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Carbon Sequestration in the Leaf, Litter and Soil of *Eucalyptus camaldulensis, Prosopis juliflora* and *Ziziphus spina-christi* Species

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ABSTRACT Carbon sequestration in soil, leaf and litter of three tree species, viz. *Eucalyptus camaldulensis*, *Prosopis juliflora* and *Ziziphus spina-christi*, plantation was investigated in the Dehloran city, Iran. Results showed that the amount of sequestered C in leaf, litter and soil was significantly different among these species. The highest amount of sequestrated C was in leaf and the lowest amount in the soil. The results of this study would be useful for selection of appropriate species to develop green space and forest parks. Forest plantation of these areas would capture significant amounts of atmospheric C, and would be expected to contribute to soil quality and conservation.

Key words: *Forest Park, Atmospheric carbon, Dehloran, Forest plantation*

1 INTRODUCTION

Global warming is an important issue and caused by increasing carbon dioxide mostly due to human activity (Korner, 2003; Lal, 2004; Nobakht *et al.*, 2011). Forests are the simple solution to reduce atmospheric carbon dioxide (Kaul *et al*., 2010; Tamartash *et al*., 2012; Ariapak *et al*., 2013) as compared to the artificial C sequestration methods with a relatively high cost such as filtering (Cannell, 2003). Both of the natural and artificial forests potentially able to absorb and store C dioxide from the atmosphere (Kaul *et al*., 2010). Forests cover about 4 billion hectares (Dixon and Wisniewski, 1995) and play an important role in C sequestration. Then, forest management, plantation and plant species are among affecting factors that influence C sequestration (Lal, 2005). There are different forest ecosystem distributed all over the world between humid to arid lands. Also, researchs have shown that afforestation in arid regions are important for C sequestration (Grunzweig *et al*., 2007; Suganuma *et al*., 2012). Moreover, some studies have evaluated the effect of tree species on C sequestration (Kirby and Potvin, 2007; Kaul *et al*., 2010).

Kirby and Potvin (2007) belived that preventing forest conversion to pasture had a great impact on C stock, while Lal (2005) reported that plantation, especially in arid and semi-arid regions, was an effective way to reduce C dioxide from atmosphere. Forest plantations provide many critical services such

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as C sequestration, create green space, produce timber and other forest function (Paul *et al*., 2002; Zarinkafsh, 2002; Updegraff *et al*. 2004; Panahi *et al.*, 2011; Wang *et al.*, 2013).

Besides different forests ecosystems and tree species, there are other factors affecting C sequestration, such as microbial activity (Hu *et al.*, 2014; Srivastava *et al.*, 2014), soil erosion and parent material (Shi *et al.*, 2009), soil compaction (Saeedifar and Asgari, 2014), and deforestation (Kooch *et al.*, 2014).

As tree species can differntially affect the soil C pool, we examined the effect of *Eucalyptus camaldulensis*, *Prosopis juliflora* and *Ziziphus spina-christi* on C sequestration in this study. These species are highly used in plantation all over the world and also in Iran, particularly in arid and semi arid regions. There are some reports about the importance of *Eucalyptus* (Zhang *et al.*, 2012) and *P. juliflora* (Bhalla and Gupta, 2013) plantation in C sequestration. Based on our literature review, there was no research about the importance of *Z. spina-christi* in C sequestration. Plantations with these species are important not only for forest restoration in arid and semiarid regions but also for C sequestration (Bhalla and Gupta, 2013). Hence, understanding the potential of these species in C accumulation would help us to understand the role of each species in C sequestration.

Although the effect of some species on C sequestration has been studied in many different parts of the world (Kirby and Potvin, 2007; Kaul *et al*., 2010), there are little information about (1) the differences among soil, leaf and litter in C sequestration, (2) the ability of *E. camaldulensis, P. juliflora* and *Z. spina-christi* species in C sequestration in arid and semi-arid areas. So, the aim of this research was to compare the effects of leaves, litter and soil of these three species on C sequestration, and also determination of the best component for C sequestration in forest ecosystems. We hypothesized that *P. juliflora* had more carbon sequestered than the other two species.

2 MATERIALS AND METHODS

2.1 Study site

The study was carried out at the Abgarm Forest Park of Dehloran city in the western province of Ilam (32° 41' 18.5" to 32° 43' 20" N and 47° 19' 0.1" to 47° 16' 14.7" E (Figure 1). Established by the Natural Resource's Bureau in 1996, this park is about 476 ha and was planted at the same time with *E. camaldulensis*, *P. juliflora* and *Z. spina-christi* 5, meters apart from each other in about 40 ha. This region is characterized by scanty annual rainfall (320 mm) and arid climate. The average maximum and minimum temperature is 28°C and 0.6°C, respectively.

In this plantation, *E. camaldulensis* is taller, while the diameter of *Z. spina-christi* is more than the other two species. Furthermore, the percentage of canopy of *P. juliflora* species is more than the other species (Table 1).

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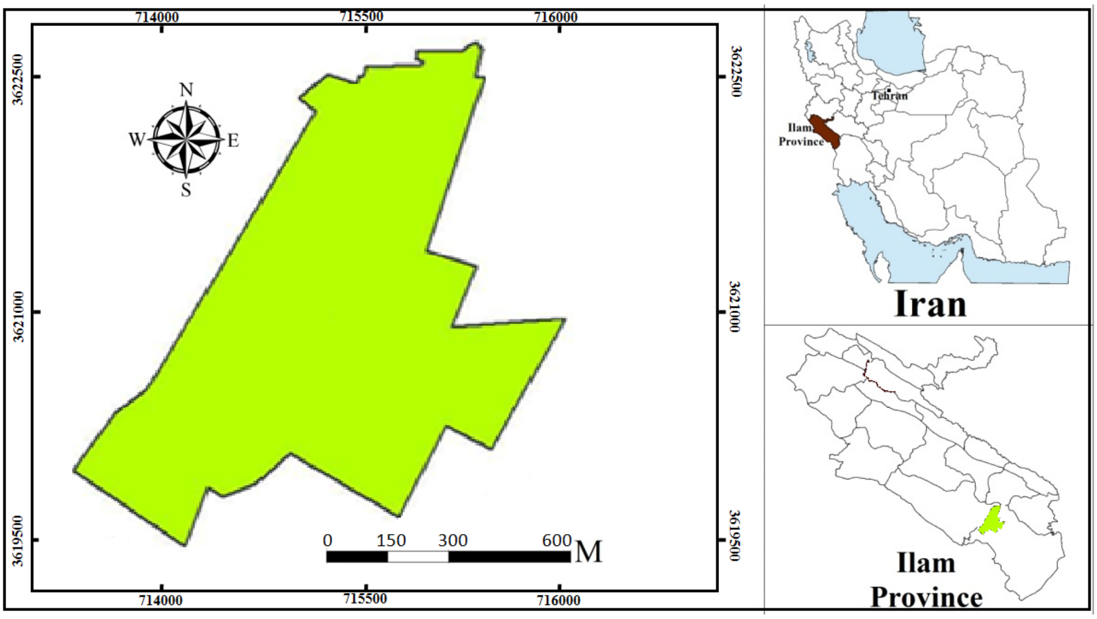

Figure 1 Location of the study area in the Ilam province and Iran

Table 1 Morphological characteristics (diameter at breast height- DBH, tree height, and percentage of canopy cover) of the three species in the Abgarm Forest Park

Plantation type	Crown Canopy (%)	DBH (cm)	Height (m)
E. camaldulensis	23.32 ± 13.66	9.51 ± 3.51	6.22 ± 2.14
P. juliflora	37.5 ± 6.57	5.59 ± 2.66	3.36 ± 1.7
Z. spina-christi	18.22 ± 12.91	10.83 ± 1.92	4.37 ± 0.9

2.2 Sampling Method

At least 10 sample plots (10 m × 10 m) were randomly taken from each stand. Plots were selected from different regions (*E. camaldulensis, P. juliflora* and *Z. spina-christi*. The frequencies of trees and shrub species were recorded in each sampling plot. Also, the percentage of the diameter, the height, and canopy cover for every species were accurately measured. Soil samples were taken in the center of each plot at depth of 0-20 cm, under the crown projection and outside it. Furthermore, in each sample plot, the leaves and litter were collected and saved in plastic bags.

2.3 Litter, leaf and soil analysis

Litter and leaf were collected, dried through the ignition method in an electric furnace, and milled to prepare samples for determination of C sequestration. After weighing, samples were heated to 500 – 600 ºC for 3 to 4 hours in an electric furnace (model F69). By subtracting the ash weight from the initial sample weight, the organic C in leaf and litter samples were calculated separately (Varamesh *et al.*, 2010). The Walkley-Black method was used to determine the organic carbon (Ardakani *et al.*, 2008).

2.4 Statistical analysis

Prior to any test, all data were subjected to the Kolmogorov–Smirnov test to check their normal distribution. After that, they were subjected to one-way ANOVA and Duncan's test was used when significant differences were evident. Furthermore, T-test analysis used to compare C sequestration between the soil, leaf and litter of *Z. spina-christi*.

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3 RESULTS

The results indicated significant differences (P<0.05) in C stock among leaf, litter and soil for the three tree species, and the leaves had the highest C stock, followed by litter and soil in all the three species (Figures 2, 3, 4).

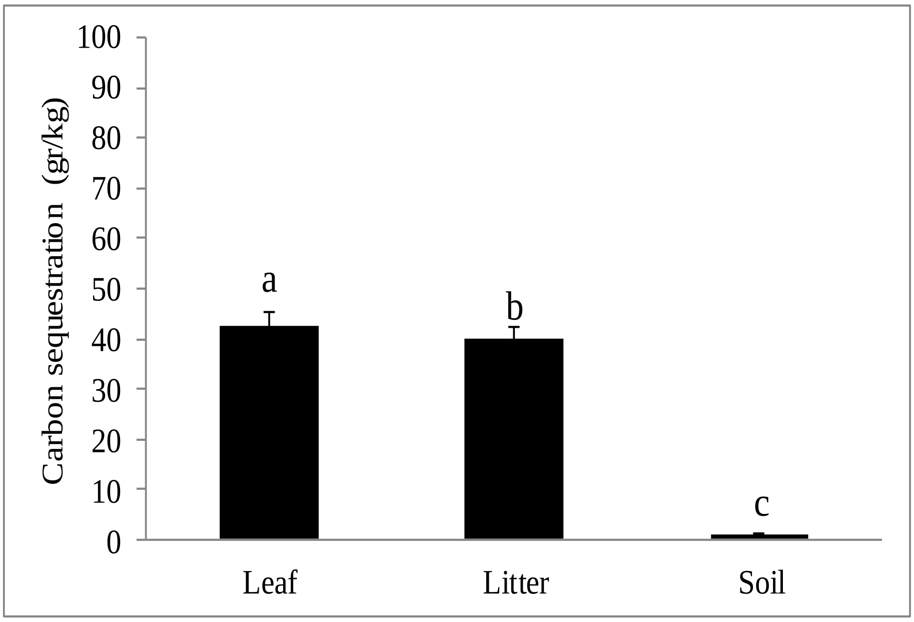

Figure 2 Mean (±SE) of C sequestration in leaf, litter and soil of *E. camaldulensis* plantation

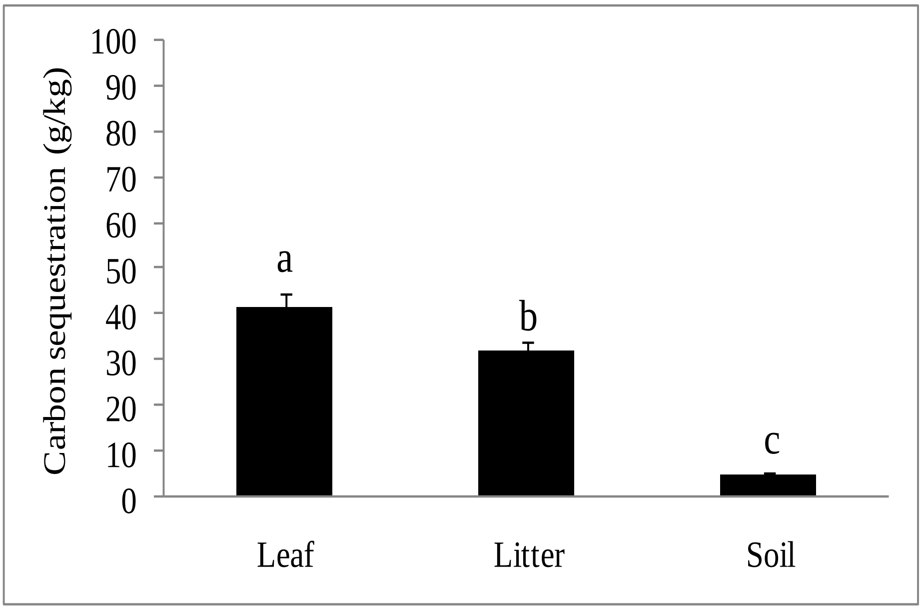

Figure 3 Mean (±SE) of C sequestration in leaf, litter and soil of *P. juliflora* plantation

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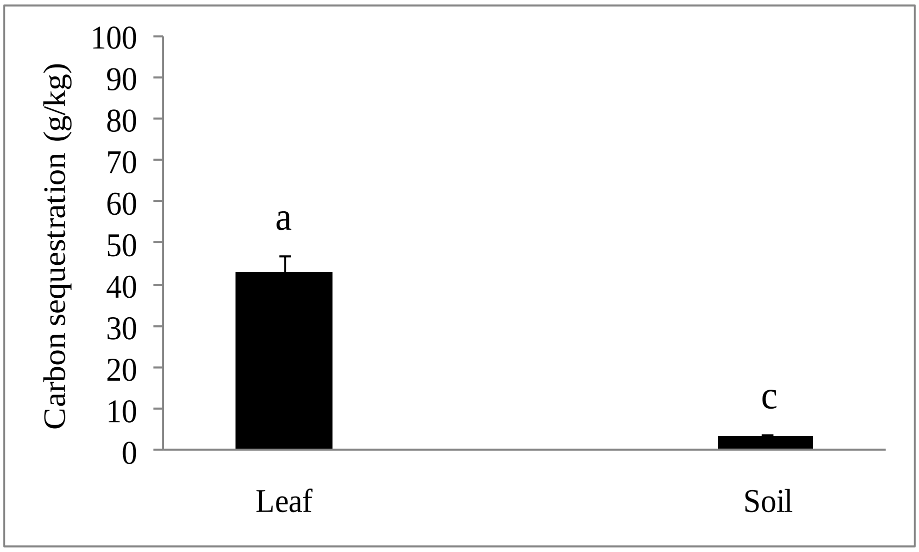

Figure 4 Mean (±SE) of C sequestration in leaf and soil of *Z. spina-christi* plantation

3.1 Carbon sequestration in the litter

Since *Z. spina-christi* had no litter, data analysis only performed for *E. camaldulensis* and *P. juliflora.* Data analysis showed significant difference ($p < 0.05$, $t = 6.28$) between *E. camaldulensis* and *P. juliflora* for litter C sequestration. So that, C sequestration in the litter of *E. Camaldulensis* (41.5 g/kg) were more than *P. Juliflora* (31.8 g/kg) (Figure 5).

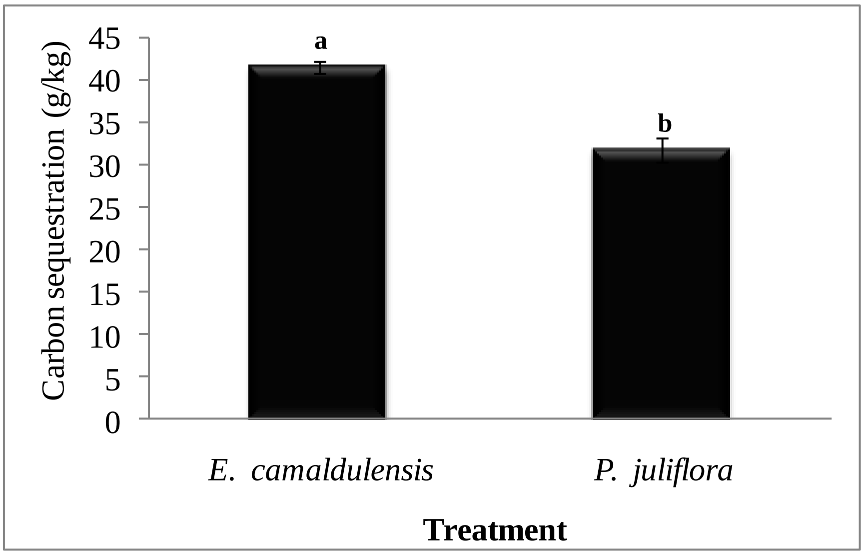

Figure 5 Mean (±SE) of C sequestration in the litter for the three tree species plantation

3.2 Carbon sequestration in the leaf

The ANOVA revealed significant difference in the amount of C sequestration among the leaves of the three species ($p < 0.01$ and $F=45.7$), the highest of which was in *Z. spina-christi*, followed by *E. camaldulensis* (Figure 6).

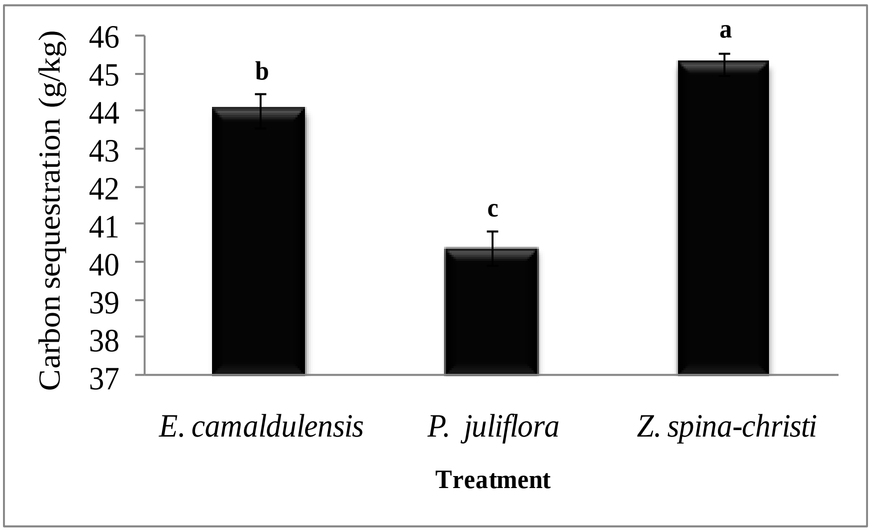

Figure 6 Mean (±SE) of C sequestration in the leaf of the three tree species plantations

3.3 Soil Carbon sequestration

Analysis revealed that soil carbon stock in the stands for *P. juliflora* (31.8%) was significantly higher ($p< 0.05$) than that for *E. camaldulensis* (41.5%) (Figure 7).

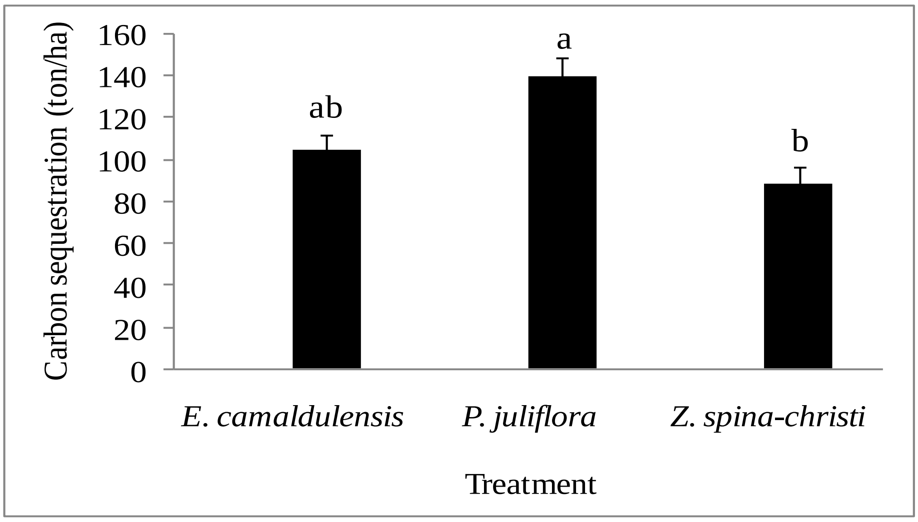

Figure 7 Mean (±SE) of C sequestration in the soil of the three tree species plantations

4 DISCUSSION

Climate change in recent years, as the result of greenhouse gasses, has greatly impacted C in the ecosystems, particularly in arid and semi-arid regions. Sequestartion of C through vast green covers seems to be an ideal solution for reducing the atmospheric C (Suganuma *et al*., 2012). Because C sequestartion in plants by photosyntesis is the simplest and economical way for atmospheric C reduction.

Results of the current study indicated that the different species had different effects on the amount of C sequestration. *P. juliflora* had a higher level of C sequestration potential in the soil than *Z. spina-christi* and *E. camaldulensis*. Besides the nitrogen fixing ability of some species (Paul *et al.*, 2002) and species effects on C sequestration (Bordbar and Mortazavi Jahromi, 2007), another possible reason for this result might be due to the canopy density, as *P. juliflora* had the highest canopy density among the three species. Moreover, accumulation and gradual decomposition rate of litters might be another reason (Varamesh *et al*., 2010). According to Kraenzel *et al.* (2003), the C sequestration rate of the compartment soil, biomass and litter had different rates, and the wood biomass had the greatest potential for C sequestration. However, the C sequestration in the litter of *E. camaldulensis* was significantly higher than *P. juliflora*, which was consistent with the findings of other studies (Bordbar and Mortazavi Jahromi, 2007; Qorbali *et al.*, 2014). Further, the leaves of *Z. spina-christi* and *P. juliflora* had, respectively, the highest and the lowest amount of C sequestration. It simply indicates the importance of *Z. spina-christi*, as an indigenous species, in C sequestration as compared to the other two non-native species. Since C sequestrationis is one of the criteria of ecosystem sustainability, the determination of plant species with high C sequestration capacity and also study of management factors affecting C sequestration could be a good help for land revival (Varamesh *et al*., 2010).

Similar to other works, our result also indicated leaf biomass had the highest portion of total sequestered C. Probably for the very same reason; most of carbon sequestration estimation methods are based on leaf biomass calculation (Honda *et al*., 2000). On the other hand, biomass estimation is the basis for economical carbon evaluation (McDicken, 1997). Considering the fact that soil and litter carbon are derived from the tree covers, it is necessary to study C sequestration in trees (Varamesh *et al*., 2010).

In our study, like another one by Varamesh (2009), there was a significant difference between plantation and barren land in C stock content, which indicated the importance of plantations in C sequestration. Different studies demonstrated that species, growth speed, site productivity, silviculture operation, tree density and diversity could have significant effects on C stock (Mortenson and Schuman, 2002; Bordbar and Mortazavi Jahromi. 2007; Mahmoudi Taleghani *et al.*, 2008; Qorbali *et al.*, 2014). Therefore, the differences between C stocks in studied species could be because of speed growth rate and kind of species.
Furthermore, our result indicated that each part of tree species had different capacity in C sequestration. For instance, *Z. spina-christi* had higher C in its leaf compared to the other species, while, *P. juliflora* and *E. camaldulensis* had higher carbon sequestration in soil and litter, respectively.

5 CONCLUSION

The present study illustrated that the possibility of expanding C storage with forest plantation as an effective alternative to mitigate climate change by sequestering atmospheric carbon dioxide. Trees can accumulate a large amount of carbon from the atmosphere and play an important role for sequestering carbon in the regional, national and world scale. Therefore, selection of appropriate species based on condition of each region to increase the C sequestration potential should be carried out.

6 ACKNOWLEDGEMENT

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ترسیب کربن در برگ، لاشبرگ و خاک گونه‌های اکالیپتوس، کهور و کنار

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چکیده: ترسیب کربن خاک، برگ و هم‌چنین لاشبرگ گونه‌های اکالیپتوس، کهور و کنار در شهر دهلران بررسی شد. نتایج نشان داد که مقدار ترسیب کربن در برگ، لاشبرگ و خاک به‌طور معنی‌داری در بین سه گونه متفاوت است. بیش-ترین مقدار ترسیب کربن در برگ و کم‌ترین مقدار آن آن در خاک مشاهده شد. نتایج این پژوهش می‌تواند در انتخاب گونه مناسب جهت توسعه فضای سبز و پارک‌های جنگلی موثر باشد. بنابراین توسعه جنگل‌کاری با این گونه‌ها می‌تواند به طور معنی‌داری باعث افزایش جذب دی اسید کربن شود و هم‌چنین می‌تواند نقش مهمی در حفاظت و کیفیت خاک داشته باشد.

کلمات کلیدی: پارک جنگلی، جنگل‌کاری، دهلران، کربن هوا

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