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Effects of electrical conductivity, acidity, and organic matter on carbon sequestration ability of soils beneath *Amygdalus scoparia* and *Ephedra procera*

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Abstract: [Objective] Carbon sequestration in plants and soils plays a crucial role in the carbon cycle, contributing to the reduction of carbon dioxide levels and enhancing soil productivity. Identifying plant species with high carbon sequestration potential is essential for the restoration and maintenance of rangelands. [Methods] This study examined carbon sequestration in various plant organs—roots, stems, and leaves—of two plant species: wild almond (*Amygdalus scoparia*) and Ephedra (*Ephedra procera*). In addition, soil characteristics and carbon sequestration levels were assessed by collecting soil samples from depths of 0–15 cm and 15–30 cm, both at the base of plants and in the inter-plant spaces. In this study, the first experiment comprised two factors: plant species (*A. scoparia* and *E. procera*) and plant organs (leaves, stems, and roots). The second experiment also had two factors. The first factor was three types of soil masses (collected at the bases of *A. scoparia*, *E. procera*, and the control), and the second factor was soil sampling depth (0–15 cm and 15–30 cm). The study was conducted in the Dolatabad region of Fars Province, Iran. [Results] Soil beneath *A. scoparia* had higher levels of organic carbon, organic matter, and carbon sequestration than *E. procera* and control soils. Furthermore, the 0–15 cm depth showed greater levels of these factors than the 15–30 cm depth. As soil depth increased, organic carbon, organic matter, and carbon sequestration decreased, while soil acidity increased. However, soil moisture content did not significantly vary between the two depths. Soil type and depth had significant effects on electrical conductivity. The control soil exhibited a significantly higher electrical conductivity than *E. procera* and *A. scoparia* soils. Additionally, average values indicated that electrical conductivity was significantly greater at the soil surface. Notably, both depths of the control soil showed the highest conductivity among all treatments, with the control differing significantly from the other groups. High electrical conductivity in the soil may indicate high salinity levels. Soils beneath *A. scoparia* and *E. procera* showed significant differences in clay content between the two soil depths, with the 0–15 cm depth exhibiting the highest clay content among all

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Funded: Estimation of Carbon Sequestration in Almond (*Amygdalus scoparia*) and Ephedra (*Ephedra procera*) in Dolat Abad, Noorabad, Fars Province

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treatments. [**Conclusions**] *A. scoparia* is found to store significantly higher amounts of organic carbon and organic matter in its tissues than *E. procera*. The cultivation of *A. scoparia* is highly feasible due to its high tolerance to drought, whereas other water-dependent species may require extensive management if cultivated in vast areas of rangelands. Organic carbon plays a more significant role than organic matter in determining the extent of carbon sequestration in the soil. Soil texture, particularly clay content, emerges as one of the most influential factors in carbon sequestration.

Keywords: carbon sequestration; organic carbon; soil texture; environmental management

The genus *Ephedra* is from the Ephedraceae family. Ephedra are dioecious plants with green stems and small leaves that are scaly. They are mostly dispersed in areas with sand or sandy loam soil with pebbles, and they can be naturally found in dry or semi-arid climates where hot summers and cold winters occur^[1]. The presence of Ephedra (*Ephedra procera*) on sand dunes can contribute to their stability and permanence. Furthermore, when present in riverbeds, the accumulation of large amounts of sediments can occur at the base of the Ephedra plant, and therefore the displacement of sediments along with soil erosion is somewhat lessened.

Wild almond (*Amygdalus scoparia*) belongs to the Rosaceae family, the genus *Amygdalus*. Specifically, the genus is comprised of 40 species worldwide. The wild almond is one of the most resistant tree species that can withstand extreme heat and cold. It can tolerate stone-bedded soils or hard ground in general. Furthermore, its strong root system can tolerate active forms of CaCO_3 . Its resistance to drought can make each tree live longer under adverse conditions, and ultimately it can have a large share in controlling soil erosion. One of the most important terrestrial ecosystems that can contribute to carbon sequestration is rangelands. Although the amount of carbon sequestration per unit of area is not significant in rangelands, their vast range compensates for the low density of vegetation and can therefore be a promising ecosystem for the practice of carbon sequestration^[2]. Rangelands comprise almost half of the planet's terrestrial areas, and their carbon storage constitutes 10% of the total carbon biomass and 30% of the total organic carbon in terrestrial ecosystems. On a global scale, rangelands are responsible for 5×10^{11} t of carbon sequestration each year^[3].

Organic matter is a primary indicator of soil quality which is considered quantitatively in connection to agricultural practices and environmental sciences. The amount of organic matter in soils has generally declined in response to climate change^[4]. The practice of carbon sequestration by plants and shrubs is one of the simplest and cheapest methods for reducing atmospheric carbon. Plant organs contribute to carbon sequestration by means of photosynthesis^[5]. Various plant species and the tolerance of species to dry climates can diversify the roles of plants and their different organs into carbon sequestration^[6-7]. Furthermore, the dominant plant species in each region primarily performs carbon sequestration due to the primacy of its canopy cover^[8]. The degree to which carbon sequestration occurs in each region depends on the types of plant species, the methods of rangeland revival, and environmental factors such as the amount of annual precipitation. The rate of carbon sequestration is influenced by plant growth traits, land management techniques, shifts in land use, types of regenerative practices, as well as the soil's physical and biological properties and its prior carbon content^[3]. Therefore, by identifying plant species that are more capable of carbon sequestration and by studying factors relating to the management of carbon sequestration, the revival of rangelands can be considered as a valuable objective for the purpose of reducing atmospheric carbon^[6]. This study considers two plant species inhabiting Iranian rangelands, i.e. wild almond and Ephedra, and their capabilities of performing carbon sequestration as they naturally store organic carbon in their tissues and in the soil where they grow. The present study tries to fill that gap by determining the amount of carbon stored within the tissues and soil. These findings would

inform evidence-based decisions on the choice of tree species for the restoration of degraded lands and mitigation of climate change impact in arid and semi-arid areas.

1 Materials and methods

The study was conducted in the Dolatabad region of Fars province, Iran. The geographical coordinates of Dowlatabad (near Nourabad Mamasani, Fars province, Iran) are E 51°57'34", N 30°01'03". The maximum altitude of the mountainous region in the location is 1 782 m above sea level, and the lowest altitude is 1 511 m. The maximum amount of rainfall occurs in the months of January, February and March, whereas the driest month's span from May to November. Precipitation mainly occurs in the form of snow and rain. The location is characterized by temperate summers and cold winters.

In order to evaluate the real potential of Ephedra and wild almond species in performing carbon sequestration, the sampling of the soil masses and plant organs was carried out in specific regions which hosted the maximum number of the mentioned plants during springtime. Taking samples from the plant organs was categorized into stems, leaves and roots. Thirty plants were taken as samples per species. The leaves and stems were dissected and were then taken to the laboratory to be weighed. Aerial parts of the plants were separated into leaves and stems.

Root sampling was performed by digging vertically at six points around the base of each plant, taking care to minimize damage^[6]. Roots thicker than 2 mm were harvested from the soil samples and were transferred to the laboratory for analyses. Following the removal of the surface litter layer, vertical excavation was carried out to a depth of 30 cm^[9]. Since sampling started at the surface level, tools such as a spade and a mattock were employed for digging^[7]. Samples were taken from two regions, i.e. from the base of plants and also from the spaces between plants. The

latter was characterized by no vegetation. The 30 plant samples selected randomly within the study area. The microhabitats (e.g., slope, aspect, initial soil

texture) were the same for all sampling.

Two depths were sampled, i.e. 0–15 cm and 15–30 cm. The depth range was specifically chosen, as most soil microorganisms were concentrated within the top 30 cm, and the majority of plant roots extended to this depth (Fig. 1). Beyond 30 cm, variations in the soil's organic carbon levels were minimal^[10]. For each plant, three holes were dug at its base, and the collected soils were combined to form a composite sample. To minimize error, a total of 40 soil samples were collected for each plant species—30 from the bases of the plants and 10 from the spaces between them. With two plant species involved, this resulted in 80 soil samples overall. The samples were air-dried and then transported to the laboratory for separate analyses of chemical and biological properties, as well as for assessment of carbon sequestration potential.

These chemical and biological factors were the soil's acidity, electrical conductivity, organic carbon content, and the percentage of soil saturation moisture content. Once the soil samples were air-dried and the soil aggregates were crushed into smaller particles, the roots were separated from the soil and stones or other impurities were removed. The removal was assisted by a sieve with 2 mm openings. The soil samples were prepared for chemical analyses via standard laboratory methods^[7]. The average weight of each set of samples taken from each specified region was determined, and the amount of organic carbon was evaluated in the aerial parts and roots of the plants in addition to the amount of organic carbon in the soil. The soil's organic matter content was determined using the following formula^[11]:

$$O_M = 15 - (B_{RN} \times 0.5) / D_{SW} \times 0.681. \quad (1)$$

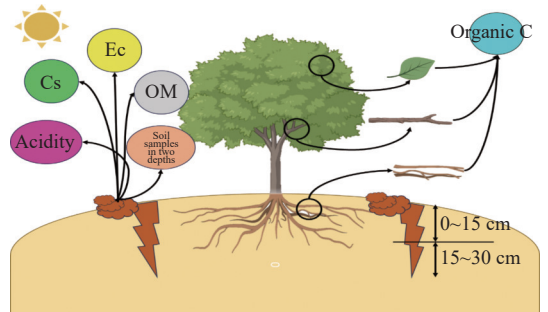


Fig. 1 Method scheme of plant and soil sampling

Where, O_M is organic matter, %; B_{RN} is Buret reading number; D_{SW} is dry soil weight, g.

$$O_C = O_M/1.724. \quad (2)$$

Where, O_C is organic carbon percentage, %; O_M is organic matter, %.

Ultimately, by using equation (3), the organic carbon content of the soil was determined (t/ha)^[12].

$$S_{oc} = O_C B_d h. \quad (3)$$

Where, S_{oc} is soil organic carbon, t/hm²; B_d is bulk density, g/cm³; h is sampling depth, cm.

Soil acidity was measured by the potentiometric method, and electrical conductivity was measured according to a method reported previously in the scientific literature^[13]. Total nitrogen was calculated by the Kjeldahl method^[14].

To assess the level of carbon sequestration in the biomass of plant stems, the carbon coefficient was calculated directly. The wood specimens taken from each stem or trunk were sampled and determined equally. The wood specimens were weighed at the beginning and were weighed again after being placed in an oven to be burnt into ashes. By having the initial weight of the wood samples and the final weight of the burnt ashes, the calculated percentage of carbon was obtained for each wood sample, while considering the ratio of organic carbon to organic matter^[15]. The percentage of carbon in the ash was added to the amount of organic carbon in the stem for each plant, and the density of each wood sample was calculated according to the following formula:

$$V = A_b H K_c. \quad (4)$$

Where, V is tree volume, m³; A_b is cross section of the tree, m²; H is height; K_c is density, g/cm³, was determined by water displacement method. K_c value was determined separately for *Amygdalus scoparia* and *Ephedra procera*.

$$A_b = \pi r^2. \quad (5)$$

Where r^2 is tree radius.

$$B_{io} = V W_D \times 1000. \quad (6)$$

Where, B_{io} is tree trunk biomass, g; V is tree volume, m³; W_D is dry wood density, g/cm³.

The information related to site history and soil characteristics before planting and shown in Tab. 1 of supplementary material. Therefore, there is time zero (control) with which to compare soil data after 32 years.

In this study, the first experiment comprised two factors: the first was the plant type (wild almond and Ephedra), and the second factor was plant organ (leaf, root, and shoots). The second experiment also had two factors: the first factor comprised three types of soil mass (which were dug at the bases of wild almond, Ephedra and the control), and the second factor was the sampling depth of the soil (0–15 and 15–30 cm). For this purpose, a completely randomized design was carried out in each experiment. The data analysis was performed using statistical software and the mean values were compared according to the Duncan test ($P \leq 0.05$). The correlation coefficients and fitting regression model were also estimated by SAS software (version 9.1).

2 Results

Results of evaluation pertaining to the amount of carbon sequestration per hectare regarding the three masses of soil under study showed that the amount of carbon sequestration in the soil of wild almond was 52.69 t/hm² among which the total carbon sequestration in the first depth (0–15 cm) was 35.71 t/hm² while the second depth (15–30 cm) contained 16.88 t/hm² (Tab. 2). The amount of carbon sequestration in the Ephedra soil amounted to 30.35 t/hm², among which the first depth contained 20.62 t/hm², while the second depth had 9.736 t/hm². The control contained a total amount of 6.66 t/hm², of

Tab. 1 Soil characteristics of the study area before planting *Amygdalus scoparia* and *Ephedra procera*

Clay/%	Sand/%	Silt/%	BD/ (g·cm ⁻³)	pH	Soil depth/cm	OM/ (t/hm ²)	OC stored/ (g·m ⁻²)	Vegetation	Carbon sequestration/ (t/hm ²) 0–15 cm
13.74	52.38	33.88	1.165	7.03	0-20	2.10	3 220.12	Grass C3	4.5

Notes: BD: Bulk density. OM: Organic matter. OC: Organic carbon.

Tab. 2 Amount of carbon sequestration in sample soil masses beneath *Amygdalus scoparia*, *Ephedra procera*, and control at two depths

Plant's soil masses	Soil depth/cm	Carbon sequestration/ (t·hm ²)	Organic matter/%	pH (Acidity)	Electrical conductivity (EC)/ (ds·cm ⁻¹)
<i>Amygdalus scoparia</i>	0–15	35.71a†	1.82a	7.63b	408.51c
<i>Amygdalus scoparia</i>	15–30	16.88c	0.30c	7.66b	332.46d
<i>Ephedra procera</i>	0–15	20.62b	0.46b	7.72b	575.61b
<i>Ephedra procera</i>	15–30	9.73d	0.47b	7.73b	400.14c
Control	0–15	4.51e	0.24c	7.15b	784.93a
Control	15–30	2.15e	0.20c	8.01a	736.09a

Notes: † The same letters demonstrate no significant difference, while different letters demonstrate significant differences by the Duncan's test ($P \leq 0.05$).

which 4.51 t/ha occurred in the first depth and 2.15 t/ha occurred in the second depth (Tab. 2).

2.1 Electrical conductivity

Soil type and depth had a significant effect on electrical conductivity, and the control soil exhibited a significantly higher electrical conductivity than the Ephedra and wild almond soils (Tab. 2). Additionally, average values indicated that electrical conductivity was significantly greater at the soil surface. Notably, both depths of the control soil showed the highest conductivity among all treatments, with the control differing significantly from the other groups. High electrical conductivity and elevated acidity in the soil may indicate the presence of high salinity levels.

2.2 Acidity

Soil depth significantly affected the soil's acidity, while the soil type did not have a notable impact on acidity (Tab. 3). Acidity levels were similar across the wild almond, Ephedra, and control soils (Tab. 3). Shallower soils exhibited lower acidity than deeper

Tab. 3 Comparison of average values of organic carbon in soil masses beneath *Amygdalus scoparia*, *Ephedra procera*, and control at two depths

		Organic carbon/%
Plant's soil masses	<i>Amygdalus scoparia</i>	0.87a†
	<i>Ephedra procera</i>	0.71b
	Control	0.25c
Soil depth	0–15	0.72a
	15–30	0.49b

Notes: † The same letters demonstrate no significant difference, while different letters demonstrate significant differences by the Duncan's test ($P \leq 0.05$).

ones. However, the depth-related differences were not significant for the wild almond and Ephedra soils but were significant for the control soil. The highest acidity was recorded at depths of 15–30 cm in the control soil.

2.3 Percentage of organic carbon

Both soil type and depth significantly affected the percentage of organic carbon. The maximum level of organic carbon was found in the wild almond soil, followed by the Ephedra and control soils, with average values of 0.87%, 0.71%, and 0.25%, respectively (Tab. 3). Organic carbon content was higher in shallower soils compared to deeper ones. Notable differences were found between the 0–15 cm and 15–30 cm depths, with average values of 0.72% and 0.49%, respectively. However, the interaction between soil type and depth did not significantly affect the organic carbon percentage (Tab. 2).

2.4 Percentage of organic matter

The percentage of organic matter in the soil was influenced by both soil type and depth ($P \leq 0.01$) (Tab. 3). The wild almond soil contained 1.06% organic matter, which was significantly higher than the Ephedra and control soils (Tab. 3). Shallower soils had higher organic matter percentages compared to deeper soils, with significant differences observed between two different depths, which contained 0.84% and 0.32%, respectively. While the Ephedra and control soils showed no significant differences between the two depths, the wild almond soil exhibited significant variations in organic matter content between the 0–15 cm and 15–30 cm depths.

The highest organic matter percentage (1.82%) in the wild almond soil was recorded at the 0–15 cm depth.

2.5 Carbon sequestration

Carbon sequestration was significantly influenced by both soil type and depth, the wild almond soil exhibited the highest carbon sequestration levels at 26.29 t/hm², followed by the Ephedra and control soils at 15.18 and 3.33 t/hm², respectively (Tab. 3). Soil depth also played a key role, with significantly greater carbon sequestration occurring at the 0–15 cm depth compared to the 15–30 cm depth. When comparing the interaction of soil type and depth, both the wild almond and Ephedra soils showed significant differences in carbon sequestration between the two depths, whereas the control soil showed no significant variation across depths (Tab. 2). The 0–15 cm depth exhibited the highest level of carbon sequestration across all soil types.

2.6 Soil texture

2.6.1 Clay percentage Soil clay content was significantly influenced by both soil mass and depth at the 1% probability level (Tab. 4). As shown in Tab. 5, wild almond had a higher cluster than Ephedra and control treatments, which was 24.26%, 19.66% and 18.41%, respectively. Also, the average of the main effects of soil texture in two depths of 0–15 and 15–30 cm showed that the soil clay content was significantly higher in the soil surface (Tab. 4). Soils with wild almond and Ephedra showed a significant difference in clay content between the two soil depths, with the 0–15 cm depth exhibiting the highest clay

content among all treatments (Tab. 4).

2.6.2 Silt percentage Mass and depth at 1% probability level had a significant effect on soil silt percentage (Tab. 4). Wild almond treatments were significantly higher than other treatments for silt percentage (Tab. 3). Additionally, the silt percentage at the 0–15 cm depth was significantly higher than at the 15–30 cm depth (Tab. 4). The results of decomposition of mass interactions and soil depth (Tab. 4) indicated that in all treatments, low soil depth had a higher percentage of silt.

2.6.3 Sand percentage The percentage of sand in the soil was significantly affected by both soil mass and depth at the 1% probability level (Tab. 3). Control treatments with 77.18% of sand had higher percentage of sand compared to wild almond and Ephedra treatments (Tab. 4). As indicated in Tab. 3, the sand percentage was significantly higher at the 15–30 cm depth. While no significant differences were observed between the wild Almond, Ephedra, and control soils at this depth, each treatment showed a significant difference between the 0–15 cm and 15–30 cm depths. In all three treatments, the maximum level of sand was consistently found in the deeper soil layer (15–30 cm) (Tab. 4).

2.7 Percentages of organic carbon and organic matter in plant tissues

The type of plant organ, plant species, and their interaction significantly influenced the recorded percentages of organic carbon and organic matter. There were significant differences between the

Tab. 4 Comparison of average values of soil texture in soil masses beneath *Amygdalus scoparia*, *Ephedra procera*, and control at two depths

Plant's soil masses	Soil depth/cm (0–30)	Mean squares		
		Clay/%	Silt/%	Sand/%
<i>Amygdalus scoparia</i>	0–15	34.05a†	25.86a	40.08d
<i>Amygdalus scoparia</i>	15–30	14.48d	7.77c	77.74ab
<i>Ephedra procera</i>	0–15	24.85b	15.92b	59.22c
<i>Ephedra procera</i>	15–30	14.48d	5.68dc	79.84a
Control	0–15	19.81c	5.76dc	74.42b
Control	15–30	16.48d	3.57d	79.97a

Notes: † The same letters demonstrate no significant difference, while different letters demonstrate significant differences by the Duncan's test ($P \leq 0.05$).

Tab. 5 Comparison of average values for interaction of organic matter and organic carbon stored in various plant organs of two species ($P \leq 0.05$)

Plant organs	Plant species		
	<i>Amygdalus scoparia</i>	<i>Ephedra procera</i>	
Organic carbon/%	Leaves	55.68a†	51.48b
	Stems	56.16a	55.68a
	Roots	52.26a	46.50c
Organic matter/%	Leaves	95.63a	81.50c
	Stems	97.33a	90.66b
	Roots	97.00a	90.21b

Notes: † indicates values with same letters in each column have no significant difference according to Duncan's test ($P \leq 0.05$).

Ephedra and wild almond regarding the percentages of organic carbon and organic matter in their plant organs. The two variables were observed at higher levels in the wild almond. Furthermore, different plant organs had significantly different percentages of organic carbon and organic matter (Tab. 5). The stems and roots of the *Ephedra* had the highest and lowest amounts of organic carbon, respectively, compared to those of the wild almond. However, there was no significant difference in the percentage of organic matter between the stem and roots of *Ephedra*. The leaves of *Ephedra* contained lower percentages of organic carbon and organic matter compared to the stem and roots. In contrast, the percentages of organic carbon and organic matter in wild almond did not show any significant difference between the stem and roots.

According to the Pearson's correlation coefficient analysis (Tab. 6), the percentage of organic matter showed a strong, positive, and significant correlation with both organic carbon content and the level of

carbon sequestration. However, it did not exhibit any significant correlation with the other measured soil traits. Similarly, the percentage of organic carbon was positively and significantly correlated with carbon sequestration (Fig. 2 and 3).

The results of the multiple regression analysis indicated that the significant F-statistic confirms a strong first-degree (linear) relationship between carbon sequestration and the percentages of organic carbon and organic matter in the soil, demonstrating the model's adequacy and reliability ($C_v = 23.34$). In this model, 92% of the variation in soil carbon sequestration is explained by the percentages of organic matter and organic carbon (Tab. 7).

The regression formula is presented as follows:

$$Y = -5.88 + 8.31X_1 + 17.19X_2 \quad (7)$$

Where, Y is carbon sequestration, t/hm^2 ; X_1 is organic matter, %; X_2 is organic carbon, %.

3 Discussion

3.1 Plant type and soil depth

The percentage of soil organic carbon was significantly influenced by both plant type and soil depth, although their interaction did not significantly affect this trait. There is an indirect relationship between the amount of carbon uptake in the dry and semi-arid regions and the soil depths by examining the effect of soil depth on the amount of carbon sequestration^[16]. This conclusion is also consistent with the previous research results^[2], which can be explained by the gradual evolution of litter decomposition into humus, which begins from the surface layers of the soil. The findings of this study revealed a significant difference in carbon storage

Tab. 6 Estimation of correlation coefficients among soil characteristics

	Organic matter/%	Organic carbon/%	Carbon sequestration/ ($t \cdot hm^2$)	Acidity	EC/($ds \cdot cm^{-1}$)
Organic matter	1.00				
Organic carbon	0.89**†	1.00			
Carbon sequestration	0.89**	0.81**	1.00		
Acidity	-0.22ns	-0.14ns	-0.51ns	1.00	
EC	-0.17ns	-0.12ns	-0.44ns	0.50ns	1.00

Notes: † denotes non-significant difference, * and ** denote statistical significance at ($P \leq 0.05$) and ($P \leq 0.01$), respectively. ns: Not significantly.

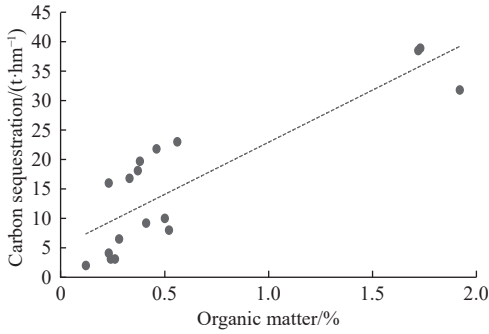


Fig. 2 Effect of organic matter on carbon sequestration

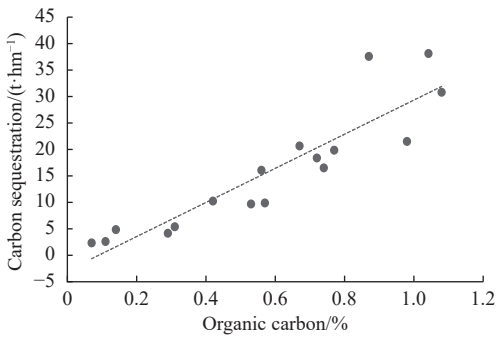


Fig. 3 Effect of organic carbon on carbon sequestration

Tab. 7 Multiple regression analysis of soil carbon sequestration under the influence of percentages of organic matter and organic carbon

Source	DF	Mean square
Model	3	2 169.08**
Error	14	170.26
Cv	—	23.34
R ²	—	92

Notes: The asterisks * and ** denote significant differences at ($P \leq 0.05$) and ($P \leq 0.01$), respectively, based on the *t*-test. DF is degree of freedom; Cv is coefficient of variation, %; and R^2 is coefficient of determination.

among various plant organs, with the stem containing the highest amount of stored carbon and the root the lowest. The results of this experiment are consistent with the previous research results^[7]. The results showed that the depth of 0–15 cm had a more clay and silt content, resulting in more carbon storage. Soil texture, particularly clay content, is one of the key factors influencing soil carbon storage. Clay soils tend to retain more organic carbon due to their high surface area, ability to form stable aggregates, and protection of organic matter from microbial decomposition^[6].

3.2 Soil properties and carbon storage

The researchers concluded that increasing the depth of bulk density and soil acidity increased, while the percentage of nitrogen reduced the amount of organic matter and organic carbon. It was also found in this study that soils containing wild Almond had a higher carbon content due to their percentage of clay. Soils with wild almond and Ephedra showed a significant difference in clay content between the two soil depths, with the 0–15 cm depth having the highest clay content among all treatments. Researchers from Costa Rica, found organic carbon concentration at very different depths in relation to soil texture, especially clay soils^[17].

3.3 Plant organs and carbon sequestration

Woody organs have a higher capacity for carbon storage, and plants with a greater proportion of woody tissues exhibit higher carbon sequestration^[16]. Carbon sequestration was significantly different between the two species by comparing the carbon sequestration between Jand and Mesquite in southern of Iran^[15]. The researchers showed that in two species, the highest carbon content in the stem is consistent with the findings of this study. In general, the effect of plant and plant species on the amount of carbon stored in plant tissue was significant.

There was a significant difference between the different organs of the plant in terms of stored carbon. The highest and lowest amount of carbon stored in the tissue was observed in the stem and leaf organs of both plants, respectively. The almond plant was more carbon stored in its tissue, which was higher by about 59.8% than the Ephedra plant. Accordingly, based on the regression formula, along with figures 1 and 2, the increase of organic carbon and organic matter in the soil is accompanied by the increase in carbon sequestration. The stronger regression coefficient of organic carbon compared to organic matter indicates that SOC is a more direct and reliable predictor of soil carbon sequestration. This difference can be explained ecologically: while soil organic matter comprises a mixture of carbon and other elements (N, P, S, etc.), only the carbon fraction contributes directly to long-term carbon storage. Variations in non-carbon

components of SOM dilute its relationship with carbon sequestration, leading to weaker statistical associations. In contrast, SOC reflects the actual carbon pool, especially the stable fractions protected within soil aggregates and organo-mineral complexes, which are central to long-term sequestration processes. Therefore, the higher coefficient of SOC relative to SOM is consistent with the mechanistic role of carbon as the main element governing soil carbon storage capacity.

3.4 Management implications and future directions

Organic carbon plays a more significant role than organic matter in determining the extent of carbon sequestration in the soil. The outlining how wild almond cultivation could be integrated into local land-use planning, soil conservation practices, reforestation projects, or carbon sequestration policies under actual ecological and socio-economic conditions. Then, it would be useful to experiment the cultivation and sequestration of this species in other terrestrial ecosystems or further rank this species when information on other rangeland species becomes available regarding their capabilities of carbon sequestration. The cultivation of wild almond is exceptionally practicable because of its high tolerance to drought, whereas other water-dependent species may need a great deal of management if cultivated in vast areas of rangelands.

Although wild almond appears more beneficial for carbon reduction than *Ephedra*, the long-term stability of carbon sequestration must also be considered. The slower litter decomposition of wild almond favors the formation of more stable soil carbon pools, whereas *Ephedra* contributes to faster nutrient cycling but less persistent carbon storage. From a management perspective, species choice should not rely solely on carbon storage potential. Wild almond entails higher planting costs and lower seedling survival in harsh conditions, but its long-lived woody structure enhances carbon permanence. By contrast, *Ephedra* is cheaper to establish, more tolerant of soil salinity and degradation, and has higher early survival, making it suitable for severely disturbed rangelands. Therefore, integrating both species in

restoration strategies—depending on site conditions—could balance short-term establishment success with long-term carbon sequestration stability, providing a more comprehensive decision-making framework for rangeland management.

4 Conclusions

This study found the surfaces soil has a higher clay and silt content than the deep soils, resulting in more carbon storage. The moisture content and acidity were the same for all three treatments without any significant differences. Soil texture, especially the percentage of organic carbon is one of the factors affecting carbon sequestration. Soils containing organic matter and organic carbon are more available to sequester carbon. It was also found in this study that soils containing wild almond had a higher carbon content due to the percentage of organic carbon and the percentage of organic matter. Difference between soil depths in terms of acidity, organic carbon percentage, organic matter content and carbon sequestration in wild almond and in terms of electrical conductivity in control soil was higher than other treatments. Carbon dioxide is among the most common greenhouse gases which result in global warming. The procedure for storing carbon in soils and plant biomass that are affected by this biomass can be the simplest and cheapest solution to reduce unwanted levels of carbon dioxide. These findings are consistent with Mediterranean and Central Asian dryland studies, highlighting their broader relevance for species selection in restoration and sustainable land-use planning.

5 References

- [1] CARLQUIST S. Wood, bark, and pith anatomy of Old World species of *Ephedra* and summary for the genus[J]. *Aliso: A Journal of Systematic and Floristic Botany*, 1992, 13(2): 255–295.
- [2] SCHUMAN G E, JANZEN H H, HERRICK J E. Soil carbon dynamics and potential carbon sequestration by rangelands[J]. *Environmental Pollution*, 2002, 116(3): 391–396.
- [3] DERNER J D, SCHUMAN G E. Carbon sequestration

- and rangelands: A synthesis of land management and precipitation effects[J]. *Journal of Soil and Water Conservation*, 2007, 62(2): 77–85.
- [4] AMIGHI S J, ASGHARI H, SHEIKH V B, et al. Effects of agroforestry systems on carbon sequestration and improvement soil quality[J]. *International Journal of Agriculture*, 2013, 3(4): 822.
- [5] FALSOLAIMAN M, SADEGHI H, CHAKOSHI B. Carbon sequestration international project; successful sample in creating people and participation organizations in village development (Hossein Abad plain, south Khorasan province, east of Iran)[J]. *Spanish Journal of Rural Development*, 2013, 4(1).
- [6] IRANMANESH M, SADEGHI H. Effects of soil texture and nitrogen on ability of carbon sequestration in different organs of two *Tamarix* species as a good choice for carbon stock in dry lands[J]. *Ecological Engineering*, 2019, 139: 105577.
- [7] IRANMANESH M, SADEGHI H. The effect of soil organic matter, electrical conductivity and acidity on the soil's carbon sequestration ability via two species of Tamarisk (*Tamarix* spp.)[J]. *Environmental Progress & Sustainable Energy*, 2019, 38(6): 13230.
- [8] HILL M J, BRAATEN R, MCKEON G M. A scenario calculator for effects of grazing land management on carbon stocks in Australian rangelands[J]. *Environmental Modelling & Software*, 2003, 18(7): 627–644.
- [9] WOOPER P L, TOURÉ A, SALL M. Carbon stocks in Senegal's Sahel transition zone[J]. *Journal of Arid Environments*, 2004, 59(3): 499–510.
- [10] ZHAO Halin, HE Yuhui, ZHOU Ruilian, et al. Effects of desertification on soil organic C and N content in sandy farmland and grassland of Inner Mongolia[J]. *Catena*, 2009, 77(3): 187–191.
- [11] WALKLEY A, BLACK I A. An examination of the Degtjareff method for determining soil organic matter, and a proposed modification of the chromic acid titration method[J]. *Soil Science*, 1934, 37(1): 29–38.
- [12] GUO L B, GIFFORD R M. Soil carbon stocks and land use change: A meta analysis[J]. *Global Change Biology*, 2002, 8(4): 345–360.
- [13] PAUWELS M, FRÉROT H, BONNIN I, et al. A broad-scale analysis of population differentiation for Zn tolerance in an emerging model species for tolerance study: *Arabidopsis halleri* (Brassicaceae)[J]. *Journal of Evolutionary Biology*, 2006, 19(6): 1838–1850.
- [14] BREMNER J M, MULVANEY C S. Nitrogen—total[M]//PAGE A L. *Methods of soil analysis: Part 2 chemical and microbiological properties*. American Society of Agronomy, 1982: 595–624.
- [15] ANSARI S, SADEGHI H. Using Jand and Mesquite for environmental progress and management: Improvement soil proprieties and carbon sequestration ability in different organs[J]. *Environmental Progress & Sustainable Energy*, 2021, 40(5): e13669.
- [16] GAO Y H, LUO P, WU N, et al. Grazing intensity impacts on carbon sequestration in an alpine meadow on the eastern Tibetan Plateau[J]. *Research Journal of Agriculture and Biological Sciences*, 2007, 3(6): 642–647.
- [17] POWERS J S, SCHLESINGER W H. Relationships among soil carbon distributions and biophysical factors at nested spatial scales in rain forests of northeastern Costa Rica[J]. *Geoderma*, 2002, 109(3/4): 165–190.

土壤电导率、酸度和有机质对野生杏仁和麻黄下土壤固碳能力的影响

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摘要: 【目的】植物和土壤的固碳在碳循环中发挥着至关重要的作用,有助于降低二氧化碳水平并提高土壤生产力。识别具有高固碳潜力的植物物种对于牧场的恢复和维护至关重要。【方法】本研究考察2种植物野生杏仁(*Amygdalus scoparia*)和麻黄(*Ephedra procera*)的根、茎和叶等不同器官的固碳能力。通过采集植物基部和株间0–15 cm和15–30 cm深度的土壤样本,评估土壤特性和碳固存水平。第1个试验包含2个因素:植物种类(野生杏仁和麻黄)和植物器官(叶、茎和根)。第2个试验也包含2个因素。第1个因素是3种土壤团块类型(分别采集于野生杏仁、麻黄和对照植物的基部),第2个因素是土壤采样深度(0–15 cm和15–30 cm)。试验在

伊朗法尔斯省多拉塔巴德地区进行。【结果】野生杏仁下方的土壤有机碳、有机质和碳固存量均高于麻黄和对照土壤。此外,0–15 cm 深度的土壤中这些指标的含量也高于 15–30 cm 深度的土壤。随着土壤深度的增加,有机碳、有机质和固碳量均有所下降,而土壤酸度则有所上升。然而,2 个深度之间的土壤含水量差异并不显著。土壤类型和深度对电导率有显著影响。对照土壤的电导率显著高于麻黄和野生杏仁土壤。此外,平均值表明土壤表层的电导率显著高于其他深度。值得注意的是,对照土壤的 2 个深度在所有处理中均表现出最高的电导率,且与其他组存在显著差异。土壤的高电导率可能表明其盐度较高。野生杏仁和麻黄下方的土壤在不同深度之间的黏粒含量存在显著差异,其中 0–15 cm 深度的黏粒含量在所有处理中最高。【结论】野生杏仁组织中储存的有机碳和有机质含量显著高于麻黄。由于耐旱性强,野生杏仁的栽培非常可行;而其他需水量大的物种,若在大片牧场种植,则可能需要精细的管理。有机碳在决定土壤固碳量方面比有机质发挥着更重要的作用。土壤质地,尤其是黏土含量,是影响固碳的最重要因素之一。

关键词: 碳固存; 有机碳; 土壤质地; 环境管理

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项目名称: 法尔斯省努拉巴德县多拉特阿巴德地区杏仁(*Amygdalus scoparia*)和麻黄(*Ephedra procera*)碳固存量估算