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Short research contribution

GHOLAM ALI JALALI [1], HOSSEIN AKBARIAN [1], CHARLES RHOADES [2], HAMED YOUSEFZADEH [1*]

[1] Department of Forestry, Faculty of Natural Resources and Marine Sciences, Tarbiat Modares University, Noor, Mazandaran, Iran;
* e-mail: hamed_seraj20@yahoo.com (*corresponding author*)
[2] United States Forest Service, Rocky Mountain Research Station, Fort Collins, Colorado, USA

THE EFFECT OF THE HALOPHYTIC SHRUB *LYCIUM RUTHENICUM* (MUTT) ON SELECTED SOIL PROPERTIES OF A DESERT ECOSYSTEM IN CENTRAL IRAN

ABSTRACT: We compared soil properties beneath naturally-occurring patches of *Lycium ruthenicum* Murray (fam. Solanaceae) to evaluate the shrub's potential to improve the fertility of saline soils. Soil pH, total nitrogen and carbon and extractable potassium, magnesium and phosphorus were respectively significantly higher in the A and B horizons of *Lycium* shrub patches compared to adjacent unvegetated soils. The influence of *Lycium* on these soil properties increased with shrub density. Total soil N and extractable Mg and K concentrations were 1.8, 2.6- and 6.6-fold higher under dense *Lycium* shrub patches compared to unvegetated, bare areas and soil pH was 0.5 units higher. In contrast, the presence of shrubs and shrub density had no clear affect on the EC, Na or CEC of the A horizon soils. The shrub effect extended to the gypsum-rich By horizon (20–50 cm depth) and underlying B horizon (30–80 cm depth) for several soil properties. Total soil C and N were 1.8- and 1.6-fold higher beneath dense *Lycium* patches than bare soil areas. Soil pH remained 0.4 units higher under dense *Lycium* than bare soil patches. In the B horizon total soil C was twice as high beneath dense *Lycium* patches compared to the other patch types. *Lycium ruthenicum* not only tolerates the saline and drought conditions, it also produces sufficient biomass to increase the nutrient and organic matter content of surface mineral soils in this arid ecosystem and may have potential to improve soil conditions, facilitate ecosystem development and slow desertification.

KEY WORDS: salinity, soil chemistry, arid land rehabilitation, soil stabilization, desertification

Woody plants are known to influence soil properties in many of the world's ecosystems (Binkley and Giardina 1998, Jobbágy and Jackson 2001). In arid and semi-arid ecosystems, the influence of trees and shrubs are expressed as 'islands of soil fertility' associated with individual canopies (Tiedmann and Klemmedson 1977, Bernhard-Reversat 1982, Rhoades 1995). In dry environments, trees and shrubs alter inputs to the soil system by increasing interception of wet and dry deposition (Belsky *et al.* 1989) and by adding N *via* N_2-fixation (Tiedmann and Klemmedson 1977). The extensive root systems of many arid and semi-arid plants scavenge nutrients laterally and from deep soil layers and concentrate them near the soil surface or beneath plant canopies (Jobbágy and Jackson 2003). Plant canopies also alter the sub-canopy microclimate and may increase productivity of understory vegetation (Dancette and Poulain 1969, Belsky *et al.* 1989, Thompson *et al.* 2006). In arid landscapes, woody plants represent hotspots of biogeochemical cycling and sites nutrient accumulation (Rhoades 1997) that can facilitate ecosystem development.

Desert ecosystems cover about 80 million hectares in Iran and include 12 and 6 million hectares of mobile sands and active sand dunes, respectively. More than 90% of the country is classified as arid or semi-arid (Pakparpvar 1998). Climate change and desertification are expanding the deserts both of Iran and worldwide (Sen and Amal Kar 1995, Pakparvar 1998). In Iran, expanding problems of salt-affected areas have become serious issues of concern as they affect productivity and threaten the vegetation and aquatic resources (Qadir *et al.* 2007, Qureshi *et al.* 2007). Effective strategies for sustaining or restoring productive ecosystems remain poorly-developed in arid, saline regions (Lieth and Al Masoom 1993, Boer 2006). One common approach for combating land degradation is the use of plants to stabilize dunes, control soil erosion and improve soil fertility (Choukr-Allah *et al.* 1996, Moghaddam and Koocheki 2003). To be effective for these purposes plants must not only tolerate the severe saline and drought conditions, but must also produce sufficient biomass to ameliorate site and soil conditions. Few studies have assessed the utility of native woody species for improvement of dry, saline environments of Asia.

The halophytic shrub, *Lycium ruthenicum* Murray (Fam. Solanaceae) grows in arid and semi arid regions of Eastern Europe and Asia, including Afghanistan, China, Iran, Kazakhstan, Kyrgyzstan, Mongolia, Pakistan, Russia, Tajikistan, Tibet, Turkmenistan and Uzbekistan (USDA 2009). *L. ruthenicum* is a multi-stemmed, spiny shrub that typically reaches 0.5 to 2 m in height. It tolerates a wide range of soil types and can grow on nutrient-poor and saline soils. The species can also survive on shallow, rocky soils and fractured bedrock (Zheng-yi and Raven 1994; USDA 2009). *L. ruthenicum* is distributed throughout Iran and it is found from 100 to 2000 m above sea level (Schönbeck-Temesy 1972, Khatamsaz 1996, Moghaddam and Koocheki 2003).

Lycium is a candidate for revegetation of marginal or degraded lands with low fertility or high salinity. It is used for erosion control in parts of Asia (Zheng-yi and Raven 1994), but its potential role in environmental protection has not been evaluated in Iran (Moghaddam and Koocheki 2003). The objective of this study was to evaluate the shrub's capacity to improve soil fertility in degraded, saline soils by comparing soil properties beneath patches of *Lycium* and adjacent unvegetated land.

The study was conducted at 1360 m above sea level in the Chah Afzal region of the Dasht-e Kavir desert in the province of Yazd, Iran (32°18'–32°25'N, 53°55'–54°7'W). Dasht-e Kavir, also known as Kavir-e Namak or The Great Salt Desert, is a large desert lying in the middle of the Plateau of Iran. This desert region has cold and dry winter and dry summer. Mean annual precipitation and temperature average 61.5 mm and 26.4°C (1960–1991 data record, Yazd, Iran); temperature maxima and minima occur in July (32°C) and January (5°C), respectively. Monthly precipitation is highest in March on average (Aref 1991).

The extreme heat and frequent wind storms in Dasht-e Kavir make the area nearly uninhabitable and impossible to cultivate. Severe wind storms cause extensive soil erosion and have created sand dunes that reach 40 m in height. Extreme temperatures and subsequent evaporation form extensive salt crusts. Vegetation in the Dasht-e Kavir is sparse and is adapted to the hot and arid climate and the saline soil conditions. The most widespread plant is *Artemisia vulgaris* L. In the Dasht-e Kavir, *Lycium ruthenicum* grows in patches 100–150 m^2 in size that are spaced 0.5 to 2.0 m apart.

To evaluate the effect of *Lycium* on soil properties, we compared unvegetated areas and adjacent areas supporting low, medium and high density shrub patches. We randomly selected three replicates of the four patch types within a 700 ha study area. High density patches had 33% shrub cover, 11 stems m^{-2} and an average stem height of 91 cm. Medium and low density patches supported approximately 50% and 25% of the cover and density of the dense shrub patches. Soil sampling was carried out in October and November 2000, prior to litter fall. Sample plots (25 m^2) were established at the center of each study patch (n = 12), 60 m from the nearest unvegetated area. Within each plot, mineral soil was sam-

Table 1. Soil properties under three densities of the shrub *Lycium ruthenicum* and adjacent bare soil patches in the Dasht-e Kavir desert of central Iran. Significant of difference between means are denoted by different letters according to Duncan's multiple range test (a = 0.05).
Soil horizons: A: 13–20 cm; By: 13–47 cm; B: 47–74 cm.

Soil Horizon	Shrub Density	pH	EC*	K	Na	Ca	Mg	P	CEC*
			ds/m	mg kg^{-1}	mg kg^{-1}	mg kg^{-1}	mg kg^{-1} mg kg^{-1}	mg kg^{-1}	cmol kg^{-1}
A	High	7.7±0.3 a	19.8±5.1 a	353.3±11.5 a	207.2±79.1 a	171.1±57.5 b	93.8±10.2 a	4.1 a±3.3	11.7±5.1 a
	Moderate	7.4±0.1 ab	16.9±7.6 a	240.0±91.6 b	208.4±67.1 a	189.1±52.5b	79.7±42.6 ab	25.0±1.1	12.6±2.5 a
	Low	7.8±0.2 a	18.6±2.8 a	156.6±50.3 c	303.7±178.1 a	274.6±46.7 a	32.5±11.5 b	3.0 a±2.3	11.6±3.1 a
	Bare	7.2±0.3 b	21.3±6.9 a	53.3±28.7 c	202.7±38.4 a	209±39.8 ab	34.8±12.2 b	31.2±1.1	9.7±5.7 a
By	High	7.9±0.1 a	11.3±0.5 a	244.1±5.1 a	184.1±55.6 a	150.0±5.5 a	94.1±6.9 a	5.2a±3.0	7.8±2.4 a
	Moderate	7.7±0.2 ab	13.4±6.5 a	250.2±49.3 a	230.3±59.7 a	179.3±42.2 a	70.8±11.7 a	2.6a±2.4	9.1±2.8 a
	Low	7.3±0.2 b	18.9±10.4 a	332.7±58.0 a	228.4±95.0 a	227.1±100.5 a	105.6±56.0 a	15.9a±3.1	10.8±5.7 a
	Bare	7.5±0.3 ab	11.2±2.1 a	243.9±44.6 a	193.2±48.1 a	181.6±37.7 a	62.2±9.5 a	8.2a±3.0	9.1±5.9 a
B	High	7.6±0.2 a	3.1±0.5 a	47.5±8.1 a	211.0±55.1 a	160.3±32.8 a	52.5±25.0 a	5.2 a±5.1	3.5±2.4 a
	Moderate	7.3±0.3 a	4.0±0.9 a	36.2±6.9 a	242.9±62.2 a	173.4±41.0 a	70.5±38.0 a	4.6b±4.4	3.5±1.8 a
	Low	7.3±0.1 a	4.1±5.8 a	43.9±8.6 a	212.3±34.7 a	146.3±30.1 a	66.9±32.5 a	6.2 b±4.7	3.2±2.0 a
	Bare	7.4±0.2 a	3.2±0.7 a	42.5±9.8 a	203.4±47.9 a	147.7±24.4 a	57.8±28.2 a	8.2 b±5.7	5.3±4.7 a

* EC (Electrical conductivity), CEC (cation-exchange capacity).

pled at 20 systematically-distributed points using a metal auger after removing the litter layer and soil cores were separated into three morphological horizons.

The samples were analyzed for pH and nutrient concentrations according to the following procedures (ISRIC/FAO-UN 1995, Black *et al.* 1965): Soil pH and electrical conductivity (EC) were measured in a 1:2.5 soil:water solution using an Orion Ion analyzer (Model 901). Soil carbon was determined using the Walkley-Black technique and total nitrogen was measured using a semi micro-Kjeldhal technique (Bremner and Mulvaney 1982). The plant available Olson-P was determined with spectrophotometer after extracting with sodium bicarbonate. Plant available Na, K, Ca, and Mg were determined with an atomic absorption spectrophotometer after ammonium acetate extraction at pH 9. Cation exchange capacity (CEC) was measured after displacement of the exchangeable base cations by 1 M ammonium acetate, washing

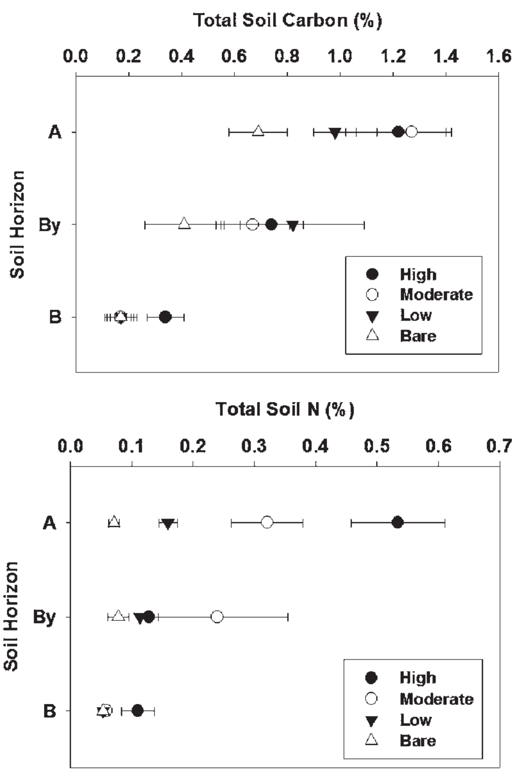

Fig.1. Total soil carbon (a) and N (b) concentrations (Mean with SD) in soils beneath shrub patches with varying density of *Lycium ruthenicum* and adjacent bare soil patches. Soil horizons – see Table 1.

with ethanol, and then replacement of ammonia by sodium chloride extraction.

Within three morphologic soil horizons (A: 13–20 cm; By: 13–47 cm; B: 47–74 cm), soil analyses were subjected to two-way analysis of variance (ANOVA) to detect differences between four levels of shrub cover (bare ground, low, moderate, high). Assumptions of normality were checked with Shapiro-Wilk's test and homogeneity of variance was tested with Levene's test (Sokal and Rohlf 1995). Duncan's multiple range test was used to group parameter means (Steele and Torrie 1980). The level of significance used was 0.05.

Soil EC and pH averaged 12 dS cm^{-1} and 7.5 in our study site (Table 1). Below the By horizon EC declined by about 80% compared to the upper horizons. CEC (8.2 cmol kg^{-1}) was low, especially below the By horizon.

The density of *Lycium ruthenicum* shrub cover significantly altered key soil properties (Table 1 and Fig. 1). The influence of *Lycium* shrubs was most apparent in A horizon soils (0 to 20 cm depth) and declined with soil depth. Extractable Mg and K concentrations and soil pH and total N were all highest beneath dense *Lycium* and differed from bare patches. Soil pH was *ca* 0.5 units higher under dense *Lycium* cover compared to bare soil patches in both the surface and in the gypsic By horizon. Soil C and N are 1.8- and 7.5-fold higher beneath dense *Lycium* shrub patches, compared to bare soil patches (Figs 1a and b). Similarly, extractable Mg and K are 2.6- and 6.6-fold higher under dense *Lycium* shrub cover. The presence of shrubs and shrub density had no clear affect on the EC, Na or CEC of the A horizon soils (Table 1).

Shrub effects on several soil attributes extended to the gypsum-rich By horizon (20 to 50 cm depth) and the underlying B horizon (50 to 80 cm depth). For the By horizon, total soil C and N were 1.8- and 1.6-fold higher beneath dense *Lycium* patches than bare soil areas. Soil pH was 0.4 units higher under dense *Lycium* than bare soil patches. Soil N is undetectable in the B horizon, but total C remains twice as high beneath dense *Lycium* patches compared to any of the other patch types.

Amount of P was increasing with depth, so that the B layer has the highest amount of P. It seems that low quantity of phosphorus in A and By layers in comparison with B layer is because of high saltiness and high calcium in these two layers (*i.e.* A and By) in comparison with B layer. Higher quantity of phosphorus in the B horizon is because of higher quantity of the sand in comparison with other layers.

These results demonstrate the *Lycium ruthenicum* is not only tolerant of the saline and drought conditions of the Dasht-e Kavir desert, but that the shrub also produces sufficient biomass to increase the nutrient and organic matter content of surface mineral soils in this arid ecosystem. Additional research and future planting trials will be needed to assess the potential of this shrub to improve soil conditions, facilitate ecosystem development and slow desertification in Iran.

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