DESERT

Desert
Online at http://desert.ut.ac.ir

Desert 25-1 (2020) 123–130

The effect of amendments on the physical and chemical properties of soil in salt-land of Nazarabad, Alborz Province

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Received: 20 December 2019; Received in revised form: 15 February 2020; Accepted: 20 February 2020

Abstract

Rangelands are very diverse, and they spread from low vegetation desert areas to those with more rainfall and more cover. In saline and desert areas, there are many restrictions on vegetation establishment, hence the use of amendments. The study area is located south of Nazarabad city in Alborz province, Iran. In this study, different amendments, such as mineral biochar, arbuscular mycorrhiza fungi (AMF), and acrylic resin polymer (ARP) were utilized at the base of *Nitraria schoberi* seedlings. Each amendment was used at four levels. A total of 13 treatments (each treatment with 10 replicates) were evaluated. Five soil samples were taken from each treatment to determine the physical and chemical properties of soil (pH, EC, C, N, P, K, C/N, bulk density, particle density, pores, moisture, soil texture) for testing. The results showed that on average, more than 60% of the soil texture was clay. Furthermore, the used amendments had different effects on the physical and chemical properties of the soil. Biochar increased the carbon and nitrogen content of the soil at all levels. Moreover, AMF increased soil nitrogen and carbon, and ARP reduced soil bulk density and increased soil porosity, moisture, nitrogen, and carbon content. With increasing the level of biochar and ARP, negative effects were observed, and these amendments increased soil acidity and salinity in the study area; however, AMF reduced the soil salinity in the study area.

Keywords: Biochar; Mycorrhiza; Polymer; Salinity; Arid-land

1. Introduction

With the increase in population, the needs of human societies become more diverse, natural resources become scarce, and rangelands become a growing valuable natural resource. On the other hand, human-dominated rangelands in the world are very widespread, varying from rangelands with very low desert cover to more rainfed and more cover areas, including bush rangelands and those with scarce trees. There are differences between these two very wide ranges regrarding environmental conditions. These changes in factors have resulted in the creation of different types of environment, each with its own set of conditions. It is imperative to pay attention to any of these environments, otherwise the plans will not be sufficiently accurate, entailing huge costs, waste of energy and time, and loss of rangeland vegetation and soil (Moghaddam, 2009). Iran has an area of over 164 million hectares, and rangelands account for nearly 54.6% of the total land area and 65% of natural resources in Iran (Badripour *et al.*, 2006). They are the largest terrestrial ecosystem in the country, thus playing an important role in the economy of the country by providing ecological goods. Approximately 7.3 million hectares of land are saline and playa regions (Jafari and Tavili, 2019). In desert areas, there are many limitations on vegetation establishment, leading to different vegetation patterns in these areas compared with other adjacent areas. Awareness of these differences allows for a more accurate understanding of vegetation cover in terms of vegetation structure, modification and development of vegetation in a more scientific and purposeful way.

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Desertification is one of the most serious types of land degradation, with various technical, economic, and social dimensions as the third major global challenge, preceded byclimate change and freshwater scarcity (Zhao *et al*., 2009).

Soil conditioner is a product that is added to soil to improve its physical properties, particularly fertility (ability to feed the plants) and sometimes to improve the mechanical conditions. In general, the term soil conditioner is used as a subset of soil amendments, often including a wide range of fertilizers and inorganic substances (SSSA, 2008). Chemical fertilizers are sometimes utilized in rangelands to improve the soil and growth of plants and seedlings. The excessive use of fertilizers adversely impacts the soil structure and leads to imbalance in the physical and chemical properties of the soil, thereby reducing nutrient uptake (Seran *et al*., 2010).

Organic matter is generally known as the basis of soil fertility owing toits constitutive effects on physical, chemical, and biological properties (Orozco *et al*., 1996). The use of biochar as soil amendment can be a good alternative to chemical fertilizers. Biochar has many positive effects on soil (physical, chemical, biological). It is also employed to maintain soil organic carbon levels and aggregate stability (Kimetu and Lehmann, 2010; Tejada and Gonzalez, 2007).

Arbuscular mycorrhizal fungi (AMF) are among the most important soil organisms critically involved in soil structure (Tisdall, 1991). Of the arid plant species, 80-90% coexist with mycorrhizal fungi, and AMF are highly dependent on plants for carbon supply (Smith and Read, 2008). Numerous studies have been conducted on mycorrhizal fungi and their association with enzymes (Wang *et al*., 2006; Moradi *et al*., 2014; Wu *et al*., 2011).

Superabsorbent polymers can absorb large amounts of water or aqueous solutions (Koochakzadeh *et al*., 2000). These polymers are also able to absorb water up to several hundred times the weight of polymer added to the soil; owingto this property, they have been introduced as a solution for crop production in light soils and arid regions (Robiul *et al*., 2013; Shooshtarian *et al*., 2012). Acrylic resin polymer and optimized acrylic resin/cellulose polymer have a positive effect on soil and vegetation improvement (Kamali, 2014).

Alborz province comprises about 0.3%of Iran's area, accounting for approximately 3% of the country's population. Rangelands of the study area are exposed to desertification in Nazarabad city (adjacent to Eshtehard city). One of the strategies for combating desertification and improving rangelands is to use modern, biologic amendments, which enhance the physical and chemical properties of the soil and enable plants to use water more efficiently. Established vegetation protects soil and water and prevent future environmental crises, such as dust, flood, erosion, and land degradation. In the present study, the effect of amendments, including natural biochar, arbuscular mycorrhizal fungi, and acrylic resin polymer was investigated on the physical and chemical properties of soil in the salt-land of Nazarabad, Alborz province, for one year.

2. Materials and Methods

2.1. Study area

The study area is located at 50º 26´ east longitude and 35º 53´ north latitude in southern Nazarabad, southwest of Alborz province (Fig. 1). The mean annual rainfall and the mean annual temperature of the region are 293 mm and 14.9 °C, respectively. The duration of the dry season is around six months from May to October, and the climate is semi-arid (based on modified Dartmouth method). The study area is part of semi-steppe rangelands and seasonally grazed in winter. The vegetation of the study area is part of the Irano-Turanian floristic region. Closeness to Shur River is also an important feature of this region, the study areas halophyte species include *Halocnemum strobilaceum* and *Seidlitzia rosmarinus* (Fig. 2).

2.2. Method

The utilized amendments consisted of mineral (or natural) Biochar, Arbuscular Mycorrhiza Fungi (AMF), and Acrylic Resin Polymer (ARP). Amendments were used at the base of *Nitraria schoberi* (from Zygophyllaceae family) seedling. *Nitraria schoberi* is a high salinity resistant species that grows in the deserts of Iran (Naser, 2014). The values considered for biochar were 250 (B 1), 500 (B 2), 1000 (B 3), and 2000 (B 4) grams per seedling, respectively. The AMF amounts were 50 (M 1), 100 (M 2), 200 (M 3), and 400 (M 4) grams per seedling, respectively. The values used for ARP were 25 (P 1), 50 (P 2), 100 (P 3), and 200 (P 4) grams per seedling, respectively. The number of replicates for each treatment was 10 and with the control treatment included, a total of 130 seedlings were investigated in 13 treatments. The site was primarily identified through field visits. The site was selected homogeneously in terms of topographic features (height, slope, direction) and soil characteristics. The distance between seedlings was 4 m, and the rows were 5 m apart. The pits were 50 cm deep and 50 cm in diameter. To use the biochar, about 10 kg of the soil was mixed with biochar and poured into drilled holes to plant the seedlings(this procedure was the same for all levels). Mycorrhizae were applied directly under the seedlings and in contact with the roots. The polymer was liquid and effused around the collar of the seedlings. The study site and surrounding areas were enclosed for one year. In each treatment, five pits were selected for soil sampling in order to specify the physical and chemical properties of the soil for testing. Samples were taken from 0-30 cm soil depths, where the seedlings were grown. Soil factors, such asacidity (pH), salinity (EC), carbon (C), nitrogen (N), phosphorus (P), potassium (P), carbon to nitrogen ratio (C/N), bulk density (BD), particle density (PD), pores, moisture, and soil texture (sand, silt, and clay) were measured at the November 2018 and November 2019. BD was measured by ring method, PD by graduated cylinder method, soil texture by Bouyoucos hydrometer method, K (Exchangeable) by Flame photometer, P (Exchangeable) by Olsen methods, pH by pH-meter, EC by EC-meter, total N by Kjeldahl methods, and C by Walkley-Black method. The effect of amendments on the physical and chemical properties of the soil was studied in a completely randomized design. One-way analysis of variance (ANOVA) was used to determine the effect of amendments, and Duncan's multiple range test compared the means.

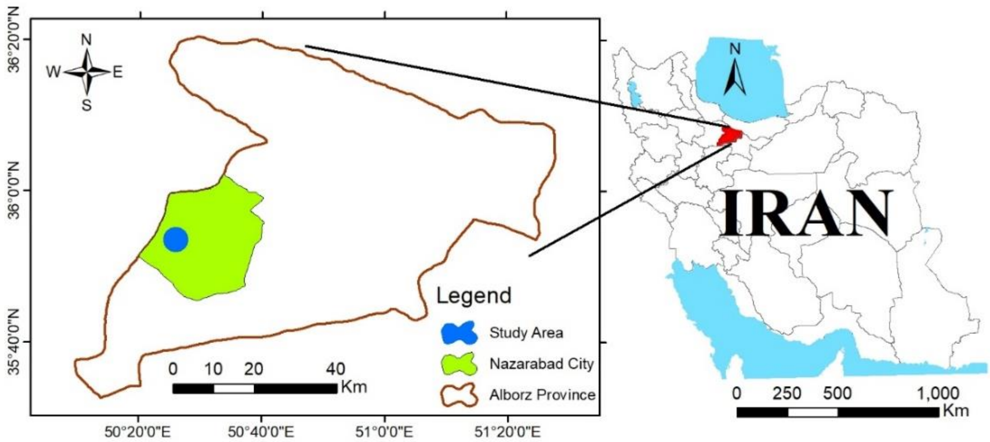

Fig. 1. Geographic location of the study area


Fig. 2. A view of the study area

3. Results

Based on the results, prior to adding the amendments to the soil (at the beginning of the study), the initial soil in the study area had a clay texture, high salinity, and low nitrogen and carbon (Table 1).

Table 1. The initial physical and chemical characteristics of the soil in the study area

Properties	Value
pH	8.058±0.044
EC (dS/m)	37.866±4.259
C (%)	0.498±0.013
N (%)	0.070±0.001
P (ppm)	15.48±2.072
K (ppm)	510.4±3.507
C/N (%)	7.073±0.125
Bulk density (gr/cm^3)	1.241±0.001
Particle density (gr/cm^3)	2.631±0
Pore (%)	52.83±0.05
Moisture (%)	8.56±0.191
Soil Texture	Clay (63.2%), Silt (25%), Sand (11.8%)

Analysis of variance indicated no significant difference between control treatment and the initial physical and chemical properties; neither did the measured properties of the soil change significantly following a year. A number of differences were observed in certain properties, but none were statistically significant. Analysis of variance showed that the amendments had a positive or negative effect on the physical and chemical properties of the soil compared to the control treatment in the study area (Table 2).

Table 2. Analysis of variance concerning the impact of amendment treatments on soil properties in the study area

Factor	Source	Sum of Squares	DF	Mean Square	F Value
pH	Between Groups	0.347	13.000	0.027	7.980**
	Within Groups	0.187	56.000	0.003	
	Total	0.534	69.000		
EC (dS/m)	Between Groups	4051.865	13.000	311.682	36.110**
	Within Groups	483.355	56.000	8.631	
	Total	4535.220	69.000		
C (%)	Between Groups	1.051	13.000	.081	38.961**
	Within Groups	.116	56.000	.002	
	Total	1.168	69.000		
N (%)	Between Groups	.007	13.000	.001	22.982**
	Within Groups	.001	56.000	.000	
	Total	.008	69.000		
P (ppm)	Between Groups	356.597	13.000	27.431	7.071**
	Within Groups	217.238	56.000	3.879	
	Total	573.835	69.000		
K (ppm)	Between Groups	80040.971	13.000	6156.998	10.503**
	Within Groups	32828.400	56.000	586.221	
	Total	112869.371	69.000		
C/N (%)	Between Groups	41.762	13.000	3.212	58.985**
	Within Groups	3.050	56.000	.054	
	Total	44.812	69.000		
Bulk density (gr/cm^3)	Between Groups	0.111	13.000	0.009	315.798**
	Within Groups	0.002	56.000	0.000	
	Total	0.112	69.000		
Pore (%)	Between Groups	118.089	13.000	9.084	221.672**
	Within Groups	2.295	56.000	.041	
	Total	120.384	69.000		
Moisture (%)	Between Groups	116.042	13.000	8.926	89.446**
	Within Groups	5.589	56.000	.100	
	Total	121.630	69.000		

** Significant at 0.01 * significant at 0.05 ^{ns} not significant

Comparison of Duncan's multivariate mean between the treatments showed that the control treatment had the lowest and biochar 4 treatment had the highest pH. Mycorrhizal 4 had the lowest EC, biochar 4 had the highest EC, and mycorrhizal 4, 3, and 2, polymer 1, and biochar 1, 2, and 3 had less EC compared with the control treatment. Polymers 3 and 4 had the highest C and C/N, and all treatments increased the carbon except for the control treatment. All treatments had higher C/N than the control treatment. Treatment with mycorrhizal 4 resulted in the highest N while that of biochar 1 had the lowest N. Polymer 4 and 3 treatments had the highest amount of P, and biochar 4 and polymer 4 treatments had the highest K (Fig. 3).

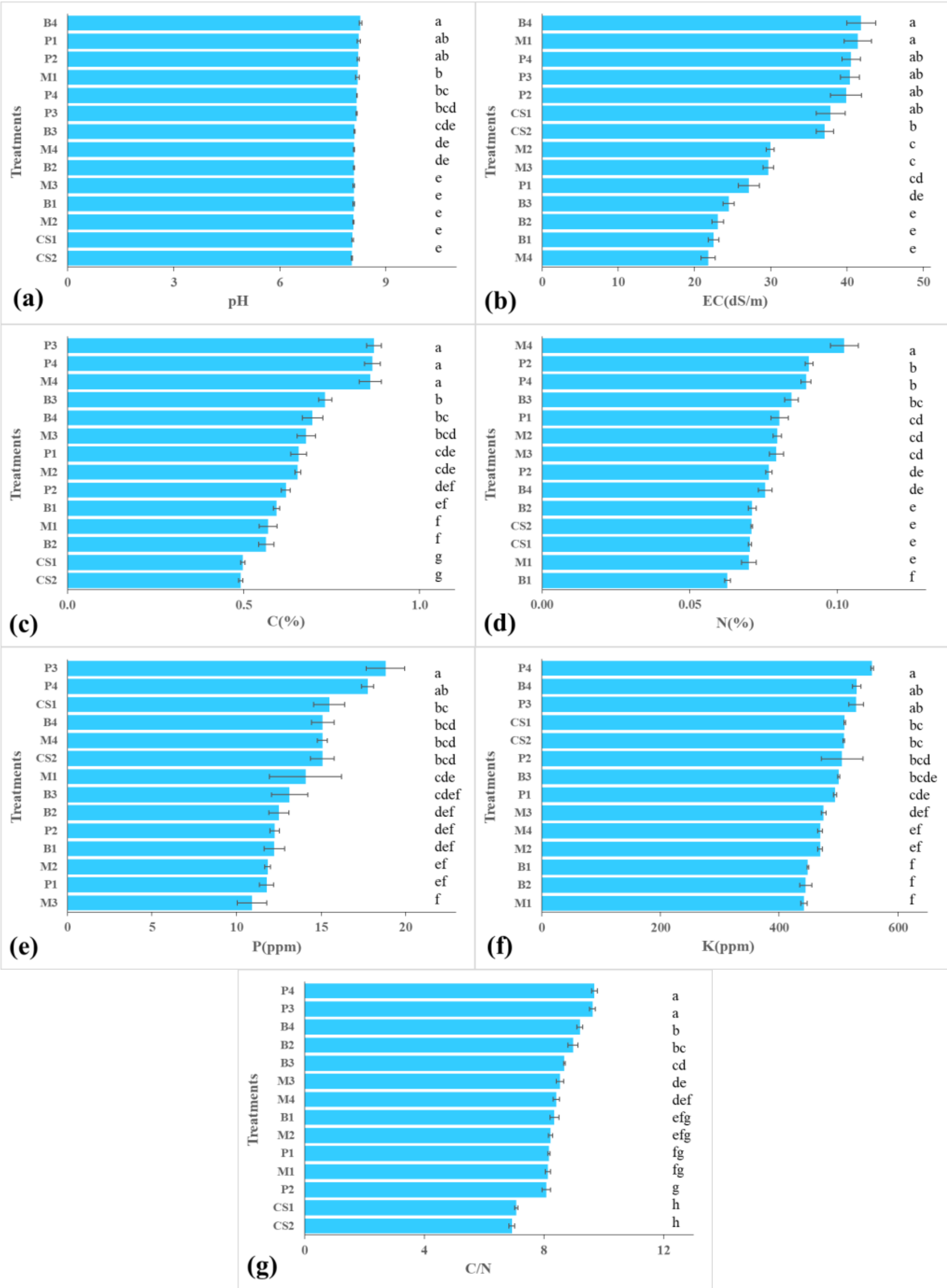

Fig. 3. Duncan's multiple range test, effect of amendments treatments on (a): pH; (b): EC; (c): C; (d): N; (e): P; (f): K; (g): C/N

All treatments had increased bulk density compared to the control treatment; this treatment had the highest BD whereas polymers 3 and 4 had the lowest BD. All treatments led to an increase in the moisture compared to the control treatment; the highest moisture belonged to polymers 3 and 4, and the lowest one was observed in the control treatment (Fig. 4). The silt content of treatments was not significantly different from the control; however, the treatments had significant differences among them, with polymers 3 and 4 having the highest silt. Except for polymers 3 and 4, clay content increased in other treatments, and the sand content was reduced in all treatments with the exception of biochar 4 treatment. Additionally, the soil texture triangle was drawn at the beginning and end of the study, showing that the soil texture did not change (Fig. 5).

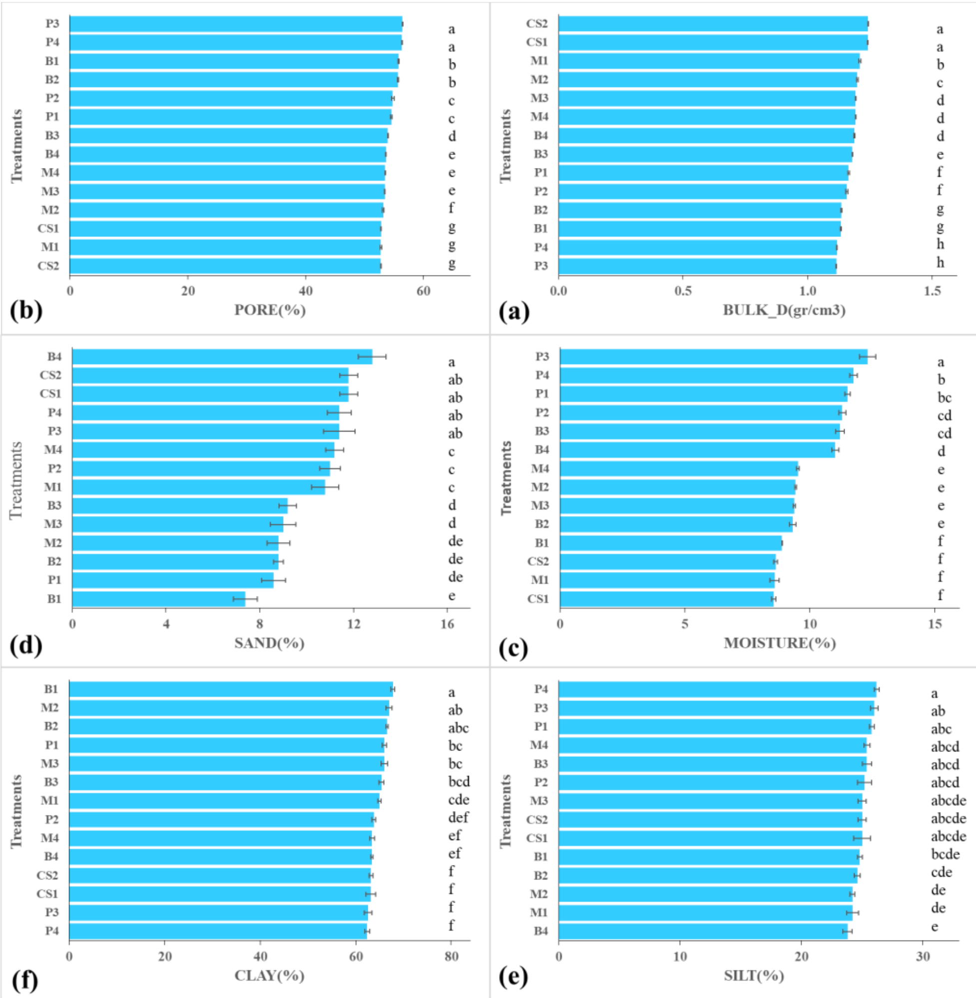

Fig. 4 Duncan's multiple range test, effect of amendments treatments on (a): bulk density; (b): pores; (c): moisture; (d): sand; (e): silt; (f): clay

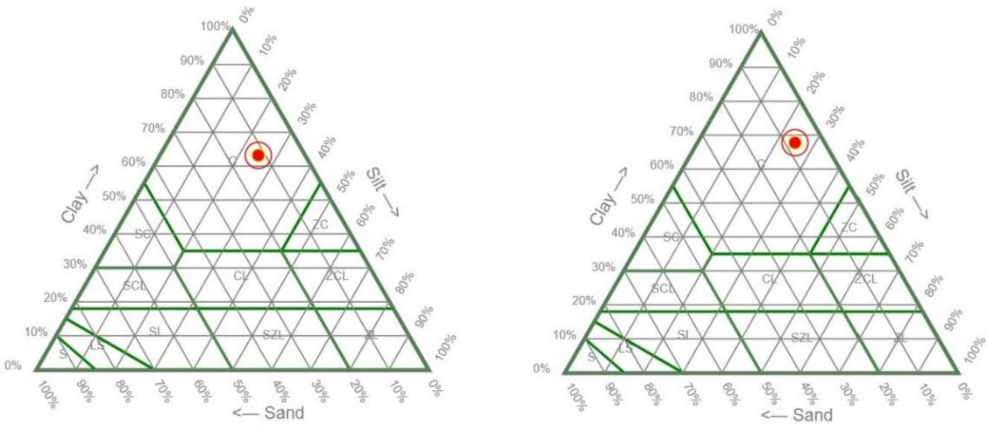

Fig. 5. Soil texture triangular at the beginning (Left) and end (Right)

4. Discussion

In the present research, biochar 250, 500, and 1000 gr (gram) treatments reduced salinity, which is in line with Wang *et al*. (2018) and Jin *et al*. (2018). Furthermore, 2000 gr biochar led to a sharp increase in acidity and salinity, which is consistent with the results of Zhang *et al*. (2016). Similar to previous research results, biochar increased the soil carbon amount at all levels (Melas *et al*., 2017; Figueiredo *et al*., 2019). Biochar 250, 500, and 1000 gr treatments increased the percentage of soil pores and soil moisture content, which is in agreement with the results of Pranagal *et al*. (2017) and Nematollahi *et al*. (2018), respectively. Consistent with Sun et al. (2017), biochar 500, 1000, and 2000 gr treatments increased the soil nitrogen. In line with previous publications, biochar 2000 gr increased the amount of soil P and K(Wang *et al*. 2018; Zhang *et al*. 2016). Biochar can be used as source of calcium, magnesium, potassium, and organic matter in soil improvement and fertilization management (Yazdanpanahi *et al*., 2019).

AMF increased soil nitrogen, as confirmed by previous publications (Tarraf *et al*., 2017; Moradi *et al*., 2014; Smith and Read, 2008). It further increased soil carbon content, which is in accordance with the findings of Bencherif *et al*. (2015). Similar to Xu *et al*. (2018), mycorrhiza 200 and 400 gr treatments increased the percentage of soil moisture. Mycorrhiza 400 gr treatment increased the amount of soil P, which is consistent with previous publications where mycorrhiza had a positive effect on soil P (Xu *et al*. 2018; Tarraf *et al*., 2017).

At all levels, ARP reduced soil bulk density and increased the percentage of soil porosity, which was corroborated by the results of Kamali (2014). ARP also increased the soil moisture at all levels, which is consistent with the previous research results (Xianglin *et al*., 2019; Guan *et al*., 2018; Cao *et al*., 2017; Kamali, 2014). It also increased the amount of soil nitrogen and carbon, which was the result of Cao *et al*. (2017). However, polymers 100 and 200 gr treatments increased soil salinity. Polymer 50 and 100 gr treatments increased amount of soil P and K, which is consistent with a previous publication which proved the positive effect of polymer on soil P and K (Cao *et al*., 2017). The use of polymers as soil stabilizers was significantly expanded in degraded lands and desertification and improved arid and semi-arid soils (Maghchiche *et al*., 2010).

The percentage of sand, silt, and clay of soil was slightly altered by the use of amendments; however, these changes were not sufficient to cause soil texture change. On average, more than 60% of the soil texture is clay.

5. Conclusions

The amendments used in this study, namely biochar, mycorrhizal, and polymer, had different effects on the physical and chemical properties of soil. Arbuscular mycorrhizal fungi had more impact on the chemical properties, acrylic resin polymer had more effect on the physical properties, and natural biochar affected both physical and chemical properties of the soil. Also, increasing use of AMF,had no negative effects on the measured properties of the soil but reduced the soil salinity in the study area. However, With increasing use of biochar and ARP, theirnegative effects were observed; in other words, biochar and ARP had a consumption threshold, such that overuse had a negative effect on the physical and chemical properties while increasing the use of biochar and ARP increased the soil acidity and salinity.

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