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Effects of different rainwater harvesting methods on the growth rate of *Pistacia atlantica* under rigid environmental conditions

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Abstract

Applying rainwater harvesting methods is very important in arid and semi-arid regions because of rigid environmental conditions and growth limiting factors such as low rainfall and its irregular distribution, high evapotranspiration, long dry season, wide range of temperature changes along the year and sever wind. In this research, effects of different rainwater harvesting methods on the growth rate of *Pistacia atlantica* under rigid environmental conditions were studied. Study area was steep lands of forest park of Laleh in north east of Tabriz city. Experimental design was Latin Square. Treatments were four water harvesting methods (crescent-shaped banquette, contour farrow, crescent-shaped banquette + soil surface plastic cover and contour farrow + soil surface plastic cover). Seedling height and diameter were annually measured from 2001 to 2003. Height and diameter growth of the seedlings were calculated for each year. Data statistical analysis did not indicate significant differences between four water harvesting methods in terms of average height growth and also average diameter growth. The range of average annual height and diameter growth in different studied water harvesting methods were 4.4 to 9.5 cm and 1 to 1.7 mm, respectively. Because of non-significant differences between four water harvesting methods in terms of height and diameter growth rate and simple and low cost of construction, contour farrow method without using any plastic cover is recommended for developing of forest parks by planting *Pistacia atlantica*.

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Introduction

The genus *Pistacia* includes many species widely distributed in the Mediterranean and Middle Eastern areas (Ben Douissa *et al.*, 2005). One of the most widely distributed species of Pistacia is *Pistacia atlantica* which is called "Baneh" in Iran. It is the most economically important tree species in many rural areas. The resin of wild pistachio, called Saqez, is used for a variety of industrial and traditional uses, including food and medicine (Pourreza *et al.*, 2008). The fruit of wild pistachio is used by natives as flavor in food after grinding it and it is used for its oil, although the fruit is small and not commercially valuable (Saber-Tehrani *et al.*, 2009). Adaptation of Pistacia trees to harsh desert conditions and their longevity make them ideal candidates for reforestation in arid zones (Golan-Goldhirsh *et al.*, 2004). *P. atlantica* is a semi-evergreen tree that grows to 60 ft tall. It is able to tolerate most soil conditions includining alkaline and will survive with no irrigation. It is also able to withstand desert heat and winds (Onay, 2000; Karimi *et al.*, 2009). Different species of Pistacia, especially *Pistacia atlantica*, as a result of their vigorous root growing ability can adopt with difficult environmental conditions (Vargas *et al.*, 1998; Jazirei and Ebrahimi Rastaghi, 2003). *Pistacia atlantica* is a multipurpose tree that valued as fuel, fruit and therapy properties. It is valuable in soil conservation (Rahemi and Baninasab, 2001) and so suitable for plantation in dry lands (Jazirei, 2001). Barzegar Ghazi*et al.* (2001) found this species have most survival and highest growth in comparison with other trees in semi-arid environment. Because of high resistance of *pistacia atlantica* for unsuitable environmental conditions, dry farming of this species using different rainwater harvesting method can be very important. Rainwater collection has been used for four thousand years. It has been started in bronze age. In this age nomads were collecting rainwater by smoothing hills and carrying the water to the fields (kardavani, 1988). Water harvesting is an ancient technique of developing water resources to augment the quantity and quality of existing watersupplies in rural and urban areas where other sources are not available or too costly.(Brooks *et al.*, 2013). Hira*et al.*(1990) increased survival, height, diameter and biomass of seedlings several times by putting a plastic sheet around the seedlings in microcatchment systems. Swatantra (1994) used semicircular grooves for collection of rainwater and planted the seedlings in the middle of the grooves. This technique increased the growth rate and survival of the seedlings. The aim of this study was to investigate the growth rate of *Pistacia atlantica* using four rainwater harvesting methods in order to develope forest parks having rigid environmental conditions by planting of this species.

Material and methods

Study area

Study area is located in steep lands of forest park of Laleh in the east of Tabriz cityin East Azarbaijan province of Iran (Fig. 1). It is situated between longitude of 46° 27′ 26″ to 46° 27′ 30″ E and latitude of 38° 3′ 21″ to 38° 3′ 28″ N. Maximum and minimum elevation in the study area are 1789 and 1765 meters above the sea level respectively. This park was constructed near Arpadarasi spring in order to develop and increase green spaces of Tabriz city and conserve native plant species.

The area has beautiful landscape because of native forest trees and range plants on attractive cliffs. Mean annual rainfall of the study area is 267.4 mm based on Khalat Pooshan climatologic station data (nearest station to the study area). Precipitation in summer is less than other seasons. The highest and lowest rainfall occurs in May and September respectively. The mean annual temperature is 10.13 ˚C. The soil depth is moderate to high and organic matter is less than 1%. The soil of the area is young because of specific topographic and climatic condition and parent rock. Based on laboratory analysis and field works the soil texture is sandy loam to loam. The soil is Calcareous and pH is 8.1-8.3. The soil EC is less than 1 ds/m.

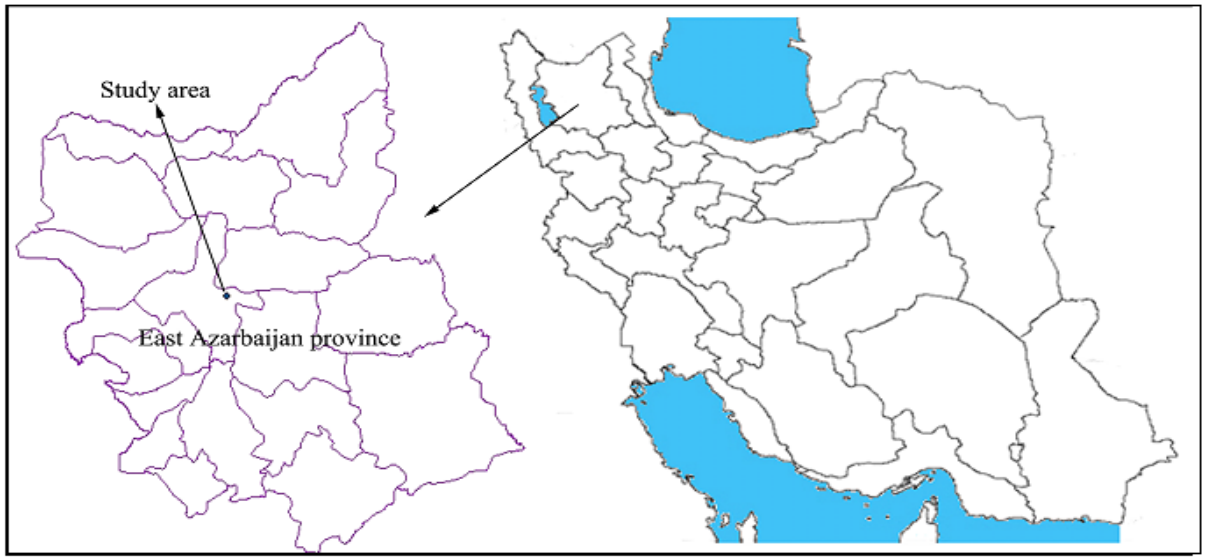

Fig. 1. Location of the study area in East Azarbaijan province of Iran.

Methods

The experimental design was Latin square with four replications. Treatments were four water harvesting methods (crescent-shaped banquette, contour furrow, crescent-shaped banquette + soil surface plastic cover and contour furrow + soil surface plastic cover). For construction of contour furrows and crescent shaped banquettes contour lines were determined by using mapping camera. The distance between contour lines and also seedlings on the contour lines was considered 4.5 m. The radius of crescent shaped banquettes was 2.25 m and the width of contour furrows was 70 cm. Contour furrows and crescent shaped banquettes were constructed based on planting map. Diameter and depth of planting holes were 60 cm and 70 cm respectively. The size of the plastic cover in relevant treatments was 80 * 80 cm. Seedlings were planted in March 12, 2001. Seedlings height and diameter were annually measured from 2001 to 2003. Height and diameter growth of the seedlings were calculated for each year. Finally average absolute and relative height and diameter growth were also calculated. Data analysis was done using SPSS Version 22 software. Duncan's Test was used for comparison of treatments means.

Results and discussion

Data analysis indicated that there are no significant differences between different rainwater harvesting methods in terms of average absolute and relative growth rate of both height and diameter (Table 1, 2, 3 and 4).

Table 1. Analysis of Variance (ANOVA) for average absolute growth of height.

Source	df	Sum of squares	Mean square	F	Sig.
treatment	3	27.389	9.130	.376	.774
replication	3	3.648	1.216	.050	.984
column	3	76.495	25.498	1.049	.437
error	6	145.781	24.297	-	-
CV (%)		56.66			

Table 2. Analysis of Variance (ANOVA) for average relative growth of height.

Source	df	Sum of squares	Mean square	F	Sig.
treatment	3	1787.382	595.794	.778	.548
replication	3	370.819	123.606	.161	.918
column	3	3984.992	1328.331	1.735	.259
error	6	4593.330	765.555		
CV (%)		31.98			

This result is in agreement with the findings of Barzgar Ghazy *et al.* (2003). They assessed adaptation of some tree species at rainfed condition in southern slopes of Oen-ebnali mountain and reported that there were not significant differences between five water harvesting methods in terms of relative growth rates of height.

Table 3. Analysis of Variance (ANOVA) for average absolute growth of diameter.

Source	df	Sum of squares	Mean square	F	Sig.
treatment	3	.334	.111	.438	.734
replication	3	2.228	.743	2.922	.122
column	3	.073	.024	.096	.959
error	6	1.525	.254		
CV (%)		59.32			

Table 4. Analysis of Variance (ANOVA) for average relative growth of diameter.

Source	df	Sum of squares	Mean square	F	Sig.
treatment	3	169.153	56.384	1.413	.328
replication	3	333.284	111.095	2.783	.132
column	3	65.346	21.782	.546	.669
error	6	239.476	39.913		
CV (%)		42.77			

Table 5 shows the comparison of treatment means based on Duncan's Test. As can be seen four water harvesting methods are in one group as "a". The maximum absolute growth of height with 12 cm/year belongs to crescent-shaped banquette. The highest absolute growth of diameter with 3.26 mm/year was observed in contour furrow+plastic cover treatment. Mean annual height and diameter growth of the seedlings were 7.7 cm and 0.9 mm respectively that indicate successful growth of *Pistacia atlantica* in unsuitable environmental conditions. It should be noted that established seedlings were very healthy during the experiment. This result is also in agreement with the findings of Barzgar Ghazy *et al.* (2003).

Table 5. Comparison of treatment means based on Duncan's Test.

Treatment	Average absolute growth of height (cm/year)	Average Relative growth of height (%)	Average absolute growth of diameter (mm/year)	Average relative growth of diameter (%)
Crescent-shaped banquette	6.02 a	33.04 a	0.7 a	9.7 a
Contour forrow	7.03 a	34.13 a	0.79 a	10.55 a
Contour forrow +plastic cover	8.37 a	52.75 a	1.02 a	14.83 a
Crescent-shapedbanquette+plstic cover	9.47 a	56.36 a	1.03 a	17.71 a

They reported that survival percentage of studied tree species were extremely high. They noted that the reasons for this success were selection of suitable species having resistance to unsuitable climatic and soil conditions and using crescent-shaped banquette and plastic mulch. Gielen (1990) and Gupta and

Mohan (1991) also increased growth rate and survival percentage by constructing microcatchments around the seedlings.

Conclusion

In this study, there were not significant differences between four water harvesting methods in terms of height and diameter growth rate therefore, contour furrow method without using any plastic cover is recommended for developing of forest parks by planting *Pistacia atlantica* because of low cost and simple construction.

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