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The effects of super-absorbent, vermicompost and different levels of irrigation water salinity on soil saturated hydraulic conductivity and Porosity and Bulk density

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ABSTRACT: It can be said arguably that low hydraulic conductivity and rapid effect of salinity on it, is among the biggest problems in heavy-textured soils. With the aim of dispelling this problem, a project was done as factorial in four levels of salinity of irrigation water containing sodium chloride (0.79, 5, 10, 15 dS/m) with two types of amendments of super absorbent and vermicompost, each at a level of 0.02 and 1.5 kg per square meter respectively with the control attendance and parameters of bulk density, porosity and hydraulic conductivity were measured. The results showed that the effect of amendments was only significant on porosity and the effect of salinity on porosity and hydraulic conductivity; bulk density was increased and porosity and hydraulic conductivity were decreased by increasing the salinity, measurement parameters were improved by amendments and modifying the effect of vermicompost on the modification of all measured parameters became more than super absorbent.
***Keywords**:* Saturated hydraulic conductivity, Bulk density, Porosity, Irrigation water quality, Amended

INTRODUCTION

Soil water content and water retentive force in the soil are two major subjects in the science of water and soil. Soil water content affects air exchange of soil with the atmosphere, releasing minerals into the roots of the plants, the rate of minerals movement in the soil (after irrigation and rainfall) and soil temperature. Water retentive force in the soil is effective on the efficiency of water absorption by plants, drainage content due to the effect of gravity and the upward movement of water (capillary action). Therefore, the soil will be appropriate agriculturally if it has both above properties, it means in addition of the ability to store needed water of the plant, transfer it easily to the soil and give it to the plant. This indicates that in heavy soils that have a higher maintenance than other soils, there will be the problem of transfer or low hydraulic conductivity.

Hydraulic conductivity not only defines the transfer power of water in the soil, but also it has a significant impact on minerals transfer, aeration, soil temperature changes and plant rooting (Lal and Shukla, 2004) and in addition of increasing crop yields by modification of it, it reduces costs of development of irrigation and drainage systems ad increases their efficiency in the field.

One of the best ways to improve soil hydraulic conductivity is, adding types of amendments such as super absorbent, vermicompost and etc to the soil.

Vermicompost is an organic biological fertilizer that is produced by continuous and slow transition of rotting organic materials through digestion mechanism of some species of earthworms and disposal of these materials from the worm's body. These materials are covered with mucus of digestion mechanism (mucosa), vitamins and enzymes while passing through the worm's body that is finally produced and consumed as a rich and organic fertilizer and is very useful for improving the mechanism and nutrition of the plants (Kabiri khosh sout, 2008).

One of the special advantages of vermicompost over other organic fertilizers is, existing large amount of humus in it and its humus-making process speed (Claudio, 2009). By using vermicompost and accession of humus to the soil, clays and silts are generally compounded with humus and adhesive materials and make up small units of soil. These small units cling to each other by adding organic materials to the soil make aggregate and shape soil structure. Aggregates clinging, causes to improve moisture retention capacity, water penetration, drainage and climate exchange in the soil and its intensity is reduced (Mahdavi damghani et al., 2007).

Water and soil researchers did a lot of studies on the effects of vermicompost on physical and hydraulic features of the soil and concluded that vermicompost by making soil structure spongy (Mirzaei et al., 2009), improves bulk and real density (Ahmadabadi et al., 2011), porosity (Matos and Arrunda, 2003), increases aggregate's stability and soil structure, and increases the rate of water penetration in the soil and aeration (Mahdavi damghani et al., 2007).

Hydraulic super absorbent polymers have a quite different structure from vermicompost that found special place in new agriculture in order to reinforce nutritional and moisture status of the plant. In fact, the main objective of using these materials is to increase the amount of soil water retention (Karimi & Naderi, 2007), and for this reason, it is studied by researchers and is used by farmers in recent years.

In studies done on types of super absorbent, it is specified that this material expands and contracts by the absorption and desorption of the water, influences the soil structure and increases pores contained of air in the soil in order to develop the root especially in fine-textured soils (Asgari et al., 1994).

Since these polymers have ionic structure, it is expected that they have lower performance in ionic environments (Allahdadi, 2003), so in this environment, it is better to estimate super absorbent performance in soil circumstances. In this regard, some studies have been done that show super absorbents reduce the amount of leaching minerals from soils by absorption and retention of minerals and salts added to the soil and reduce polymer inflammation in these environments (Kabiri and zohorianmehr, 2006; Omidian, 1999).

The performance of described amendments is fully under the field properties. Thus, the study of their effects on saturated hydraulic conductivity, regardless of its interaction with the properties of soil environment, does not make us close to the reality. Therefore, the aim of this study is to evaluate the performance of vermicompost, superabsorbent in different levels of salinity of water irrigation, bulk density, total porosity and saturated hydraulic conductivity of the soil.

MATERIALS AND METHODS

This research has been implemented in a part of research farm of Agriculture Faculty of University of Zabol in Sistan Dam. Soil samples were taken from depth of 0-50 cm compositely in order to specify the features of the soil. Then, the physical and chemical structure and features of the soil were specified by using conventional methods of analysis. The measured characteristics of the studied soil are presented in table (1):

Table 1. physical and chemical features of the studied soil

texture	Sand (%)	Silt (%)	Clay (%)	PH	EC(ds/m)	OC (%)
Clay Loam	31	39.4	29.6	8.1	1.94	2.28

Vermicompost used in this study has been produced by the activity of Eisenia foetida worm on bestial fertilizer. The amount of acidity and electrical conductivity of its aqueous solution are 8 and 14.65 dS/m, respectively.

Regarding that interior A200 super absorbent is equal to its exterior one, of the absorption features of ionic solutions (Kabiri and Zohorian mehr, 2006); this type of super absorbent was used in this study. A200 super absorbent polymer used in this study is the copolymer of acrylic acid-potassium acrylate that PH of its aqueous solution is 6-7 and applicative capacity of absorption of its aquapura is 220 g/g.

Therefore, the purposed field was plowed to a depth of 30 cm by plow and 12 plots of 1×1 m were established in it. The plots were spaced 1m from each other in order to eliminate the interaction of studied parameters. The experiment was done as factorial in four levels of salinity of irrigation water containing sodium chloride (0.79, 5, 10, 15 dS/m) with two types of amendments of super absorbent and vermicompost, each at a level of 0.02 (Tavakkoli Kavarim, 2011) and 1.5 (anonymous, 2011) kg per square meter with the control attendance.

After two months irrigation, in each plot, 3 sinks with diameter of 5 and depth of 30cm were dug in order to test Guelph permeameter. Then the amount of discharge from permeameter will be read in two depths of 5 and 10cm of submergence for each sink. In each sink, the amount of drop of water level in the reservoir was recorded in time unit per each submergence depth, and the values of saturated hydraulic conductivity for each sink were obtained by using the following equations:

$$K_{fs} = G_2 Q_2 - G_1 Q_1 \qquad (1)$$

$$G_2 = \frac{H_1C_2}{\pi[2H_1H_2(H_2-H_1) + a^2(H_1C_2 - H_2C_1)]} \quad (2)$$

$$G_1 = G_2(\frac{H_2C_1}{H_1C_2}) \quad (3)$$

$$Q_1 = A \times R_1 \quad (4)$$

$$Q_2 = A \times R_2 \quad (5)$$

$$C_1 = \frac{1}{\left(\frac{a}{H_1}\right) + 0.5(\frac{a}{H_1})^2} \quad (6)$$

$$C_2 = \frac{1}{\left(\frac{a}{H_2}\right) + 0.5(\frac{a}{H_2})^2} \quad (7)$$

In above equations, K_{fs} is saturated hydraulic conductivity (m/s), Q_1 and Q_2 are discharges from reservoir (m^3/s) respectively, R_1 and R_2 are penetration rates (m/s) and C_1 and C_2 are coefficients of sink's shape in Porsche solution in submergence depths of H_1=5 and H_2=10 cm respectively, A is area of reservoir of Guelph device (m^2) and a is radius of sink in cm (Reynolds, 1985).

Bulk density and porosity experiments were done in three replications for each plot by Excavation (Dane and Clarke., 2002a) and Gravimetric (Dane and Clarke, 2000b) methods, respectively.
The SPSS software was used in order to analyze the results of the study and the means were compared with Duncan's multiple-range test.

RESULTS AND DISCUSSION

Table (2) shows the variance analysis of measured parameters.

Table 2. variance analysis (mean squares) of measured parameters

Source	df	mean squares Bulk density	Porosity	Hydraulic conductivity
Salinity levels	3	0.002 ^{ns}	0.002*	578*
Amended	2	0.002 ^{ns}	0.001*	163 ^{ns}
Salinity level* Amended	6	0.000 ^{ns}	0.001*	67 ^{ns}
Error	24	0.001	0.000	60

Ns: no significant, *: Significant at the 0.05 level

The effects of amended materials and salinity levels on bulk density

the main effects of salinity levels and amended and their interaction was not %95 significant, statistically (table 2). The comparison between the means of obtained values of bulk density in different levels of salinity (table 3) shows that bulk density values are increased by increasing salinity of irrigation water, but only the values of control of salinity levels of (0.79) and 15 dS/m differ significantly at the %95 probability level and the rest of the levels are not significantly different from each other. In figure 1 which shows the effect of type of amended of different salinities on soil bulk density, the rate of increase in bulk density can be seen in each amended as well.

Table 3. comparison between measured values ad different levels of salinity

Salinity level (ds/m)	Bulk density (gr/cm^3)	Porosity (%)	Saturation Hydraulic conductivity (cm/day)	Percent reduction in saturated hydraulic conductivity
0.79	1.35A	42.56A	62.3A	0
5	1.36AB	41.94A	59.4AB	4.65
10	1.36AB	41.28AB	52.9B	15.1
15	1.39BC	39.61B	43.4C	30.34

Means with dissimilar letters have significant differences at the %5 level, statistically.

Variance analysis of bulk density values as compared with amendments shows that vermicompost and super absorbent have significant differences at the mentioned statistical level while the control attendance does not have a significant difference from amendments at this statistical level (table 4). Also, the mean of bulk density values in plots containing vermicompost, is lower than control and control is lower than super absorbent. Figure 1 shows that bulk density values of plots containing vermicompost at all salinity levels, except for salinity of 15 dS/m, became lower than bulk density values of plots of control and super absorbent at the same salinities and in salinity of 15 dS/m, density changes are influenced mostly by salinity as compared with type of amended.

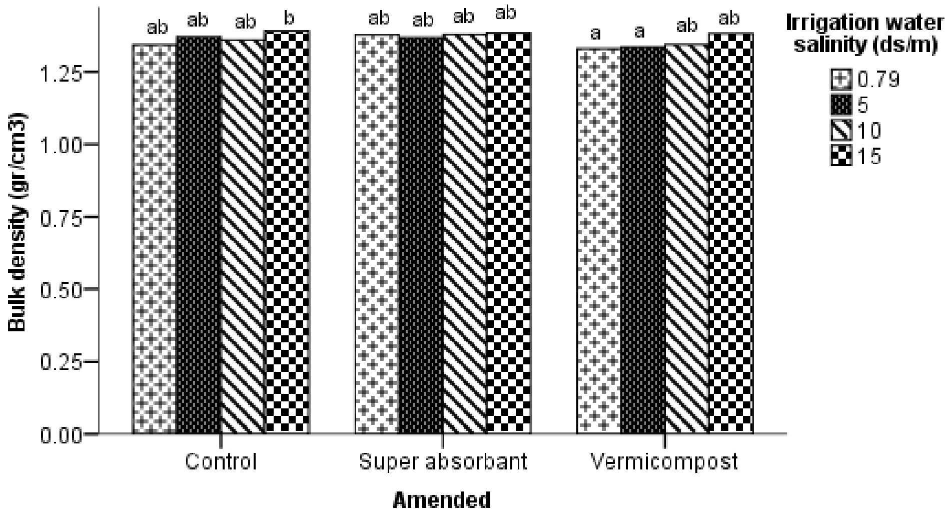

Figure 1. the effect of type of amended on bulk density in different salinities of irrigation water;Means with dissimilar letters have significant differences at the %5 level, statistically.

In studies done on the effects of vermicompost on bulk density, it has been mainly reported decrease in bulk density. Mirzaei et al. (2009) concluded with adding vermicompost to the soil and study of its effects that vermicompost increases soil porosity by making its structure spongy and decreases soil bulk density.

The results of this study are similar to the results of the study done by Ahmadabadi et al. (2011), he concluded in the study of effects of vermicompost on soil physical properties that although this organic material decreases soil bulk density, this decrease was not statistically significant. Decrease of bulk density can be explained by formation and increase of aggregates with adding vermicompost to the soil and its rapid humus formation (Mahdavi damghani et al., 2007) and improves states of aggregation and stability of soil structure and by increasing the percentage of soil porosity, predisposes decrease of bulk density (Mirzaei talarposhti et al., 2009).

Studies on the super absorbent show decreasing effect of this material on bulk density (Al-harbi et al., 1999; Liue et al., 2006; Yang et al., 2006; Bai et al.,2010;Almarshadi, 2012; zangoei nasab et al., 2012). Behbahani et al. (2009) stated the decreasing effect of polymer's grains between soil particles and it expands and contracts with absorption and desorption of moisture and makes soil particles close to each other and with establishment of aggregate, causes stability of soil structure and increase of soil porosity that will decrease bulk density. Also, Zainuddin and Aldakhil (2006) stated that high capacity of polymer's water absorption leads to further increase of micro-porosity and capillary effect and causes decrease of bulk density and increase of porosity. Studies done on the effects of salinity on bulk density and its interaction with the super absorbent show increase of bulk density and decrease of improvement of superabsorbent on soil structure in ionic environments (Dorraji et al., 2010; kabiri, 2005).

Table 4. comparison between means of measured values in amendments

amender	Bulk density (gr/cm^3)	Porosity (%)	Hydraulic conductivity (cm/day)
Vermicompost	1.35A	42.75A	59.31A
Control	1.37AB	40.38B	50.62BC
Super-absorbent	1.38B	40.92B	55.4AC

Means with dissimilar letters have significant differences at the %5 level, statistically.

The effects of amended materials and salinity levels on the porosity

salinity levels and amended and their interactive effects on the amount of soil porosity were significant at % 95 statistical level (table 2). The comparison between means of obtained porosity values in table 3 shows that salinity levels of (0.79) and 5 control have significant difference from salinity level of 15 dS/m at %95 probability level and the rest of the levels are not significantly different from each other. Also, soil porosity is decreased by increasing the salinity of irrigation water. Figure 2 shows interactions of type of amended and salinity levels of irrigation water on the amount of soil porosity. In this figure, it can be seen that the amount of porosity is equal at salinity levels in all plots containing vermicompost, except in the salinity of 5 dS/m, it became more than plots containing superabsorbent and control, and soil porosity is decreased by increasing salinity in each amended. In addition, the maximum amount of porosity belongs to the plot containing vermicompost in the lowest level of exerted salinity (control). Generally, it can be said in similar salinity levels that the maximum porosity amount belongs to plots containing vermicompost and its minimum belongs to plots without amended. The comparison between mean of related porosity to each amended is shown in table (4). In this figure, in can be seen that there is no significant difference between plots without amendments and super absorbent at %95 statistical level and measured porosity values in plots containing vermicompost are greater than super absorbent and no amended, and have significant difference from them.

In similar study, Ahmadabadi et al. (2011) examined vermicompost effect on the porosity of silty at %1 statistical level and found that vermicompost has significant effect on increasing soil porosity in this statistical level and the maximum soil porosity value was obtained at the highest level of used vermicompost (40 ton per hectare). Azarmi et al. (2008) concluded by studying vermicompost effect on soil porosity and bulk density at four levels of 0, 5, 10, 15 ton per hectare that bulk density is decreased and porosity is increased by increasing used vermicompost level and the minimum amount of bulk density and the maximum amount of porosity were introduced at the level of 15 ton per hectare. Taylor et al. (2003) and Parthasarathi et al. (2008) also reported increase of porosity in the case of adding vermicompost. Increase of porosity in plots containing vermicompost can be known as increase of numbers of small pores in the soil in the case of adding vermicompost to the soil (Marinari et al., 2000; Pagliai et al., 1980) that is probably due to correlation between soil particles by the action of microorganisms in vermicompost that with the production of polysaccharides, improves cementation between soil particles (Six et al., 1995) and makes soil structure spongy (Edwards and Bohlen, 1996).

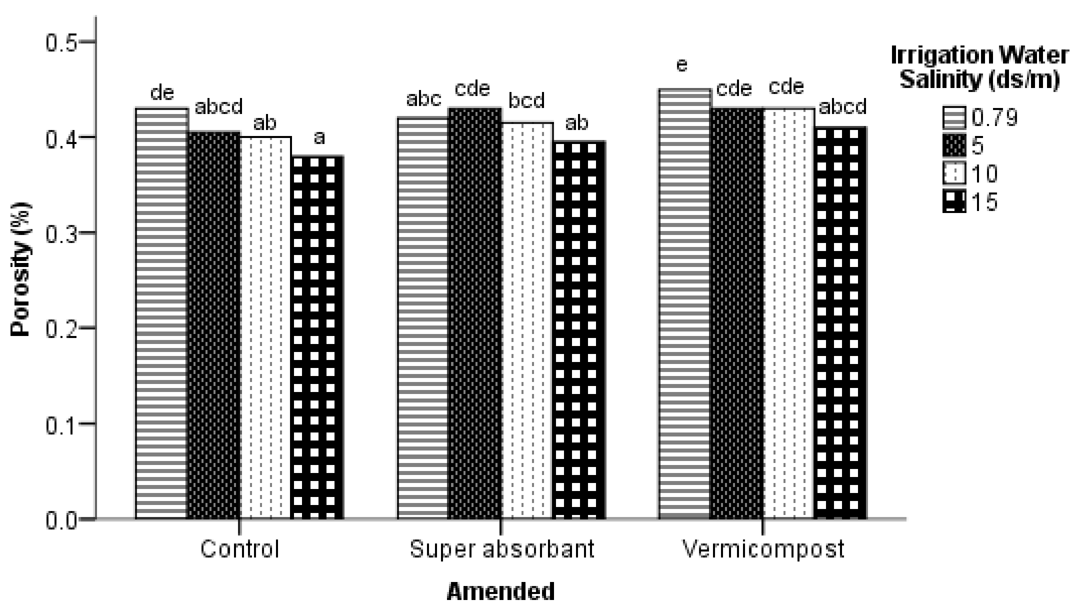

Figure 2. interaction of type of amended and salinity levels of irrigation water on soil porosity value; Means with dissimilar letters have significant differences at the %5 level, statistically.

Most studies on the effects of polymers on the soil show increase of porosity by adding polymer to the soil (Yonter Yagmur, 2011; Brandsma et al, 1999). Dorraji et al. (2010) concluded by combined study of salinity and super absorbent on physical features that polymer levels increase ventilatory porosity and capillary and decrease salinity of porosity, so that these decreases and increases are significant at %1 level. He stated the reason of porosity decrease with salinity increase that double electrical layers of clays are compacted by increasing minerals density; thus, bulk density is increased and porosity is decreased. Kabiri (2005) also reported decrease of polymer effect by increase of salinity on soil porosity and stated according to the structure of super absorbent ,which is ionic, that their placement in ionic environment cause pressure difference between outside and inside solutions of the gel, that will decrease swelling of super absorbent polymer and decrease its effect on increase of porosity. It should be noted that Omidian (1999) also stated the same reason for decrease of polymer effect on the soil.

Effects of amended materials and salinity levels on saturated hydraulic conductivity

the main effects of salinity levels on saturated hydraulic conductivity were significant at %95 statistical level; however, amended and salinity interaction of amended were not significant on saturated hydraulic conductivity (table 2). The comparison between the means of obtained hydraulic conductivity values in table (3) shows that soil saturated hydraulic conductivity is significantly decreased, except in salinity level of 5 dS/m, by increasing salinity of irrigation water. Decrease of hydraulic conductivity has a significant process with increase of salinity, so that the amount of decrease reaches %30 in salinity level of 15 dS/m. the comparison between mean of hydraulic conductivity in amendments is shown in table (4). The results of comparisons show that amendments have increased hydraulic conductivity and modifying effect of vermicompost is more than super absorbent; while the difference between their values was not statistically significant, there is a significant difference between values of plots containing vermicompost and plots without amended, and there was no significant difference between plots containing super absorbent and no amended.

The results of comparison between interaction of type of amended and salinity levels of irrigation water on soil saturated hydraulic conductivity shown in figure 30 also have similar results in table (4). In can be seen in figure 3 that hydraulic conductivity values in plots without amended are lesser than plots containing super absorbent, and in plots containing super absorbent is more than plots containing vermicompost, but each of these amendments does not have a statistically significant difference in salinity levels of 0.79 and 10 dS/m and in salinity of 15, vermicompost and control and in salinity of 5, super absorbent and control have a significant difference from each other. Decreasing process of hydraulic conductivity with increase of salinity can be seen in all amendments but according to figure 3, it is expected that this decreasing slope will be lesser in vermicompost.

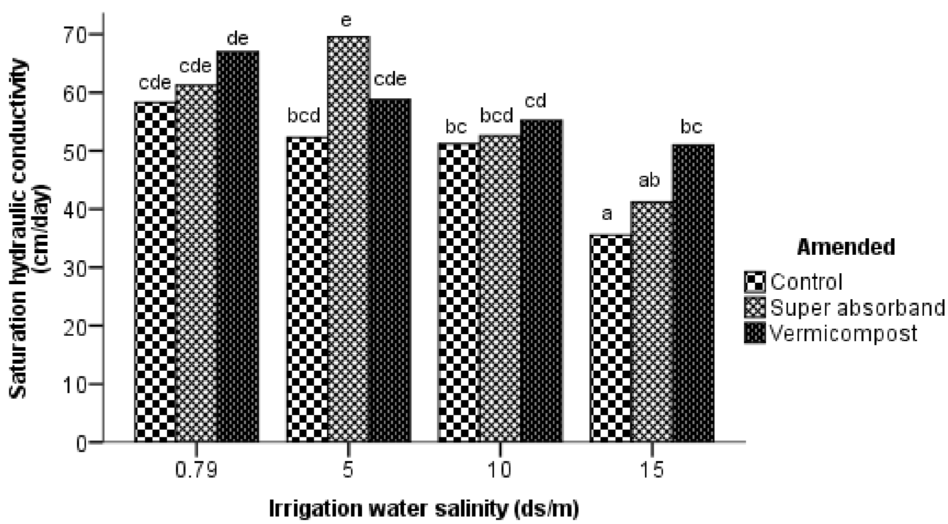

Figure 3. interaction of type of amended and salinity levels of irrigation water on soil saturated hydraulic conductivity; Means with dissimilar letters have significant differences at the %5 level, statistically.

Vermicompost is an organic material, rich of carbon. Carbon causes correlation between soil particles and decreases bulk density and thereby predisposes increase of hydraulic conductivity (Saxton and Rawls, 2006; Gupta et al., 1977; Kladivko and Nelson, 1979; Webber, 1978; Weil and Kroontje, 1979). Increase of hydraulic conductivity of plots containing vermicompost can be analyzed by regarding decrease of bulk density and increase of porosity in them, because in most studies done in this case, it is acknowledged that decrease of bulk density (Dexter et. al., 2004; Nakano & Miazaky, 2005;Zhang et. al., 2006;Wysocka et. al., 2007; Islam et. al., 2008; Ahn & Jo, 2009) and increase of porosity cause to increase soil hydraulic conductivity (Staub et. al., 2009; Carman, 1937; Scheidegger, 1960).

It has been reported decrease of bulk density and increase of soil porosity and hydraulic conductivity in most of similar results obtained in conducted study on the super absorbent effect on hydraulic conductivity (Shanmuganathan and Oades, 1982;Zhang et al., 2010). John (2011) stated that light soils in which swelling condition of super absorbent is provided; polymer causes significant increase of hydraulic conductivity and in heavy soils such as loamy clay causes increase of hydraulic conductivity in conditions where there is no limitation on polymer swelling while this increase was not statistically significant. Singh et al. (2011) expressed in the study of effects of various salts on hydraulic conductivity that hydraulic conductivity is decreased by the presence of high density of sodium salt. Bardhan et al. (2007) concluded by study of effect of irrigation quality on saturated hydraulic conductivity that saturated hydraulic conductivity is decreased by increase of soil electrical conductivity. Rahmati et al. (2012) showed that hydraulic conductivity coefficient is decreased by increase of salinity in saturated soil in both methods of Guelph and sink in which water table should be high.

RESULTS

In this study, super absorbent and vermicompost amendments caused decrease of bulk density and increase of porosity and hydraulic conductivity in which the vermicompost effect on increase of saturated hydraulic conductivity and porosity was significant. Also, adding salinity to irrigation water had a significant effect on decrease of soil hydraulic conductivity and porosity. Decrease of super absorbent effect on measured features relative to vermicompost can be known as more sensivity of super absorbent to the type of environment because super absorbent has less scope to absorb water and expand in ionic and heavy-textured environments and on the other hand, decay rate of vermicompost is decreased by placing in environment with high electrical conductivity, but super absorbent is more influenced than vermicompost by circumstances and its modifying effect is decreased relative to vermicompost. According to the results of this study, vermicompost, as compared with super absorbent, can be the best option for the use of farmers because it increases soil fertility in addition of more effect on physical and hydraulic features and is economical.

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