Neltuma laevigata and its influence on soil fertility in the Valle del Mezquital, Hidalgo, Mexico

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ABSTRACT

Objective: The physicochemical characteristics of soil fertility, based on the influence of mesquite (*Neltuma laevigata*) were evaluated in an agricultural community of Ixmiquilpan, Hidalgo, Mexico.

Design/Methodology/Approach: Based on NOM-021-SEMARNAT-2000, physical and chemical parameters were evaluated. Nine samples were taken from each of the four sites with and without mesquite (n=36). The relationship between soil fertility and the presence or absence of mesquite mesquite was determined with a paired t- test ($p<0.05$).

Results: A significant difference in organic matter content was recorded. Humic substances and acids are higher in soils with natural vegetation with mesquite than in soils with natural vegetation without mesquite.

Study Limitations/Implications: The study does not consider changes in microbiological biodiversity or the influence of other plant species in organic matter content and humic substances.

Findings/Conclusions: Mesquite promotes soil fertility in the area; consequently, proposing management strategies for this species is fundamental in the Valle del Mezquital.

Keywords: mesquite, deforestation, nitrogen fixation, organic matter.

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INTRODUCTION

Deforestation has rapidly impacted more than half of the Mexican territory (Godínez-Montoya *et al.*, 2022). Overgrazing, land use change, post-harvest tillage, and poor management of agricultural soils have speeded the process (Hernández-González *et al.*, 2018). The introduction of agricultural irrigation systems to the Valle del Mezquital that use sewage water from urban areas has caused an almost complete change in the semiarid landscape, significantly reducing the original plant cover. This process has diminished the regional extension of mesquite forests, potentially impacting soil structure and fertility (Domínguez-Narváez *et al.*, 2023).

Arid and semiarid ecosystems -which cover approximately 60% of the Mexican territory- are fundamental, as a result of their plant diversity (6,000 species) and their endemism (50%) (Montaño *et al.*, 2016). These ecosystems have processes that maintain soil function and microbial activity, favoring biogeochemical cycles (Jurado-Guerra *et al.*, 2021). Some

of the major species in these ecosystems belong to the genus *Neltuma* sp., including mesquite (*Neltuma laevigata*), formerly known as *Prosospis laevigata* (Hughes *et al.*, 2022). Depending on soil depth, this evergreen thorny tree can grow up to 10 m. This legume belongs to family Fabaceae and it is a valuable resource for the inhabitants of semiarid areas, such as El Alberto community (Del Valle-Martínez *et al.*, 2023). *Neltuma laevigata* is a key species of the semiarid ecosystem, because it helps secondary vegetation to thrive (nurse effect), favoring the ecological succession of these systems (Estrada-Castillón *et al.*, 2024).

The properties of mesquite are not limited to their environmental benefits. Some parts of this multipurpose species, such as roots, trunk, branches, leaves, pods, flowers, and gums, have medical uses. Batista-Roche and Huerta-Campo (2021) pointed out that the extracts of mesquite leaves have analgesic, anthelmintic, antiemetic, antioxidant, and healing effects, as a result of its flavonoids, tannins, alkaloids, and phenolic compounds. Meanwhile, Armienta *et al.* (2008) studied the genus *Neltuma* sp. and highlighted its soil bioremediation and restoration potential; these capacities are ideal to mitigate the volatile component dispersion in open-pit mining areas. Therefore, some physicochemical characteristics of soil fertility, resulting from the influence of mesquite (*Neltuma laevigata*), were evaluated in an agricultural community of Ixmiquilpan, Hidalgo, Mexico.

MATERIALS AND METHODS

Study area

The study was carried out in El Alberto community, located at 20° 29’ N and 99° 13’ W, at 1,700-2,250 m.a.s.l., 12 km away from Ixmiquilpan, Hidalgo, Mexico (Figure 1). The community has an extension of approximately 22 km^2. It borders with Cantinela (north), Panales (west), the municipality of Alfajayucan (southwest), Dadhó, Boxaxni, and Loma (south), and La Estancia (southeast) (Del Valle-Martínez *et al.*, 2023). The climate is semiarid, with a mean annual precipitation of 389 mm. The area has a predominant xerophytic vegetation.

Figure 1. Map of El Alberto, Hidalgo, Mexico.

Sampling and physicochemical characterization of the soil

The analysis of the samples included a selection of agricultural soils with mesquite (ASWM) and without mesquite (ASWOM), as well as soils with natural vegetation with mesquite (NWM) and without mesquite (NWOM). A 20-cm deep sampling was carried out with a selection by convenience process, obtaining nine samples per site (n=36) (Cabrera-Rodríguez *et al.*, 2024). Soil samples were air dried under shade conditions; afterwards, they were sieved with a 2 mm mesh and stored in polypropylene bags, awaiting their chemical and physical analyses. Gravimetry was used to determine their moisture content (AOAC, 2005) and a pressure plate was used to establish moisture retention capacity (Richards, 1956). The pH, electric conductivity, and total nitrogen content of each sample was determined (Rowell, 1994). The silver thiourea method was used to establish the interchangeable bases (SEMARNAT, 2000). In addition, the Walkley-Black method was used to determine organic matter and organic carbon content. The Bouyoucos method was used to determine the texture of the samples (SEMARNAT, 2000). Humic and fulvic acid content was established following the protocol proposed by Sánchez-Monedero *et al.* (2002). The statistical analysis included a verification of the assumption of normality and homoscedasticity of the variables. In addition, a student's t-test ($p<0.05$) was performed with the SPSS software to determine any differences between the physical and the chemical variables of the agricultural soils and the soils with natural vegetation, with and without mesquite.

RESULTS AND DISCUSSION

The Valle del Mezquital is made up of a vast network of agricultural plots, both under irrigation and rainfed systems. Hernández-González *et al.* (2018) carried out a comparative study about soil fertility changes caused by anthropic activities. In their study, these authors pointed out that anthropic activities influence physicochemical parameters of soils, regarding organic matter, pH, and aggregate stability. In the case of El Alberto, soils with natural vegetation with mesquite (NWM) and without mesquite (NWOM) have a slightly acid pH (pH=6.7). Agricultural soils with mesquite (ASWM) and without mesquite (ASWOM) have a strongly alkaline content (pH=8.23). An alkaline pH can indicate that there are less nutrients available for the crops (Riaz *et al.*, 2020). In both cases, soils have a sandy and sandy loam texture (Table 1).

Table 1. Soil texture in El Alberto, Ixmiquilpan, Hidalgo.

Variable	With natural vegetation with (NCM) and without mesquite (NSM) (g kg^{-1})	Agricultural with (ACM) and without mesquite (ASM) (g kg^{-1})
Texture	Sandy and sandy loam	
Particle size distribution	Clay 25.3, silt 105 and sand 869.6	Clay 57.2, silt 150.8 and sand 792
pH	6.7	8.23

NWM (NCM): soils with natural vegetation with mesquite; NWOM (NSM): soils with natural vegetation without mesquite; ASWM (ACM): agricultural soils with mesquite; ASWOM (ASM): agricultural soils without mesquite. Source: table developed by the authors.

Variable With natural vegetation with (NCM) and without mesquite (NSM) Agricultural with (ACM) and without mesquite (ASM)

Table 2 shows the physical and chemical characteristics of the soil. The organic matter and organic carbon percentages, as well as the nitrogen and phosphorous concentrations, were higher in the sites with mesquite, regardless of soil use (α=0.05). Mesquite favors organic matter and organic carbon concentrations in the soil, as a consequence of litterfall decomposition (Cuss and Guéguen, 2013). The mineralization of these organic compounds increases nutrient concentration (phosphorous and nitrogen); in addition, Carrillo-Flores *et al.* (2007) pointed out that mineralization allows a greater fixation of atmospheric nitrogen. Table 2 shows another positive element of *Neltuma laevigata* in agricultural areas: the improvement of water retention capacity and moisture in the soil (α=0.05). Soils with higher water retention capacity and higher moisture percentages guarantee a constant supply of water to the roots, even during draughts (Rodríguez-Sauceda *et al.*, 2019).

Soils with mesquite recorded an enhanced water retention capacity and moisture content. Organic matter (particularly humus) is a natural sponge that can absorb and retain large amounts of water, improving water availability in the soil (Lehmann and Kleber, 2015). This phenomenon could explain the higher moisture and water retention capacity of soils with mesquite, both in areas with natural vegetation or in agricultural soils.

The average concentrations of calcium, magnesium, and sodium recorded higher concentrations (3.8, 2.1, and 7.8, respectively) in agricultural soils (with and without mesquite) than in soils with natural vegetation (with and without mesquite). These values

Table 2. Physicochemical parameters evaluated to determine soil fertility in El Alberto, Ixmiquilpan, Hidalgo.

Physical and chemical tests Sites	Sites			
	Soils with natural vegetation		Agricultural soils	
	with mesquite	without mesquite	with mesquite	without mesquite
rganic carbon (%)	3.15±1.30*	1.67±0.26	1.72±0.33*	0.72±0.03
Organic matter (%)	5.43±2.24*	2.88±0.45	2.97±0.98*	1.24±0.09
Total nitrogen (%)	0.32±0.12*	0.18±0.04	0.18±0.04*	0.11±0.04
Electrical conductivity (dS/m)	3.56±3.88 *	0.42±0.17	2.77±2.56*	3.12±3.11
Water holding capacity (mm/m)	81.44±7.66*	91.64±1.27	108.17±12.6*	82.16±3.15
Moisture percentage (%)	7.91±2.59*	13.79±2.67	13.55±4.40*	14.12±7.91
Phosphorus (mg kg^{-1})	54.85±15.0*	29.75±3.35	48.85±11.6*	25.48±5.43
Calcium (Cmol (+) kg^{-1})	14.43±4.96~	14.27±6.11	29.69±12.6~	24.56±9.78
Magnesium (Cmol (+) kg^{-1})	4.91±1.63~	3.86±1.39	11.69±4.79*	7.05±1.82
Sodium (Cmol (+) kg^{-1})	0.24± 0.22~	0.14±0.93	0.98±0.88	2.03±0.95*
g CAH / kg humic acids	6.11±2.41*	3.26±1.75	3.12±2.14~	1.51±0.25
g CAF/ kg fulvic acids	4.18±1.78*	2.68±1.64	4.29±3.39~	3.94±3.97
g C humins /kg	23.59±11.7*	20.67±7.55	22.49±14.1~	11.42±11.3

Asterisks (*) show significant differences between soils with and without mesquite, while the (~) shows no significant differences.

are related to the use of fertilizers in agricultural areas, although their long-term use can cause salinity in soils. Armienta *et al.* (2008) proved that this species can grow in areas with a high salinity content and regulate the number of these ions in soils. Consequently, *Neltuma* sp. is a viable option for the restoration of soils degraded by salts.

The results of humic substances showed a significant difference of humic acid content between NWM and NWOM. However, there was no significant difference (α=0.05) between ASWM and ASWOM sites. The same results were obtained in the comparison of fulvic acid and humic substance contents. Moraes-Tavares and Nahas (2014) pointed out that the land use influences humic substance content and the humification process that takes place in the first 20 cm of the carbon reservoir.

CONCLUSIONS

The sampling areas with mesquite (*Neltuma laevigata*) are more fertile as a result of their higher organic matter and humic acid content. In addition, the total nitrogen and phosphorous levels available are higher in this soil than in areas without mesquite, both in soils with natural vegetation and mesquite and in agricultural soils. In conclusion, mesquite conservation in the semiarid ecosystems of the Valle del Mezquital can help to maintain soil fertility and improve water retention.

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