	0	0	2	7	2	0
Number of sunshine hours	223	214	317	321	316	319	266	211	210	184	172	201
Maximum wind speed ($m\ s^{-1}$)	140	360	340	330	330	360	340	320	360	160	180	260
Evaporation ($mm\ d^{-1}$)	209	344	574	678	660	570	353	188	91	38	58	112

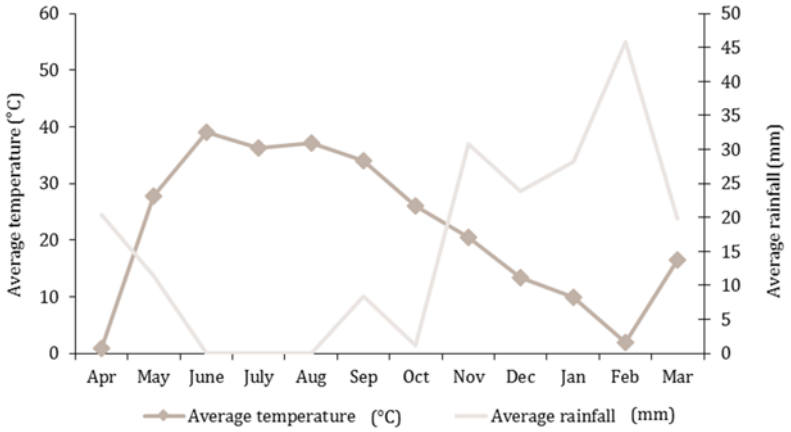


Diagram 1) Ambrothermic curve of Mehran weather station during 2004-2014

Table 2) Regional conditions of Eucalypt seedling origins

Origin	Geographical direction	Latitude	Longitude	Altitude (m)	Mean annual temperature (°C)	Mean annual precipitation (mm)
Shafaroud (Guilan)	North	37 35′26″ N	48°54′42″ E	15	16	1311
Zaghmarz (Mazandaran)	North	36°27′48″ N	52°17′00″ E	71	15.8	853
Chamestan (Mazandaran)	North	36°41′15″ N	53°22′23″ E	20	16.9	566
Ahwaz (Ahwaz)	South	31°18′45″ N	48°41′10″ E	35	24.9	215
Mehran (Ilam)	Southwest	33°07′20″ N	46 09′53″ E	138	22.4	238

Table 3) Some physical and chemical characteristics of the soil in the studied area

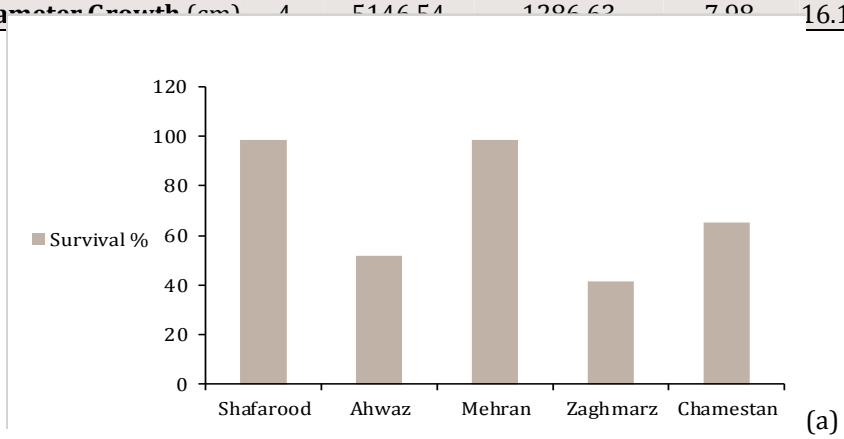
Soil depth (cm)	Soil pH	EC (dSm^{-1})	OC (%)	N total (%)	Sand (%)	Silt (%)	Clay (%)	Soil texture	P ($mg\ kg^{-1}$)	K ($mg\ kg^{-1}$)
0-30	7.02	1.07	0.64	0.05	63	26	11	Sandy loam	6	130
30-60	7.11	1.54	0.29	0.03	63	24	13	Sandy loam	4.2	105
60-90	7.80	1.75	0.097	0.01	73	16	11	Sandy loam	4	100

Findings

Based on the results, a significant difference at the level of 99% was observed in survival, height growth, growth of the circumference at breast height and canopy diameter growth among the five provenances tested (Table 4). Mean comparison results showed that the maximum survival of provenances of Mehran and Shafaroud is 98.3% whilst the minimum survival related to the provenance of Zaghmarz with 41.7%. For the height of the seedlings, the maximum and minimum height belonged to provenance Shafaroud and Chamestan with average values of 205.29 and 64.57cm, respectively, and there was a significant difference with other provenances (Diagram 2). The maximum circumference growth at breast height belongs to provenance *E. camaldulensis* (Shafarood) with 9.44cm and no significant difference was observed with seedling origin of Ahwaz. There weren't statistical differences in circumference at breast height (C.B.H) among provenances of *E. camaldulensis* from Chamestan, Mehran, and Zaghmarz (Diagram 2). Regarding canopy diameter growth, the maximum and minimum amounts belonged to Ahwaz and Chamestan with 72.26 and 25.51cm, respectively, (Diagram 2). By comparing the traits using Duncan's method, data can be classified into three groups according to height growth, two groups based on the growth of the circumference at breast height, and three groups regarding the crown diameter.

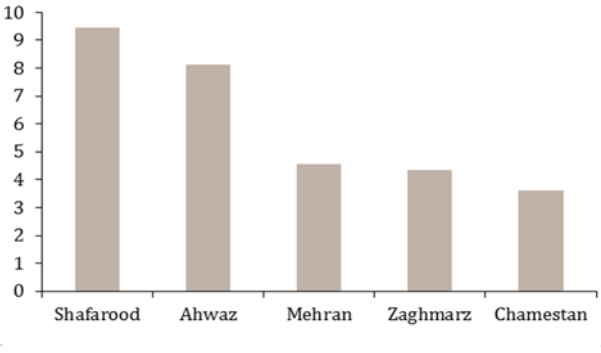
Table 4) Results of ANOVA between traits with seedlings in different origins

Characteristics	DF	Type III SS	Mean Square	Root MSE	CV	F Value	Pr.>F
Survival (%)	4	8293.33	2073.33	3.41	4.81	177.714	<0.0001
Height growth (cm)	4	39799.62	9949.90	16.30	13.23	37.44	<0.0001
Circumference Growth (cm)	4	80.88	20.22	1.06	17.63	17.97	0.0001
Canopy diameter Growth (cm)	4	5146.54	1286.63	7.98	16.13	20.21	<0.0001

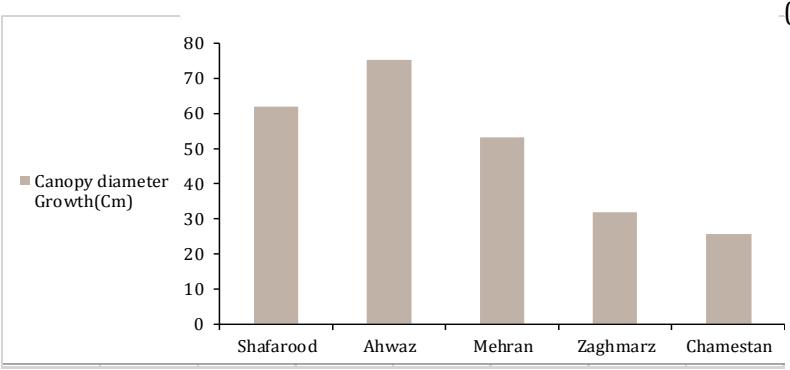


(a)

(b)



(c)



(d)

Diagram 2) Comparison of the mean of measured of seedling traits among different seed origins; Survival (a); Height (b); Circumference at breast height (c); Canopy diameter growth (d)

Discussion and Conclusion

The seeds of forest species that are gathered from different conditions due to different growing conditions may have different responses to germination, growth, and exposure to stress. Some studies indicated the difference

among the provenances based on some habitat features such as latitude and longitude, altitude, slope direction, and soil characteristics [26-28]. Since growth and survival are the most important indicators of judgment in the adaptation of non-native species [29], in the present study, the results of survival, diameter growth, and height indices were considered as the most important indices to be considered in adaptation of Eucalyptus provenances [30]. The results of the current study, as reported in other researches [2, 19-23], indicated that the selection of source for seed or seedlings can be effective in better growth of seedlings. The percentage of seedling survival was the highest in provenances of Shafaroud and Mehran but the other features studied in Mehran's provence were not in a good position compared to other provenances. Comparison of vegetative traits of seedlings including mean annual height growth, growth of the circumference at breast height and canopy diameter growth among different provenances showed that provenances of Shafarood and Ahwaz in Mehran region conditions had the highest growth rate. Three provenances of Shafarood, Chamestan, and Zaghmarz in the northern profile in terms of latitude are approximately in the same range, but provenance of Shafarood has a significant difference in terms of growth and survival compared to two other provenances. These results may be attributed to differences in climatic conditions between the three provenances tested. The origin of Shafarood seeds is in better condition in terms of moisture and rainfall. In addition, it is worth noting that the survival of more seedlings is a sign of greater compatibility with environmental conditions. Based on Goodarzi and Ahmadloo study [11] and Rostamikia and Sardabi [30], the seedlings of Eucalyptus seed with different origins showed that survival and vegetative traits at different origins were different due to different climatic, native trees, and altitude.

The elevation of the source of seed in the present study is considered as one of the important factors affecting germination, survival, and growth rate [31]. The highest survival rate and vegetative traits occurred in provence Shafaroud with the lowest altitude. Cecil and Fare [32], in their study on various provenances such as *Quercus phellos* and *Quercus shumardii*, found that the seedlings from the seeds collected from low altitude or warmer areas have more growth than those collected from high altitudes or colder regions. In another study, the mean height and diameter of the seedlings were significantly different among provenances although a negative and positive correlation was observed with latitude, and the average summer temperature of seed source, respectively [33]. Pounders and Fare [32] showed that the seeds of warmer regions have more growth (lower altitude) than the colder regions. This may be due to the longer growth period of lower altitudes than high altitude, which affected the growth characteristics of seedlings [34].

In the present study, the results suggest that *E. camaldulensis* has a high tolerance to both drought and heat. This tolerance varies significantly with provenance when grown in the tropical areas of the southern plains of Ilam Province indicating the importance of choosing correct provenances. Of the five provenances of *Eucalyptus camaldulensis* tested, the provenance of Shafaroud is the most suitable for the region and planting it in poor and low-yield areas like Mehran in the form of wood farming can help the country greatly by increasing the production of wood for the paper and particleboard industries on the one hand and increasing employment, income of residents and economic growth on the other.

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