

## Investigating the effects of cow manure, vermicompost and Azolla fertilizers on hydraulic properties of saline-sodic soils

Parastoo Sharifi<sup>1\*</sup>, Mahdi Shorafa<sup>1</sup>, Mohammad Hossein Mohammadi<sup>1</sup>

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### Abstract

**Purpose** Soil salinity and sodicity are among the factors involved in soil degradation, especially in arid and semi-arid areas of the world. The use of modifiers, including organic matters, can be considered as an appropriate strategy to improve the fertility of saline-sodic soils.

**Method** In this study, saline-sodic control soil was collected from Karaj and mixed with three levels of 1%, 3% and 5% of cow manure, vermicompost and Azolla. The soil columns were then incubated at 20 °C and field capacity moisture for 5 months. The physical and chemical properties of the treatments were evaluated before and after incubation.

**Results** After the incubation period, the lowest salinity level was observed in 5% Azolla and vermicompost treatments. The highest amount of change in sodium absorption ratio was related to 5% cow manure treatment. There was an insignificant difference in moisture levels in a given suction among the different treatments. After the incubation period, salinity and sodium absorption decreased and increased in most of the treatments, respectively. Moreover, the decrease of saturation dehydration coefficient in the treatments revealed the disruption of soil structure and conversion of large pores to fine grains as a result of adding the mentioned organic matters.

**Conclusion** According to the results, cow manure at 1% level had no significant effect on soil properties. However, at higher levels, it had a negative effect on quality and conditions of the saline-sodic soil in terms of physical and chemical properties. In contrast, Azolla and vermicompost fertilizers at 5% proved to be suitable for correcting the saline-sodic soil.

**Keywords** Incubation, Organic matter, Saline-sodic soil modification, Soil properties

### Introduction

Nowadays, land degradation is considered as a global threat and, in many ways, it reduces crop yield in agricultural lands. Soil salinity and sodicity are among the main factors involved in soil degradation is (Flagella et al. 2002). Saline and sodic soils have undesirable physical, chemical and biological properties which can reduce the nutrient supply and ultimately decrease the plant growth and yield (Qadir and Oster 2004). In Iran, saline and sodic soils occupy an area of about 15-26 million hectares (10-15% of the country's total area) (Mosta-

fazadeh-Fard et al. 2007). Most of the soil properties are improved by the use of organic modifiers (Chaney and Swift 1986). Sodium depletion is expedited by the addition of organic matters which improve building conditions and increase soil permeability (Walker and Bernal 2008). A basic method for modifying sodium soils is to replace the exchangeable sodium with calcium. The sodium-substituted leaching exits the root or soil profile. A conventional source of calcium is a substance that contains calcium itself or dissolves calcium in soil solution after use. Thus, sodium soils can be modified by: 1) adding a source of calcium to non-calcareous soils, and 2) increasing the solubility of calcium, especially in calcareous soils (Quirk 2001). In arid and semi-arid areas where the soil is mainly calcareous, due to low solubility of lime, carbon dioxide gas pressure can be increased by adding organic matters. This increases the solubility of lime, reduces the reaction of soil, and finally increases

✉ Parastoo Sharifi  
p.69.sharifi@ut.ac.ir

<sup>1</sup> Soil Science and Engineering Department, University of Tehran

the rate of substitution of exchangeable sodium with soluble calcium (Hanay et al. 2004).

Different methods yet have been used to modify the saline and sodic soils (Wang et al. 2009). Organic matter (Leogrande and Vitti 2019; Valzano et al. 2001; Li and Keren 2009; Wong et al. 2009) and gypsum (Mitchell et al. 2000; Wong et al. 2009) are some of the modifiers used to modify the saline and sodic soils. Gonçalo Filho et al. (2020) showed that a combined use of gypsum and cow manure could reduce soil sodicity, improve soil chemical properties, and increase water infiltration better than the use of gypsum alone. Sundha et al. (2020) demonstrated that the use of gypsum (GR25) along with compost was as effective as the use of gypsum (GR50) in decreasing soil pH values and leaching of soluble salts. The positive effect of vermicompost on crop production has been reported by several studies (Joshi et al. 2013).

Given the high importance of agriculture, in this study, three organic matters of cow manure, vermicompost and Azolla were used to improve the hydraulic properties of saline-sodic soils and, finally, the most efficient organic matter was determined.

## Materials and methods

The soil samples were collected from saline-sodic soils of Nazar Abad village from the depths of 25-110 cm. The study area was devoid of crop due to high salinity and sodium. The soil samples were completely dry, mixed and uniformly air-dried. Then, they were passed through a 4-mm sieve for incubation and a 2-mm sieve for initial physical and chemical tests and transferred to the laboratory. Cow manure, vermicompost and Azolla fertilizers, as organic modifiers, were placed in an oven at 70 °C for 24 hours to be subjected to equal moisture conditions and dried. Afterwards, the fertilizers were separately passed through a 4-mm sieve to be ready for use. To prepare the soil columns, cylinders (made up of PVC material) with inner diameter of 12 cm and height of 30 cm were used. The columns were fastened with metal mesh and cloth, and the bottom of each column was filled with sand up to 2 cm as drainage. The soil samples were poured into the columns up to the height of 17 cm and the specific gravity of 1.3 g/cm<sup>3</sup>. The treatments were separately applied to the columns in 3 replications, at three levels of 1%, 3% and 5% of each fertilizer (Tazeh et al. 2013; Jalali and Ranjbar 2009). Finally, a filter paper was applied to the soil of each column to protect the soil structure from disintegration during the irrigation. The columns were kept in the incu-

bation chamber at 20±1° C for 5 months, under the field capacity moisture conditions. During this period, the field capacity moisture conditions were maintained by weekly weighting and distilled water irrigation. After the incubation period, the soil physical and chemical properties, including saturation hydraulic conductivity) Ksat, (moisture curve, sodium absorption ratio) SAR (and electrical conductivity) EC, (were measured in all the treatments and repetitions. Using an EC meter, the EC was also measured in the treatment saturated extract with an extract to fertilizer ratio of 5:1 (McLean 1982). The sodium absorption ratio was estimated according to Eq. 1.

$$SAR = \frac{Na^+}{\sqrt{\frac{Ca^{2+}+Mg^{2+}}{2}}} \quad (1)$$

By measuring time, soil height, water flow height, soil cross-sectional area, and water volume passing through the soil, the Ksat could be obtained according to Darcy's law (Kirkham 2005). The weight percentage of soil moisture in the suction was determined by a pressure plate (Klute 1986). Using Excel software, the moisture curves of the samples were also plotted.

## Results and discussion

Table 1 shows soil characteristics and Table 2 shows fertilizer characteristics:

**Table 1** Some characteristics of studied soil

Some characteristics of studied soil	Value
P <sub>s</sub> (g/cm <sup>3</sup> )	2.72
P <sub>b</sub> (g/cm <sup>3</sup> )	1.29
SAR	23.02
CEC (meq/ L)	1.62
pH	7.72
EC(dS/m)	13.09
Texture	Sandy Loam
Organic Matter (%)	0.02
K (meq/ L)	1.75
Ca (meq/ L)	20.58
Mg (meq/ L)	27.33
Na (meq/ L)	115.35
Cl (meq/ L)	21.3
SO <sub>4</sub> <sup>-2</sup> (meq/L)	121.65
CO <sub>3</sub> <sup>-2</sup> (meq/L)	14.53
HCO <sub>3</sub> <sup>-</sup> (meq/L)	4.91

P<sub>s</sub> is particle density, P<sub>b</sub> is bulk density, SAR is sodium absorption ratio, CEC is cation exchange capacity, pH is a measure of the acidity and alkalinity in the saturated extract with distilled water, EC is electrical conductivity in soil.

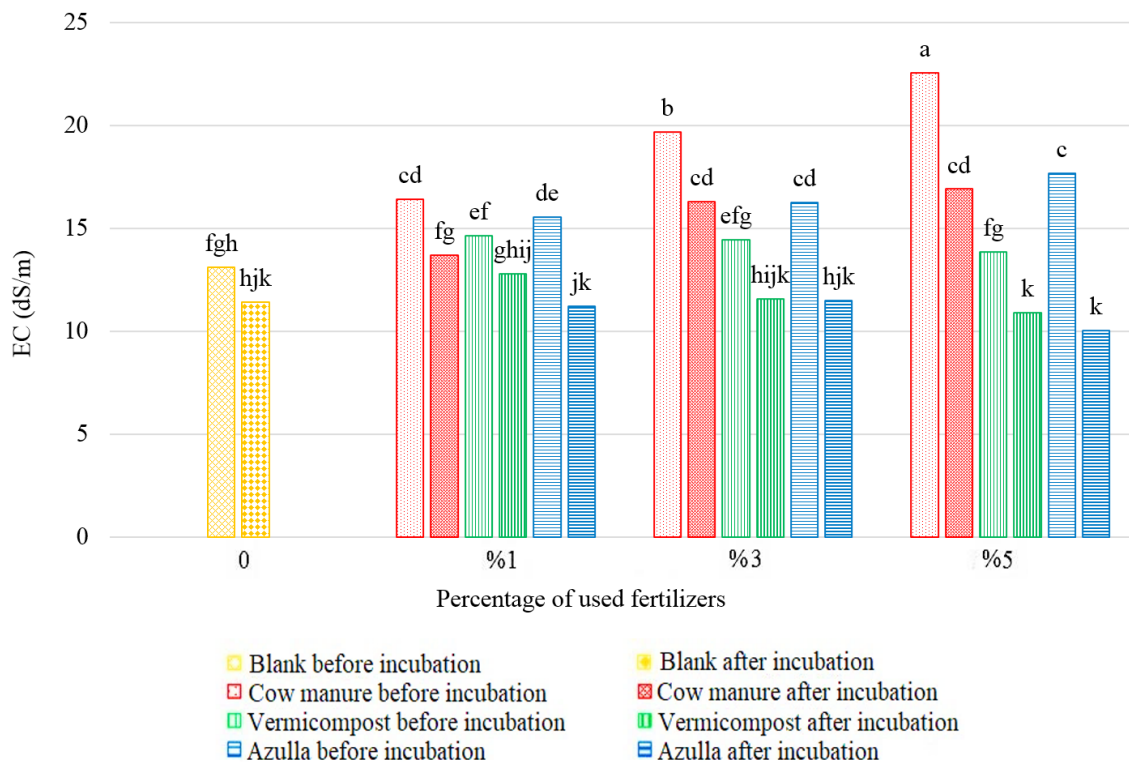
**Table 2** Some characteristics of studied fertilizer

Properties	Cow manure	Vermicompost	Azolla
EC (dS/m)	20.11	2.39	4.79
SAR	20.11	6.89	18.44
P <sub>b</sub> (g/cm <sup>3</sup> )	1.16	1.21	1.16
pH	7.03	7.62	6.42
C/N	12.28	10.96	12.05

### Electrical conductivity (EC) of the extracts of treatments

As can be seen in Table 2, among the fertilizers, cow manure has the highest EC, followed by Azolla and vermicompost. Fig. 1 illustrates that, before incubation, salinity was significantly increased with the increase of cow manure compared to other treatments. However, after incubation, there was a significant decrease in salinity in all the treatments, exception for the control treatment, due to leaching and chemical interactions of

the modifying fertilizers. In the post-incubation period, the sharpest decrease in salinity was related to 5% Azolla treatment, which was not statistically significant compared to the control treatment in the same incubation period. Moreover, the reduction in EC in 5% Azolla treatment can be explained as 1 :) Azolla, with an EC of less than soil EC, reduced the EC of the treatment after 5 months of incubation, 2) after 5 months of incubation, a lower SAR and a higher Ksat (compared to the control soil) induced the process of washing of salinity from the soil in the treatment with 5% Azolla..

**Fig. 1** Comparison of electrical conductivity in soil treatments before and after incubation

Rusta et al (2003) examined the sodic soils with sandy loam texture in Qazvin. They separately added wheat straw, manure, gypsum and cement at different

levels to the control soil for 4 months. After incubation, they observed a significantly increased EC in cow manure treatment and no significant decrease in wheat

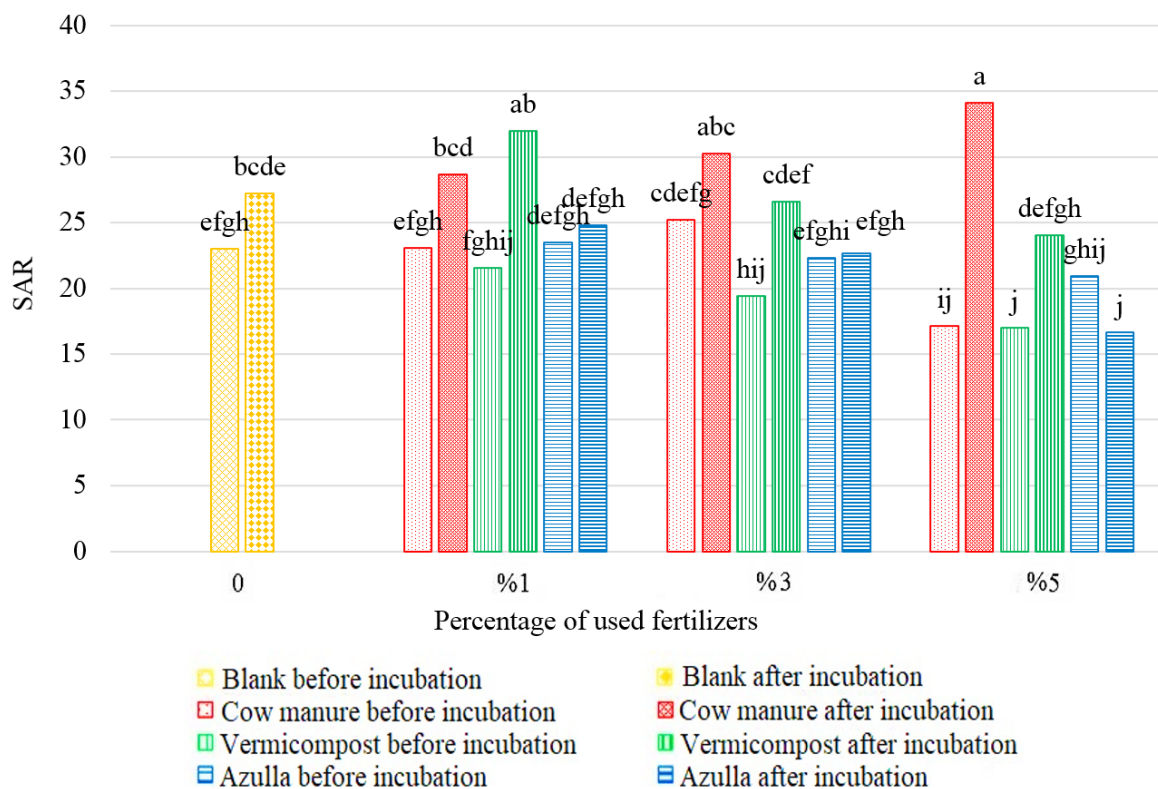
straw treatment. This finding was consistent with the results obtained in the present study. Yazdan Panah et al. (2013) separately and collectively added livestock manure, pistachio pulp and gypsum to the saline-sodic and calcareous soils with loamy texture during 4 months. Finally, they observed no significant difference in EC between the treatments with pistachio pulp and cow manure and the control treatment after the incubation period. We obtained a similar result for Azolla and a conflicting result for cow manure. Khatbaei et al. (2014) attempted to treat the saline-sodic soil with EC of 5 dS/m control. (They mixed the soil with municipal waste compost, gypsum, vermicompost and poultry manure (3 g/kg) and after two months of incubation started to cultivate corn. They found that treatments with poultry manure and vermicompost had higher and lower ECs, respectively. These findings were consistent with the results reported in the present study.

### Sodium absorption ratio in the extracts of treatments

Cow manure and vermicompost showed the highest and the lowest sodium absorption ratios, respectively, which

were statistically significant (Table 2). As shown in Fig. 2, this behavior was also reflected in the treatments before incubation. After incubation, a significant increase in sodium absorption was observed in all the treatments, except Azolla treatment. After incubation, the highest sodium absorption ratio was related to 5% cow manure treatment compared to all treatments, while the lowest sodium absorption ratio belonged to 5% Azolla treatment compared to control. In the cow manure treatment, due to the high sodium absorption ratio, especially at the level of 5%, the aggregates were destroyed after the incubation period (Carrow and Duncan 2011).

Organic matter, through the production of carbon dioxide and as a result of increased lime dissolution, produced calcium ions which prevented sodium from entering the exchange sites (Walker and Bernal 2008; Qadir et al. 2001). However, vermicompost and Azolla fertilizers improved the physical and chemical properties by inducing lower sodium absorption and salinity ratio in saline-sodic soil. Tejada and Gonzales (2006) stated that adding rotten cotton plant residues to saline-sodic soil could reduce the exchange rate of sodium absorption. In this study, addition of Azolla at 5% level significantly reduced the exchange rate of sodi-



**Fig. 2** Comparison of sodium absorption ratio in soil treatments before and after incubation

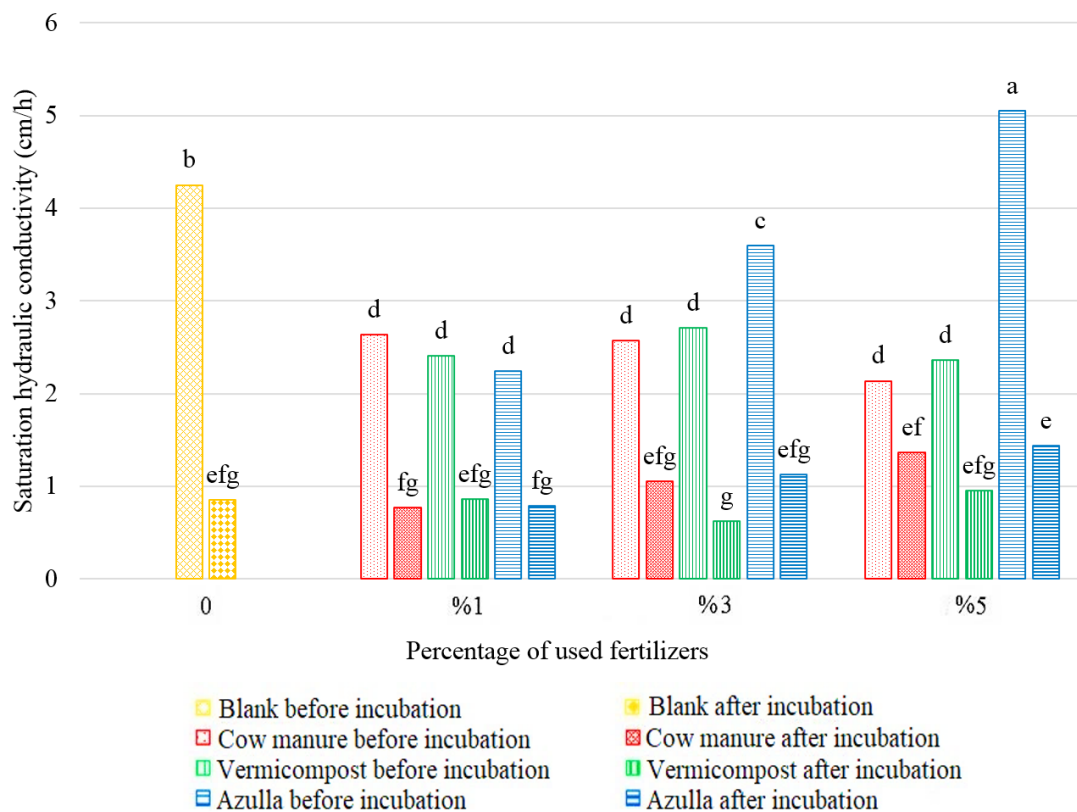
um absorption compared to control. Yazdan Panah et al. (2013) separately and collectively mixed livestock manure, pistachio pulp and gypsum with the saline-sodic soil of an agricultural area during 4 months of incubation with leachate by ordinary or sulfuric acid. They noticed that the ratio of sodium absorption in animal manure treatment was significantly increased compared to other treatments and control. These findings were consistent with the results of the present study.

### Saturation hydraulic conductivity in different treatments

Before the incubation period, the highest hydraulic conductivity was related to 5% Azolla treatment compared to the control and other treatments. However, the hydraulic conductivity significantly decreased in all the treatments after the incubation period (Fig. 3). This could be explained by the increased sodium absorption ratio after incubation and preferential washing of calcium and magnesium ions. The remaining sodium ions, with a higher hydrated radius, blocked the water passages, reduced the coarse pores and converted them

into fine pores, which reduced the saturation coefficient in the saline-sodic soil treatments.

Ali Mardani et al. (2012) added alfalfa plant residue at 2% and 5%, gypsum and aluminum sulfate to sodium soils after 2 and 4 months of incubation, respectively. They observed a significant increase in the saturation hydraulic conductivity of the treatments after 4 months of incubation. Although 2% and 5% alfalfa treatments showed the lowest hydraulic conductivity compared to other breeding materials, they reported that organic matter increased the sodium absorption ratio in sodium soils with the production of organic anions and the increase of diffusible clay. They believed that soil and blocking of empty spaces as well as complexation of multivalent cations, such as calcium, made the solitary application of the organic matters less effective. This justification partly applied to the soil we studied. Aksakal et al. (2016) mixed the sandy loam, loam and clay soils with different levels of vermicompost, and showed that its addition at 1% and 4% levels to the sandy loam soil significantly increased and decreased the saturation coefficient, respectively, compared to control. However, in the saline-sodic soil examined in the present



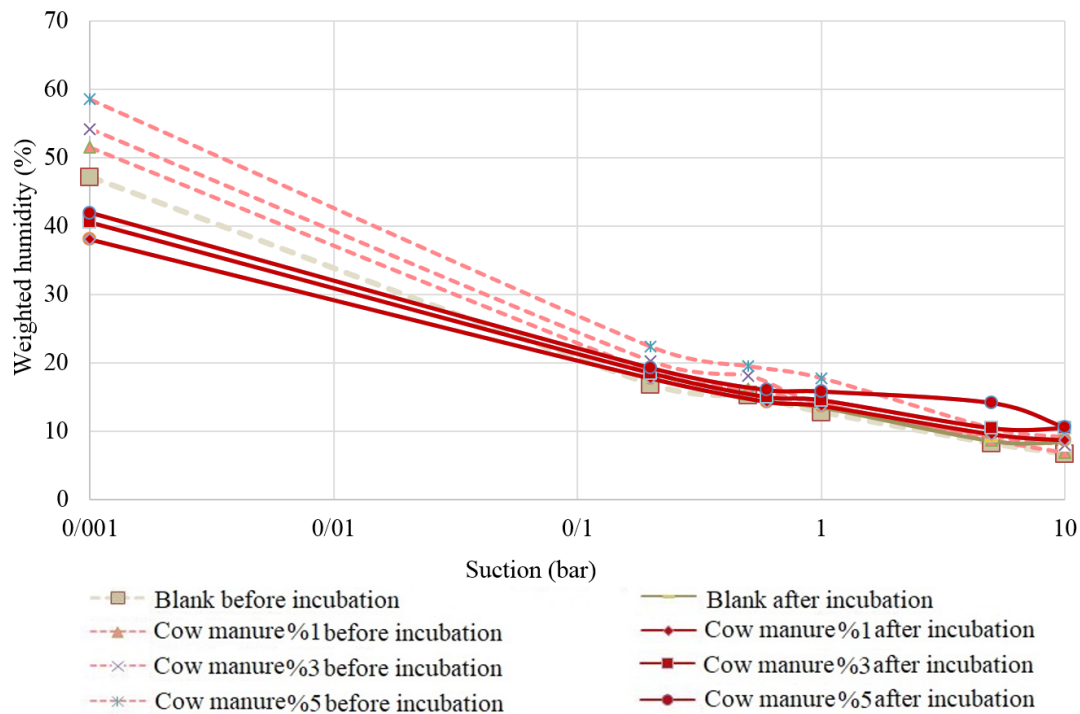
**Fig. 3** Comparison of saturation coefficient of hydraulic conductivity in soil treatments before and after incubation

study, after the incubation, no significant difference was observed in the hydraulic conductivity between the treatment with vermicompost at different levels and the control. This could be due to the salinity-sodium content of our soil, which prevented the disintegration of sodium ion and significant differences among the levels of vermicompost applied.

### Moisture curve of all the treatments

Considering the moisture curves presented in Figs. 4, 5 and 6, the highest and the lowest saturation moisture

contents were related to 5% Azolla treatment before the incubation and control treatment after the incubation, respectively. Comparison of all the treatments at zero suction point revealed that they had a higher saturated moisture before the incubation period rather than after the incubation period. This indicated the reduction of total pores in the treatments due to the increase of sodium absorption and aggregates breakdown during the incubation period (Carrow and Duncan 2011). However, there was a little difference in the moisture curves among the different treatments.

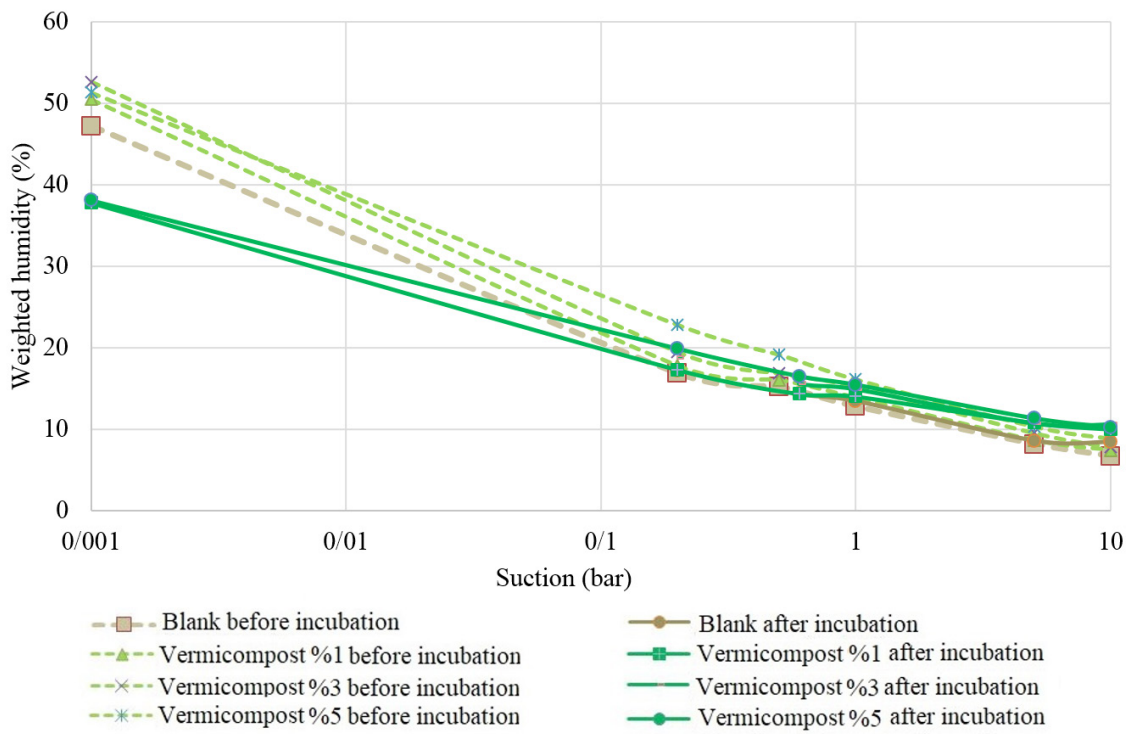


**Fig. 4** Comparison of moisture curve of different soil treatments of Cow manure and control before and after incubation

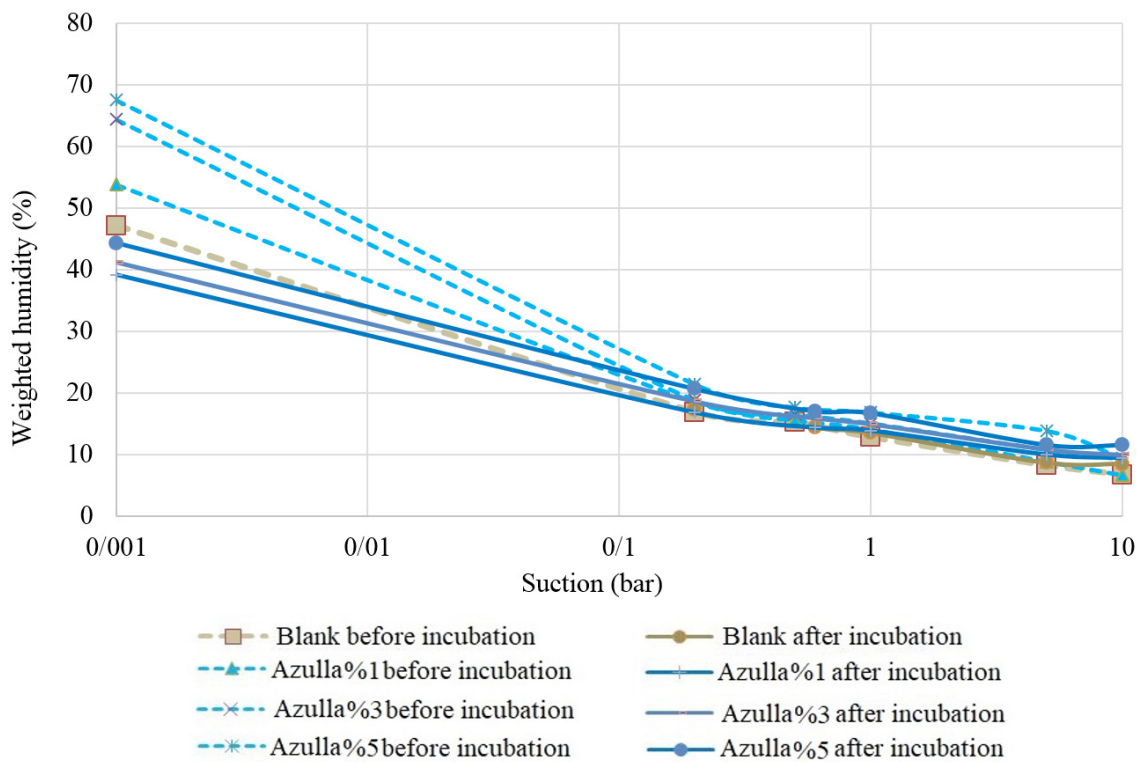
### Conclusion

The results of chemical experiments showed that the properties of the studied fertilizers were directly reflected by the properties of the soil samples. Cow manure, with the highest EC, increased the soil salinity, while vermicompost and Azolla fertilizers reduced the soil salinity. The highest sodium absorption ratio was also obtained in the cow manure treatment. After 5 months of incubation, salinity and sodium absorption ratios were lower in the treatments with 5% vermicom-

post and Azolla fertilizers than in other treatments. This difference was quite significant in the subsequent incubation period. The results of physical experiments showed no significant difference in the saturation hydraulic conductivity among the treatments. However, decrease of the saturation hydraulic conductivity in all the treatments during the incubation period compared to the pre-incubation period was mainly attributed to the effect of sodium ions on aggregate collapse, blockages and destruction of large pores. The highest saturation hydraulic conductivity was observed in 5% Azolla



**Fig. 5** Comparison of moisture curve of different soil treatments of vermicompost and control before and after incubation



**Fig. 6** Comparison of moisture curve of different soil treatments of Azolla and control manure before and after incubation

treatment before and after incubation. Generally, it was found that vermicompost and Azolla fertilizers both at 5% level were suitable and cow manure was unsuitable to be used in the saline-sodium soils.

### Compliance with ethical standards

**Conflict of interest** The authors declare that there are no conflicts of interest associated with this study.

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