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Native versus non-native Prosopis woody species: Which fertilize the soil better?

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Abstract

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This study assessed differences in the physical, chemical, and microbial properties of soils under trees of the native species *Prosopis cineraria* and the invasive species *Prosopis juliflora* trees, focusing on implications for ecosystem management and restoration. At the start of the growing season, 30 trees of each species with a trunk diameter of 15–30 cm were randomly selected. Soil samples were taken from the top 20 cm of soil profiles east of each tree, under the tree crowns and from control plots in open areas. Three soil samples per site were pooled for chemical and microbial analysis. Soil moisture was highest under *P. cineraria* (14.64 ± 0.3) and lowest in control plots (9.04 ± 0.65). Soil pH was highest in control soils (7.91 ± 0.09), slightly lower under *P. cineraria* (7.77 ± 0.06), and lowest under *P. juliflora* (7.49 ± 0.0). Electrical conductivity, soil salinity was highest under *P. juliflora* (2.25 ± 0.12). Microbial activity indicators (basal respiration and microbial biomass carbon) were greater under *P. cineraria* than under *P. juliflora* trees. Native *P. cineraria* trees enhance soil conditions, benefiting ecosystem management. In contrast, invasive *P. juliflora* trees raise soil salinity, threatening soil quality, biodiversity, and ecosystem services in the Sahara-Sahel region. Managing the spread of *P. juliflora* is crucial to maintaining ecosystem functions.

Keywords

arid lands, biological invasions, degraded lands, microbial communities, non-native species impacts

Introduction

Natural hazards, such as storms, floods, and wildfires, can be catastrophic events, just as biological invasions can be. However, the impacts of biological invasions are often irreversible and subtle. Despite this, public awareness of biological invasions is significantly lower compared to natural hazards, and investments in managing these invasions remain severely inadequate and delayed (Turbelin et al., 2023). Biological invasions are a worldwide challenge, posing a major threat to natural ecosystems. They rank as the second-largest threat to biodiversity, following

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closely behind habitat destruction (Drake et al., 2003). By definition, invasive alien species are organisms that have been moved by humans from their native habitats to new locations, spread over large areas causing considerable harm to the environment, economic systems, and/or human health (Beck et al., 2008; Richarson et al., 2000). In simpler terms, invasive alien species are those whose ranges have been modified either unintentionally (through accidental introductions) or intentionally (through purposeful introductions) by humans (Essl et al., 2015). Invasive species often exhibit greater tolerance than native species to a broad spectrum of environmental conditions and pose novel biological traits that provide them with various competitive advantages (Sundarapandian et al., 2015; Sundarapandian and Subashree, 2017). Previous studies have shown that environmental conditions and leaf quality can have significant impacts on litter decomposition and nutrient cycling (Castillo-Figueroa, 2024). Additionally, significant differences in soil carbon concentration and storage at a depth of 0–10 cm among different tree species have been linked to factors such as reduced litterfall input and increased decomposition processes (Baek and Kim, 2024). Alien plant invasions can lead to the displacement of native plant species, causing harm to local flora and biodiversity (Pysek et al., 2020; Moslehi et al., 2022). Additionally, these invasions may have adverse effects on various ecosystem functions and services, influencing the regional social-ecological context (Pysek et al., 2020) with the potential to significantly transform entire ecosystems. This transformation can occur through the alteration of physical, chemical, and biological properties within the habitat, alterations to biotic communities and through disruption to ecological processes such as fire regimes, hydrology, and nutrient cycling (Pysek et al., 2020). As such there is a pressing need to implement effective measures for the management and control of alien plant invasions (Moslehi et al., 2022). To achieve this goal, it is essential to first evaluate the impacts of alien plant invasions on ecosystem functions, such as soil microbial communities as well as the physical and chemical properties of the soil (Shen et al., 2021; Zhang et al., 2020).

The genus *Prosopis* L. (Fabaceae) comprises 44 species (Pasiecznik et al., 2001). Among these species, *Prosopis juliflora* has been introduced worldwide and become highly invasive in many regions and in some cases now coexists with native species for the genus (Shackleton et al., 2014). For example, nowadays mixes of *Prosopis cineraria* and *P. juliflora* are now common in the delicate arid ecosystems of southern Iran (Moslehi et al., 2022; Sharifian et al., 2023) and other regions of eastern Asia.

Acknowledging the fragility of ecosystems in arid regions, non-native species like *P. juliflora* can cause fundamental alterations to ecosystems, including on soils and plant communities (El-Keblawy and Al-Rawai, 2007; Linders et al. 2019; Alizadeh et al., 2022). For example, Imani et al. (2016) found that the electrical conductivity of soil samples collected under the crowns of *P. juliflora* were higher than those of open area. Bibi et al. (2023) showed that *P. juliflora* significantly ($p \leq 0.05$) reduced both the germination rates and seed radicle length of various native species, including *Acacia tortilis, P. cineraria*, *Sueda aegyptica*, *Halopeplis perfoliata*. Their findings suggest that *P. juliflora* releases allelopathic compounds that inhibit seed germination and seedling growth of native species, which is a common impact and mechanism of invasion for other plant species globally (Ferguson et al., 2013). Furthermore, in the deserts of the United Arab Emirates, El-Keblawy and Al-Rawai (2007) show that the effect of *P. juliflora* on the associated flora depends significantly on canopy density and size. Larger individuals and greater densities have significantly greater negative impacts on associated native plants.

Considering the implications of biological invasions on soils in arid ecosystems and to gather evidence to guide management and restoration, this study attempted to answer the following questions: (1) do soil physicochemical properties in areas with invasive alien and native *Prosopis* species differ, and (2) does the invasion of *P. juliflora* alter soil microbial communities in Iran?

Materials and methods

Study area

The study was conducted in Minab district, Hormozgan province. The site is 38 to 40 m asl (E 56º54’31.39’’ to 56º55’1.42’’; N27º23’45.54’’ to 27º23’45.54’’) and covers an area of 40 hectares (0.4 km^2). Mean annual precipitation and temperature are 226.96 mm and 28.1 °C, respectively (Iran Meteorological Organisation (IMO)) (Fig. 1). The district is classified as an arid and semi-arid area falling within the Sahara-Sindhi habitat (Fig. 2). The sampling area included a natural stand where the native species *P. cineraria* was dominant and a site invaded by non-native *P. juliflora* trees.

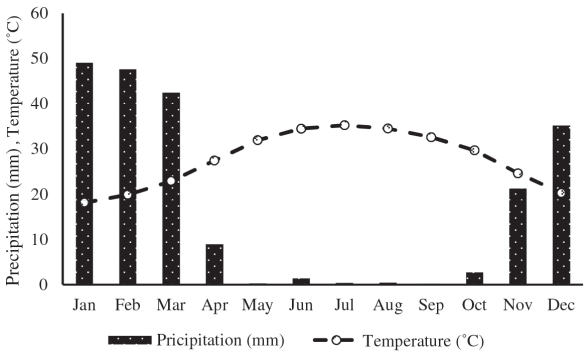

Fig. 1. Ombrothermic curve displaying mean values for monthly precipitation and temperature (1987–2021) in Minab.

Data collection

In the early growing season (April 2021), 30 trees of *P. cineraria* and 30 trees of *P. juliflora* with a diameter at breast height of between 15 and 30 cm were selected randomly, and their locations were recorded by GPS. Soil samples

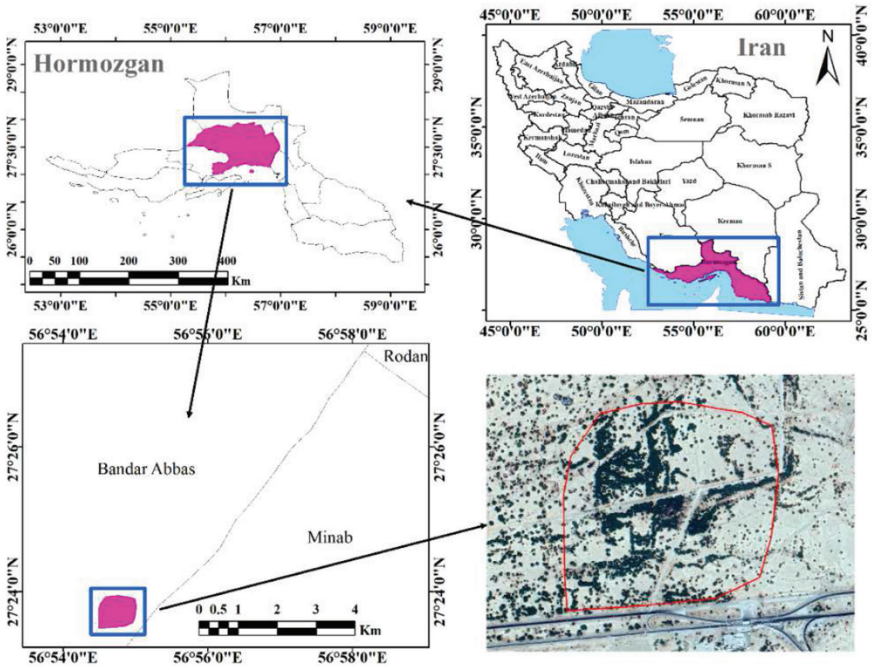

Fig. 2. The study site located in the natural Sahara - Sindian Forest of southern Iran.

were extracted from the upper 20 cm of the soil profile on the eastern side of the sample trees. Soil samples were taken from under the crown (near the edge of the crown) and control samples were taken in an open patch (area with no trees) close to the sample tree (Fig. 3). Three soil samples were taken at each location and mixed together. In order to conduct physical and chemical analysis, part of the composite samples was air-dried, homogenised and sieved to eliminate large particles. The remaining part of the samples (200 g) was transferred to the laboratory and stored at –20 °C until analyses of soil microbial activities and other indicators of ecological functions (including basal respiration, substrate-induced respiration, of carbon content of microbial biomass, nitrification potential, microbial ratio, and metabolic quotient).

Soil moisture (SM) was determined by calculating the mass loss of 20 g of fresh soil samples after oven-drying at 105 °C for 48 hours. Soil texture was assessed using the Bouyoucos hydrometer method (Bouyoucos, 1962) and bulk density (BD) using the clod method (Plaster,

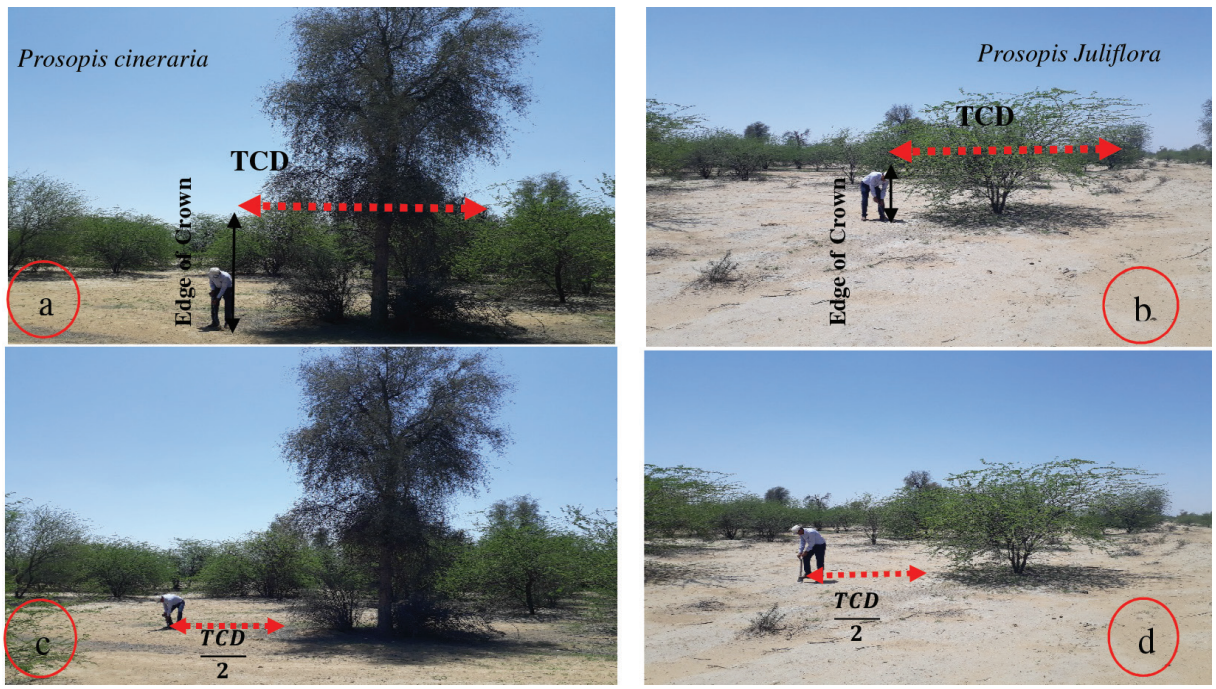

Fig. 3. Soil sampling under and outside the canopy of *P. cineraria* (a and c) and *P. juliflora* (b and d). Solid black arrows indicate crown edge, and red dashed arrows indicate Tree crown Diameter (TCD).

1985). Soil pH was measured using a glass electrode in a suspension of deionised water or 0.01 M $CaCl_2$ solution with fine earth at a ratio of fine earth to deionised water of 1:2.5, and electrical conductivity (EC) was determined in saturated soil extracts using an EC meter (Black, 1965). Calcium carbonate equivalent ($CaCO_3$) was estimated using the back titration procedure (Nelson, 1982). Total nitrogen (TN) and organic carbon (OC) were evaluated through Kjeldahl digestion and the Walkley-Black method (Nelson, 1982), respectively. Available phosphorus (P) was determined using the Olsen's method, and available potassium (K), soluble calcium (Ca), and magnesium (Mg) were determined by the ammonium acetate method using atomic absorption spectrophotometry (UNICAM 919, Unicam Ltd., Cambridge, UK) (Thomas, 1982).

After a three-day incubation experiment at 25 °C, the amount of CO_2 was measured to assess soil basal respiration (BR) and glucose to assess substrate-induced respiration (SIR) (Mahdhi et al., 2019). Samples were adsorbed in NaOH and measured using HCl titration (Stonlnikova et al., 2011). To determine total microbial biomass carbon (MBC), the chloroform fumigation-extraction method was used. In order to evaluate nitrification rate (NP), the difference in NO_2-N concentrations between the aerated frozen samples was calculated (Chodak and Niklinska, 2010). The soil microbial ratio (MBC: OC) (Jia et al., 2005) and the metabolic quotient (qCO_2 = BR: MBC) (Stonlnikova et al., 2011) were estimated based on the values of organic carbon, basal respiration, and microbial biomass carbon.

Statistical analysis

Statistical analyses were conducted in both SPSS (version 26) and R (R Core Team, 2023.03.1). The normality and homogeneity of variables were examined with the Kolmogorov Smirnov and Levene's tests, respectively. A one-way analysis of variance (ANOVA) was conducted to assess any differences in soil properties (biotic and abiotic) from under *P. cineraria* and *P. juliflora* tree canopies and of control soils located away from tree canopies. In order to test the post

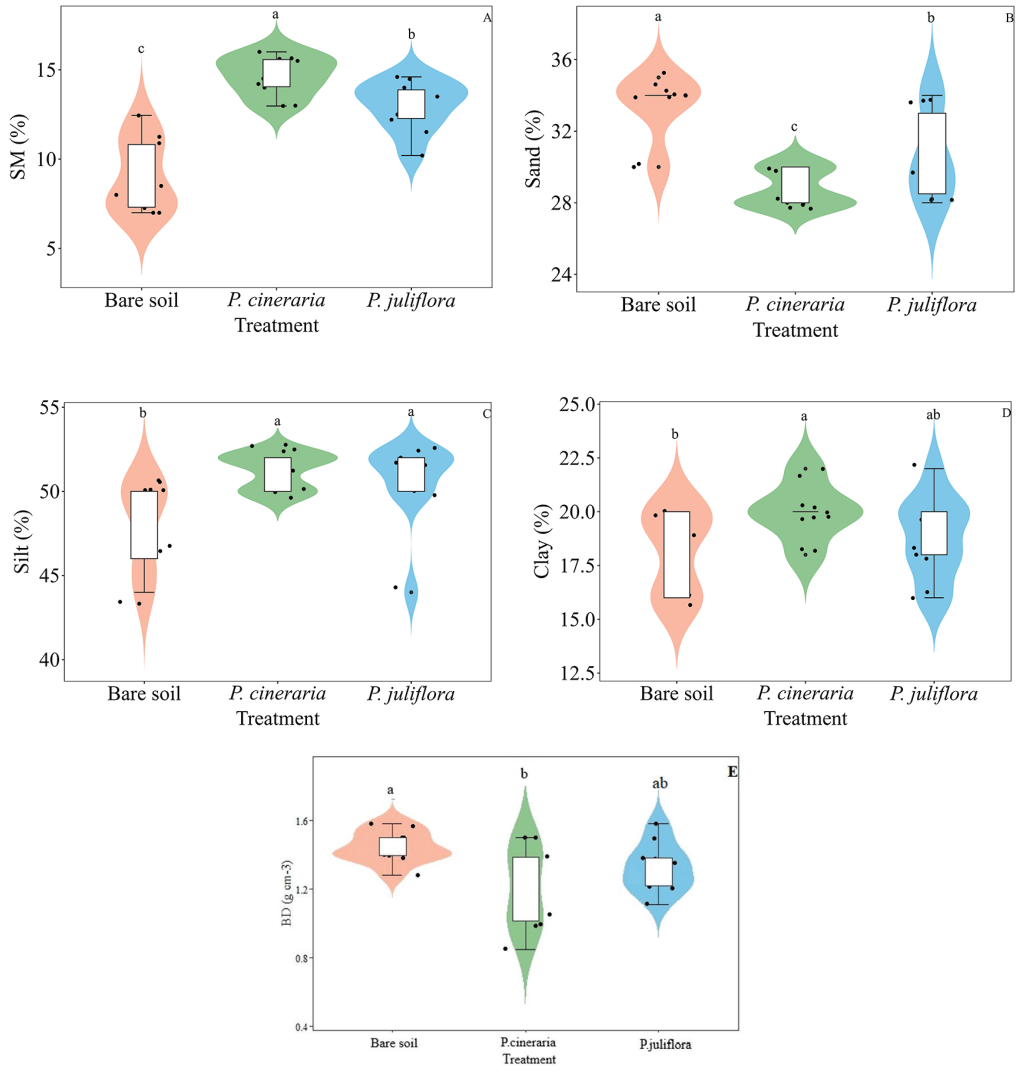

Fig. 4. Physical properties of soils under *P. cineraria*, *P. juliflora* and control (bare) soils. Different lower-case letters indicate significant differences between different groups according to the Duncan test. SM – soil moisture, BD – bulk density.

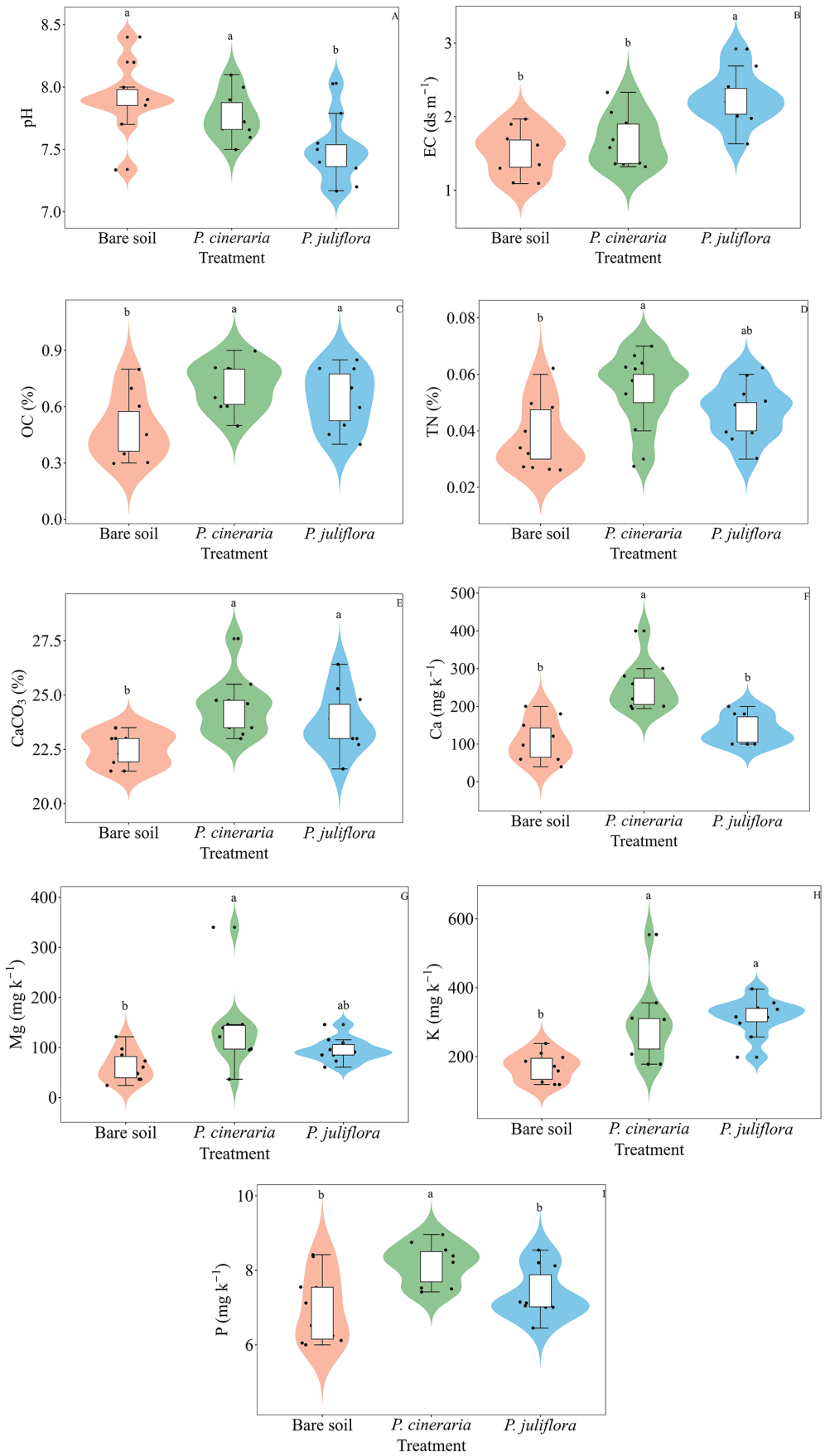

Fig. 5. Chemical properties of soils under *P. cineraria*, *P. juliflora* and control (bare) soil. Different lower-case letters indicate significant differences between different groups according to the Duncan test. OC – organic carbon, TN – total nitrogen, $CaCO_3$ – calcium carbonate equivalent, Ca – available calcium, Mg – available magnesium, K – available potassium, and P – available phosphorus.

Table 1. The mean ± SE values of the physio-chemical properties of soils from under the crowns of *P. cineraria* and *P. juliflora* and control soils situated in bare areas away from the trees (SE: standard error)

Variable	*P. cineraria*	*P. juliflora*	Control (Bare) soil	F test
SM (%)	14.64 ± 0.34^{a}	13 ± 0.44^{b}	9.04 ± 0.65^{c}	33.94^{**}
Sand (%)	28.8 ± 0.33^{c}	30.6 ± 0.79в	33.4 ± 0.58^{a}	15.05^{**}
Silt (%)	51.2 ± 0.33^{a}	50.6 ± 0.79^{a}	48 ± 0.84^{b}	6.01^{**}
Clay (%)	20 ± 0.42^{a}	18.8 ± 0.61^{ab}	18.2 ± 0.61^{b}	2.73^{*}
BD (g cm^{-3})	1.2 ± 0.07^{b}	1.32 ± 0.04^{ab}	1.44 ± 0.03^{a}	5.15^{*}
pH (1:2.5)	7.77 ± 0.06^{a}	7.49 ± 0.08^{b}	7.91 ± 0.09^{a}	7.42^{**}
EC (ds m^{-1})	1.68 ± 0.11^{b}	2.25 ± 0.12^{a}	1.53 ± 0.1^{b}	12.47^{**}
OC (%)	0.71 ± 0.04^{a}	0.64 ± 0.05^{a}	0.48 ± 0.05^{b}	6.06^{**}
TN (%)	0.06 ± 0.00^{a}	0.05 ± 0.00^{ab}	0.04 ± 0.00^{b}	5.71^{**}
$CaCO_3$ (%)	24.49 ± 0.43^{a}	23.75 ± 0.44^{a}	22.52 ± 0.24^{b}	6.75^{**}
Ca (mg kg^{-1})	252.4 ± 19.97^{a}	138.7 ± 11.71^{b}	108.8 ± 16.92^{b}	20.94^{**}
Mg (mg kg^{-1})	135.19 ± 25.11^{a}	95.46 ± 7.51^{ab}	63.13 ± 9.73^{b}	5.00^{*}
K (mg kg^{-1})	292 ± 34.56^{a}	314.8 ± 17.4^{a}	170.4 ± 12.74^{b}	10.89^{**}
P (mg kg^{-1})	8.17 ± 0.17^{a}	7.37 ± 0.21^{b}	6.99 ± 0.3^{b}	6.67^{**}

Significant differences between groups of soils (according to Duncan's test) are marked with different letters (^{a,b,c}). Level of significance: $^{*}P < 0.05$, $^{**}P < 0.01$. SM – soil moisture, BD – bulk density, OC – organic carbon, TN – total nitrogen, $CaCO_3$ – calcium carbonate equivalent, Ca – available calcium, Mg – available magnesium, K – available potassium, and P – available phosphorus.

hoc comparison of the means, Duncan's test was performed. We used principal component analyses (PCA) to assess the relationships between the variables assessed.

Results

Soil physical and chemical properties

Soils under *P. cineraria* had significantly higher soil moisture content (SM) (14.64 ± 0.34), pH (7.77 ± 0.06), Ca content (mg kg^{-1}) (252.4 ± 19.97), and P (8.17 ± 0.17) as compared to *P. juliflora* (SM 13 ± 0.44, pH 7.49 ± 0.0, Ca 138.7 ± 11.71, P 7.37 ± 0.21) (Figs 3 and 4, Table 1). The converse was found for BD and EC, which were higher in soils taken under *P. juliflora* (1.32 ± 0.04, and 2.25 ± 0.12) crowns as compared to *P. cineraria* (1.2 ± 0.07 and 0.71 ± 0.04, respectively) tree crowns. Soils under *P. cinerar-ia* also had significantly lower sand content than control soils and soils from under *P. juliflora*. There were no differences between the two *Prosopis* species with regards to silt and clay content and BD, OC, TN, $CaCO_3$, Mg, and K concentrations (Figs 4 and 5, Table 1), although in general, these variables had higher values in the soils from under both *Prosopis* species compared to the control soils (Fig. 5 and Table 1).

Soil microbial properties

Overall, BR values were significantly higher in soils from under *P. cineraria* tree crowns (63.58 ± 7.58 mg $C\text{-}CO_2$ kg^{-1}) compared to soils from under *P. juliflora* (43.59 ± 4.34) and the control soils (25.69 ± 5.62 mg $C\text{-}CO_2$ kg^{-1}) (Fig. 6, Table 2). Similarly, MBC was also significantly higher in soils under *P. cineraria* than those from under *P. juliflora* and the control soils. There were no significant differences in SIR, NP, MBC, OC, and qCO_2 between soils from under *P. cineraria* and *P. juliflora* tree crowns; however, they were generally higher compared to the control soils.

The results of the principal component analysis (PCA) with 20 biotic and abiotic soil variables show three distinct clusters (differences) in the soil matrices corresponding to soils from under *P. cineraria* (top right corner), *P. juliflora* (bottom right corner), and control (bare) soils (left-hand side) (Fig. 7), though the values of some variables slightly overlapped. The first (PC1) and second (PC2) PCA axes explained 31.54% and 15.23% of the total variation, respectively (Fig. 7). The main reason for the differentiation in clusters was related to soil acidity, sand content, and bulk density. Soils related to *P. cineraria* (the top right corner), were primarily influenced by EC, Mg, K, BR, MBC, and MBC: OC values. The distribution of soils associated with *P. juliflora* (in the bottom left quadrant) were mainly controlled by silt, clay, OC, TN, $CaCO_3$, Ca, P, SM, SIR, and NP (Fig. 7).

Among the above-mentioned variables, soil moisture (SM) and sand had the highest positive and negative effects on the first PCA axis. Moreover, MBC: OC and pH had the highest positive and negative effects on the second PCA axis. Additionally, with the inclusion of the third (PC3), fourth (PC4), and fifth (PC5) components, the cumulative percentage of explained variance increased to 71.37%, specifically highlighting the added impacts of factors like NP, qCO_2, and clay on data distribution within these components (Table 3).

Discussion

In this study, we found several differences between the abiotic and biotic properties in soils under native and invasive *Prosopis* tree species in the arid ecosystems of Iran.

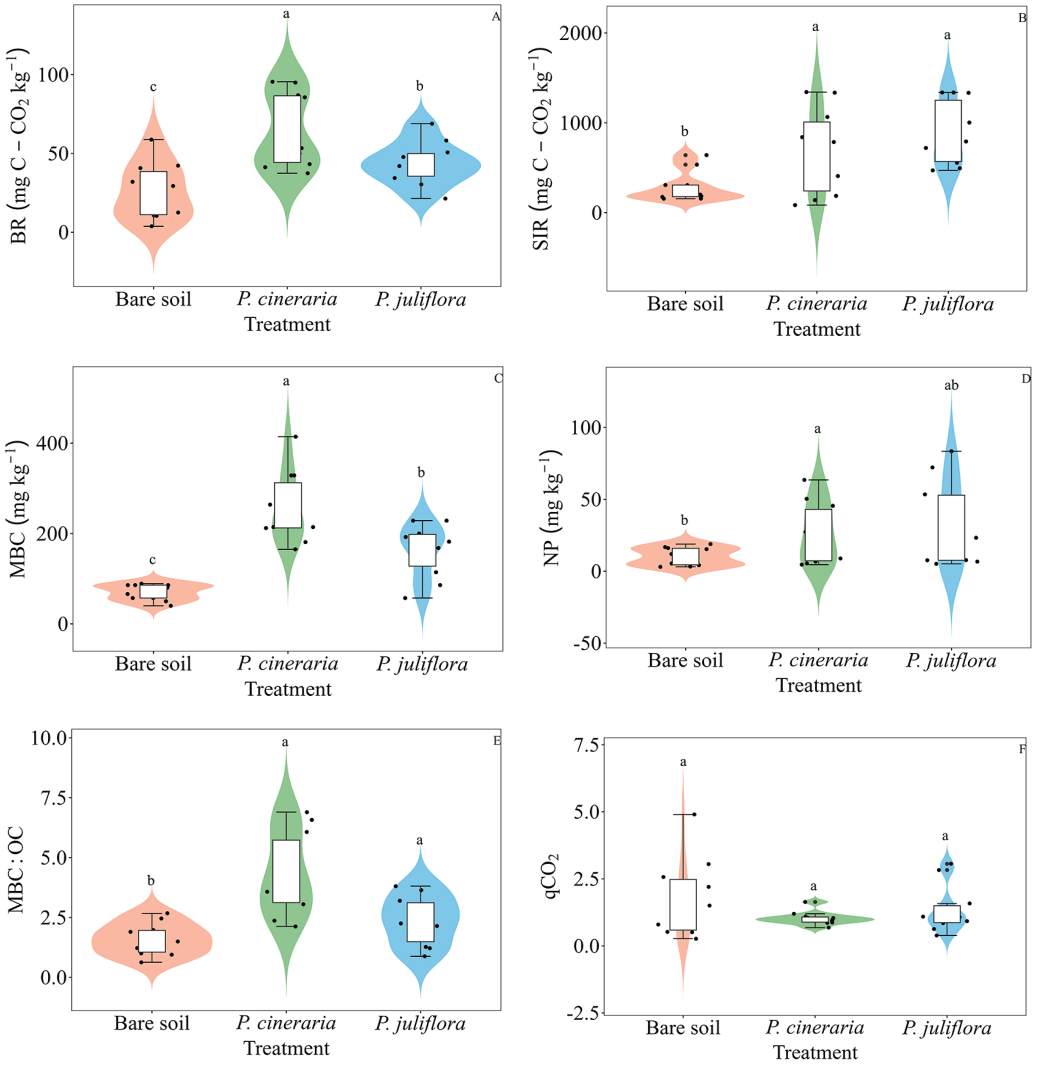

Fig. 6. Biological properties of soils under *P. cineraria* and *P. juliflora* trees and control (bare) soil. Different lower-case letters indicate significant differences between different groups according to the Duncan test. BR – basal respiration, SIR – substrate-induced respiration, MBC – microbial biomass carbon, NP – nitrification potential, MBC: OC – soil microbial ratio, qCO_2 – metabolic quotient.

Table 2. The mean ± SE values of the microbial properties of soils under from the crowns of *P. cineraria* and *P. juliflora* and control soils situated in bare areas away from trees (SE: standard error)

Variable	*P.cineraria*	*P.juliflora*	Bare soil	F test
BR (mg C-CO_2 kg^{-1})	63.58 ± 7.58^{a}	43.59 ± 4.34^{b}	25.69 ± 5.62^{c}	24.87^{**}
SIR (mg C-CO_2 kg^{-1})	865.77 ± 113.7^{a}	665.96 ± 151.27^{a}	285.80 ± 53.7^{b}	6.73^{**}
MBC (mg kg^{-1})	256.48 ± 24.75^{a}	163.86 ± 18.59^{b}	69.64 ± 5.62^{c}	9.35^{**}
NP (mg kg^{-1})	34.93 ± 9.23^{a}	26.91 ± 6.69^{ab}	10.30 ± 1.96^{b}	3.54^{*}
MBC: OC	4.27 ± 0.54^{a}	2.34 ± 0.32^{a}	1.60 ± 0.21^{b}	3.63^{**}
qCO_2	1.03 ± 0.80^{a}	1.37 ± 0.28^{a}	1.72 ± 0.46^{a}	1.95^{ns}

Significantly different values between groups of soils (according to Duncan's test) are marked with different letters (^{a,b,c}). Level of significance: $^{*}P < 0.05$, $^{**}P < 0.01$. BR – basal respiration, SIR – substrate-induced respiration, MBC – microbial biomass carbon, NP – nitrification potential, MBC: OC – soil microbial ratio, qCO_2 – metabolic quotient.

This has major implications for ecosystem functioning and biodiversity in the region and highlights the need to manage *P. juliflora* invasions and promote restoration using appropriate species in Iran and elsewhere – reinforcing suggestions made by (Sharifian et al., 2023).

More specifically, we found significant differences in under-canopy soil moisture between *P. cineraria* and *P. juliflora*, with it being higher under the canopies of the native species (Table 1). The same finding was observed by Bijani et al. (2020). The lower soil moisture content beneath the

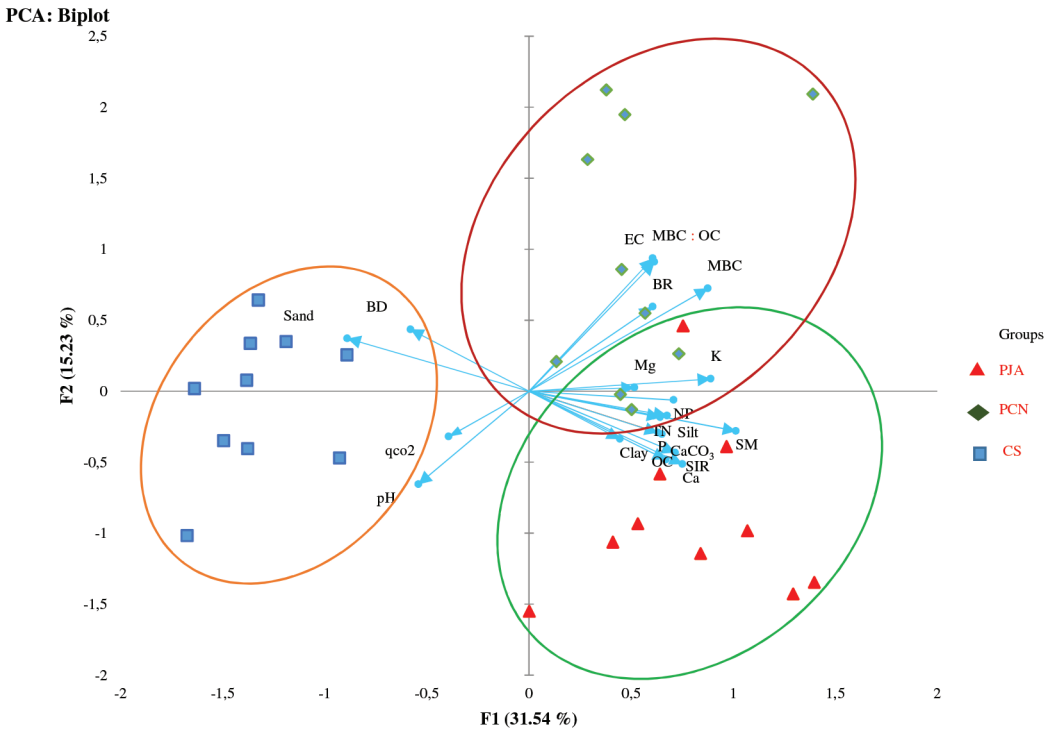

Fig. 7. Principal component analysis (PCA) of abiotic and biotic soil variables. PCN – soils under the native species *P. cinerar-ia*, PJA – soil under the non-native species *P. juliflora*, CS – control (bare) soils, BR – basal respiration, SIR – substrate-induced respiration, MBC – microbial biomass carbon, PN – potential nitrification, MBC: OC – soil microbial ratio, qCO_2 – metabolic quotient, BD – bulk density, EC – electric conductivity, $CaCO_3$ – calcium carbonate equivalent, Mg – available magnesium, Ca – available calcium, OC – organic carbon, TN – total nitrogen, K – available potassium, P – available phosphorus, and SM – soil moisture.

Table 3. Analysis of principal components (PC) of loading and eigenvalues of the abiotic and biotic soil variables. Higher loadings shown in bold had a significant influence on the components

Variables	PC1	PC2	PC3	PC4	PC5
BR	0.494	0.486	–0.119	**0.583**	–0.163
SIR	**0.585**	–0.353	0.358	0.119	0.296
MBC	**0.715**	0.592	–0.159	0.036	–0.022
NP	0.573	–0.051	**0.612**	0.193	–0.251
MBC: OC	0.494	**0.765**	–0.044	0.029	0.174
qCO2	–0.322	–0.261	–0.042	**0.665**	–0.246
Sand	**0.727**	0.303	–0.169	0.161	–0.013
Clay	0.363	–0.275	0.269	0.325	**0.621**
Silt	**0.551**	–0.139	–0.063	–0.436	–0.498
BD	–0.474	0.356	**0.569**	–0.048	–0.262
pH	–0.443	**–0.535**	–0.009	–0.072	0.076
EC	0.502	**0.743**	0.154	0.024	–0.002
CaCO3	0.532	–0.246	**–0.548**	0.267	–0.064
Mg	0.422	0.021	–0.175	**–0.596**	–0.084
Ca	**0.614**	–0.420	0.102	0.192	–0.243
OC	**0.548**	–0.392	–0.183	0.139	–0.299
TN	**0.524**	–0.149	–0.238	–0.184	0.487
K	**0.726**	0.071	0.081	–0.088	0.194
P	0.516	–0.238	**0.519**	–0.186	–0.077
SM	**0.828**	–0.229	–0.215	0.060	–0.147
Eigenvalues	6.308	3.047	1.753	1.727	1.438
Percent of total variance	31.54	15.23	8.763	8.637	7.192
Cumulative percent	31.54	46.77	55.536	64.173	71.365

BR – basal respiration, SIR – substrate-induced respiration, MBC – microbial biomass carbon, NP – nitrification potential, MBC: OC – soil microbial ratio, qCO_2 – metabolic quotient, BD – bulk density, EC – electric conductivity, $CaCO_3$ – calcium carbonate equivalent, Mg – available magnesium, Ca – available calcium, OC – organic carbon, TN – total nitrogen, K – available potassium, P – available phosphorus, and SM – soil moisture.

canopy of *P. juliflora* as compared to *P. cineraria* could potentially have adverse effects on the growth of native plant species many of which are important for grazing, thereby impacting local biodiversity and the livelihoods of pastoralists (Sharifian et al., 2023). Similarly, we observed that the soil pH was lower under the canopy of *P. juliflora* compared to soils from under the canopy of *P. cineraria*, a finding also observed by El-Keblawy et al. (2014). Moslehi et al. (2019) suggest that the decrease in soil pH under the canopy of *P. juliflora* trees can be attributed to the acidic nature of phenolic compounds present in the soil rhizosphere of *P. juliflora*. Further, we observed a significantly higher concentration of absorbable phosphorus in the soils beneath the canopy of *P. cineraria* compared to both *P. juliflora* and open space control sites (Table 1). The heightened humidity and pH levels beneath the canopy of *P. cineraria* trees likely create a more favorable environment for microorganisms leading to increased soil biota activity and as such the release of more phosphatase enzymes and higher phosphorous levels in soils (Kaur et al., 2012; Watts et al., 2010; Alizadeh et al. 2022).

Electrical conductivity (EC) was higher under the crown of *P. juliflora* compared to *P. cineraria* and even more so the open space sites, which is consistent with the findings of Kaur et al. (2012) and El-Keblawy et al. (2014) that *Prosopis* species contribute to the increase of soluble salts in soils. The reason for this may be attributed to the roots' absorption of salts, subsequently transporting them to the soil surface, as well as the recycling and decomposition of plant residues rich in absorbed salts (Farahi et al., 2014). The rise in electrical conductivity observed under *P. juliflora* in comparison to *P. cineraria* can be ascribed to the heightened suction power of its roots (Cable, 1976), which might also explain the lower moisture content in soils under *P. juliflora*.

Soil biota are sensitive to environmental changes, such as the presence of invasive species (Inderjit and Cahillm 2015). Plant invasions can drastically alter the abundance and diversity of soil microbial communities, which can have knock-on effects above ground (Kourtev et al., 2002; Aguilera et al., 2010; Hejda et al., 2009). This is an important consideration when planning and implementing arid land management and restoration. We found that the basal respiration (BR) in the soils beneath native *P. cineraria* trees was notably higher compared as to those under non-native *P. juliflora* trees (Table 2). Soil respiration can be affected by various factors such as tree canopy structures and the chemical release of plants which in turn affect soil nutrients, structure and soil biota (Raich and Tufekciogul, 2000; Catovsky and Bazzaz, 2002; Follastad Shah et al., 2010). *Prosopis juliflora* has an expansive crown that casts a wide shadow, limiting light penetration to the sub-crown area. Consequently, this region remains consistently shaded, likely contributing to the higher accumulation of litter beneath its crown. While this litter layer serves a crucial function in moisture retention, it likely exerts adverse mechanical and chemical impacts (allelopathic effects) which in turn affects soil microorganism activity (Facelli and Carson, 1991). Conversely, *P. cineraria* typically boosts soil fertility by virtue of its non-allelopathic nature and facilitation of optimal conditions for soil microorganism activity, thereby augmenting organic matter content (Bijani et al., 2020). These factors help to explain the higher soil organic carbon under *P. cineraria* trees as compared to *P. juliflora* which also is likely a key contributing factor to the heightened basic respiration activity under the native species. These observations align with the findings of Prasad and Baishya (2019). As such, the microbial biomass carbon (MBC) in soils beneath the canopy of native *P. cineraria* trees was notably higher compared to soils from beneath non-native *P. juliflora* trees.

Conclusion

This study explores the environmental impact of the invasive tree *P. juliflora*, originally introduced to southern Iran in the late 1970s for desertification control and wood production. Though it was initially valued for its role in soil and water conservation, *P. juliflora* has since posed significant threats to biodiversity and local livelihoods due to its aggressive spread and influence on ecosystem dynamics. The study contrasts the soil impacts of *P. juliflora* with those of the native species *P cineraria*, showing that in comparison *P. juliflora* is less valuable for soil conservation and health due to having lower nutrient levels and microbial activity which could further impact native plant community structures (biodiversity) and grazing potential. Overall, our results imply that the native *P. cineraria* promotes better soil fertility and microbial health, making it more beneficial for local ecosystems and used in restoration in land areas in Iran. As such we recommend better control of *P. juliflora* invasions to protect soil health, biodiversity, and regional economies reliant on agriculture and livestock and to promote the planting of native species instead.

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Author contributions

All authors contributed to the study's conception and design. Material preparation was conducted by Mohammad Matinzadeh, and Seyed Musa Sadeghi, Maryam Moslehi. Data collection, and analysis were performed by Maryam Moslehi. The first draft of the manuscript was written by Maryam Moslehi, Ross T. Shackleton, Masoumeh Izadi, Nafiseh Fanaei, Tahereh Alizadeh, and Farzad Ahmadi. Review was conducted by Maryam Moslehi and the editing was carried out by Ross T. Shackleton and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

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