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Effect of different rates of wooden ash application on physic-chemical properties of sandy desert soil

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Key words: Wooden ash, Soil chamber, Field pit, Physico-chemical properties, Nutrient level

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Abstract

In Pakistan, generally traditional irrigation methods are widely used to irrigate crops in which the entire soil surface is saturated without considering the soil properties. In sandy soil, irrigation application to crop is not only waste of the water but also leaches valuable nutrients out of the effective root zone. The present study was based on randomized complete block design including 4-Treatments (T_0 = control, T_1= 2 tons' Wooden ash /ha, T_2 = 4 tons' Wooden ash /ha and T_3 = 6 tons' Wooden ash /ha) with 3 replications and all treatments were arranged in field and laboratory. The soil samples were collected at the depth of 0-30 cm from Mithi and wooden ash randomly collected from homes of various villages of Taluka Mithi, Sindh, Pakistan. The results revealed that the soil textural class was changed in T_3 because effective ash application in desert soil and similar tends were observed. Similarly, the average dry bulk density, porosity and were significantly affected under all treatments. The variation in water holding capacity ranged from 20 to 23 percent under all treatments at both experimental sites after experiment. However, the similar trends were observed that the wooden ash treatments effect significantly increased with the application of different levels of soil pH and EC due to chemical reaction of soluble salts present in the ash. Moreover, the average organic matter, total nitrogen and phosphorus were also improved at desired depths under both experiments and approximately same trend was observed at both cases.

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Introduction

Growing pattern of world population and consumption rates will lead to increase the food production up to 40% of the present time within next 30 years. Likewise, competition for land, water, and energy, in addition to the overexploitation of fisheries, will affect our ability to produce food, as will the urgent requirement to reduce the impact of the food system on the environment is the major challenge (Charles *et al.*, 2010).The literature shows that earth is covered with 71% of ocean while remaining 29 % is land surface out of that 29% land and 33% of which is desert which means 1/3rd of the land surface area and only 11 percent of the world's land is used to produce food for the world population (Cain, 2015), whereas 10.57 % of world area is still arable land. But due to many constraints either environmental, soil characteristics or water availability were the major of them. This land is kept barren. The utilization of this land can be the alternative to mitigate the food demand. In Pakistan about 200,000 square kilometers of desert area which always suffers from food and water scarcity. Mostly rainfall is generally limited to 100-500 mm per year and sandy soils are widely distributed in tropics where they occupy most of arid and semi-arid areas. Despite harsh living conditions these desert areas are also inhabited by a significant number of people and livestock. The desert people mostly lead a semi-nomadic life and are on the continuous move from one place to another in search of water and fodder for their animals. In consideration of above conditions, researchers suggested many possible solutions but still there is a keen requirement to work and implement the solutions in backward areas like Thar Desert, where the lively hood is totally based on rain water harvesting which is very limited. Therefore, water productivity is of keen interest and as sandy soil is having the worst water holding capacity among all the soils so it is necessary to modify the soil properties before cultivation. There are various approaches of soil modification which are traditionally and experimentally used from decades but still these approaches need amendments from time to time with the changing environmental and soil conditions.

The wood ash has been successfully used all around the world in order to enhance the soil properties for various agricultural products. It is derived from plant material, it contains most of the 13 essential nutrients the soil must supply for plant growth. When wood burns, nitrogen and sulfur are lost as gases, and calcium, potassium, magnesium and trace element compounds remain. The carbonates and oxides remaining after wood burning are valuable liming agents, raising pH, thereby helping to neutralize acid soils. In Pakistan, having a huge production of wooden ash which is wasted annually in a million of tons, therefore, the potential that can be utilized as a soil modifier for agricultural production. The concept of environmental management basically revolves around the title of "reusability of waste materials". It is also underestimated in the beginning and it was just considered useless and it was disposed of by dumping in landfills. With advancement of time it was found very useful admixture for soil improvement and was started to use as admixture used in gardening widely.

Organic amendments have been proposed as an effective method to improve physical and chemical properties of sandy soils on the other hand, the increase in the organic matter content will improves the water capacity of these soils (Chiroma *et al.*, 2006). These soils are characterized by low soil organic carbon (SOC), low cation exchange capacity (CEC), high risk of nutrient leaching, low structural stability and high sensitivity to erosion and crusting. In addition, chemical fertility and physical stability are weak in these soils. Keeping the above facts in view, this research was conducted to evaluate the effects of different rates of wooden ash on soil properties in terms of physical and chemical soil properties at field and laboratory level.

Materials and methods

Experimental sites

This research study was conducted to improve the soil properties of desert soil through wooden ash application in winter season at the experimental station of Department of Irrigation and Drainage, Sindh Agriculture University Tandojam.

The experimental site is located at latitude: 25° 25' 28" N; longitude: 68° 32' 25" E; altitude: 26 m. The approximately same climate condition at experimental site as well as Thar and assumed as semi-arid climate area. The present research study was based on randomized complete block design including 4-Treatments (T_o = control, T_1= apply 2 tons' Wooden ash/ha, T_2 = apply 4 tons' Wooden ash/ha and T_3 = apply 6 tons' Wooden ash/ha) with 3 replications and all treatments were arranged in field and laboratory experiment, the experimental layout is shown in Fig.1(a) and 2(a).The experimental design, total 24 plots divided into two experiments (soil chambers and field pits) with an average pits size of 0.30 m by 0.30 m width and length and 0.30 m depth was constructed for field experiment. Similarly, 0.105 m of the diameter and 0.30 m depth was constructed for laboratory experiment. Fill these cylinder blocks and pits with porous material in the bottom and sandy soil on its top and show in the figure. The soil chambers and field pits designed parameters are shown in Fig.1(b) and 2(b).

Soil and wooden ash sampling

The soil samples were collected at the depth of 0-30cm from Mithi city as well as wooden ash (raw material of Khejri or Kandi) randomly collected from homes of various village of the Taluka Mithi District Tharparkar.

Determination of soil physical and chemical properties

The composite soil samples were collected at depths of 0-15 cm from the top of the surface under all experimental plots. Soil texture was determined by Bouycous hydrometer method (Bouyoucos, 1962), dry bulk density was determined using the method adopted by Blake and Hartge (1986), field capacity was determined by Veihmeyer and Hendrickson method (1931) and porosity was determined with the help of dry bulk density and particle density (2.65 g/cm^3). The infiltration rate of field was determined by double-ring infiltrometer method. In order to determine water holding or water retention capacity of soil. The 100-gm soil sample and 100 ml of water was collected, and soil filled in fluke and then added 100 ml water in it. The water drain was collected from the sample and recorded. Similarly, same water store retuned in soil, then that water stored in soil called as water retention capacity of soil. However, soil EC, pH and Nutrient contains bases on saturated soil paste extract using appropriate techniques and calculated by using their standard equations given by Rowell, 1994. Total Nitrogen was determined by Kjeldahl method while Organic content was determined by the (Walkey and Black 1934) dichromate oxidation procedure.

Irrigation delivery scheme (Depth and frequency of irrigation)

The soaking doze of 100 mm was applied under all treatments, when the soil came into the workable condition it was ploughed again with arrows and then leveled through scale. The irrigation scheduling is based on the soil moisture depletion and each irrigation application will be applied at 50% deficit in soil moisture content on crop requirements (MINFAL, 2005) and monitored by Tensiometers under all treatments.

Data analysis

The correlations were also developed for soil physico-chemical properties, i.e. water holding capacity, bulk density, porosity, soil pH, electrical conductivity of saturated soil extract, organic matter (%), phosphorus (P) and nitrogen (%) for experiment study using Microsoft Excel 2016.

Results and discussion

Soil physical properties

The knowledge of the soil texture, dry bulk density, porosity and water holding capacity of the soil provides useful tool to develop the relationship between water saving and water consumptive use. In present study soil, textural class were remained same under T_o, T_1 and T^2. Soil texture class was changed in T_3 because effective ash application in desert soil and similar tends were observed on both experimental sites. The soil at samples site was same, so that the variation in the soil texture has been expected because of the different wooden ash applications rates.

Soil dry bulk density

The average soil dry bulk density was 1.56 and 1.50 g cm^{-3} under T_0 after field and laboratory experiments respectively. Similarly, in field experiment, the average dry bulk density at desired depth increased to 1.60 g cm^{-3}, 1.62 g cm^{-3} and 1.69 g cm^{-3} under T_1, T_2 and T_3 respectively as shown in the Fig.3. However, the average dry bulk density at desired depths increased to 1.53 g cm^{-3}, 1.54 g cm^{-3} and 1.63 g cm^{-3} under T_1, T_2 and T_3 respectively under laboratory experiment and reading as shown in the Fig. 4. Variation in the values of soil bulk density was significant throughout the 0-15 cm depth soil profile under all treatments with R^2 value was 0.938 and 0.832 at both experimental sites.

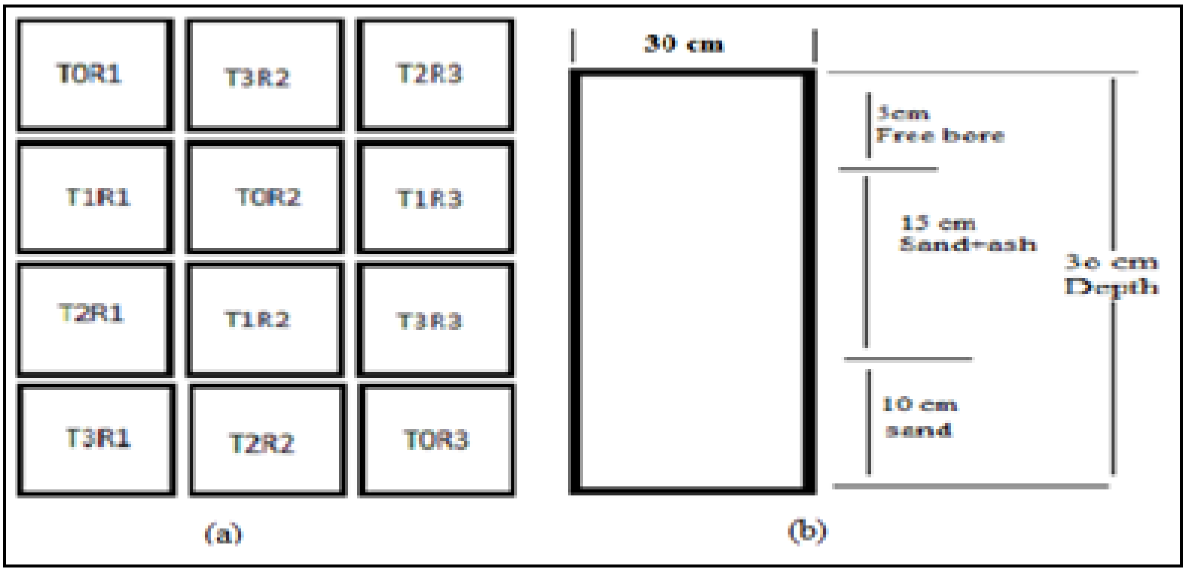

Fig. 1. Experimental layout and pots size field experiment.

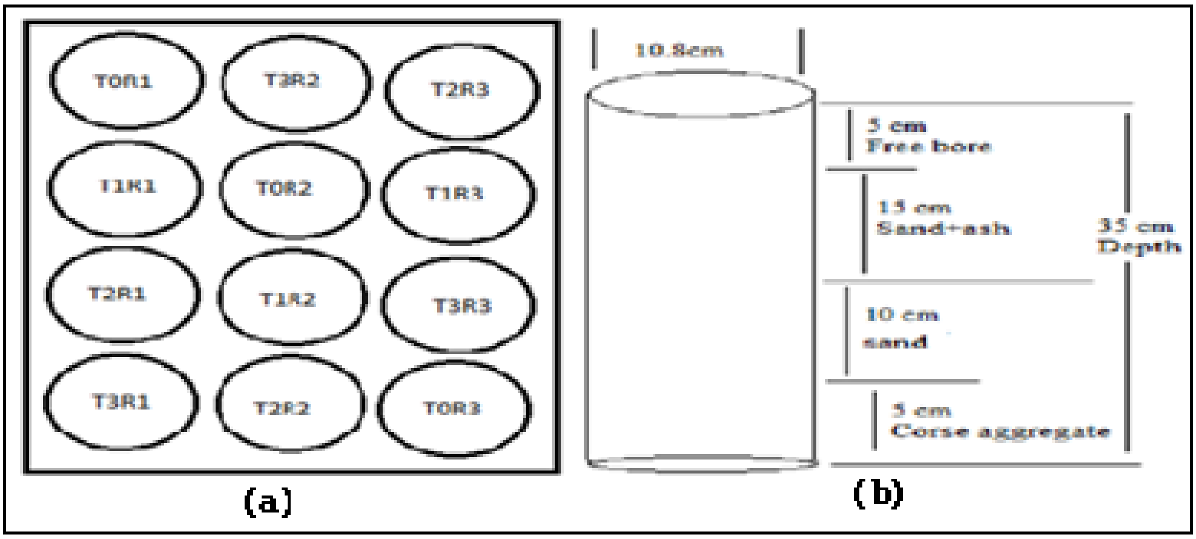

Fig. 2. Experimental layout and chamber size for laboratory experiment.

Porosity of the Soil

After experiments, the average porosity of the soil was 41 and 43 % at 0-15 cm depth under T_0 in field and laboratory experiments respectively.

In field experiment, the average soil porosity at desired depths was slightly decreased to 40, 39 and 36 % under T_1, T_2 and T_3 respectively as shown in the Fig. 5.

Similarly, the average soil porosity at desired depths at slightly decreased to 42, 42 and 38 % under T_1, T_2 and T_3 respectively in laboratory experiment and reading as shown in the Fig.6. Statistically, it is observed that difference in the values of soil porosity is significant under all treatments with R^2 value was 0.938 and 0832 in both experiments.

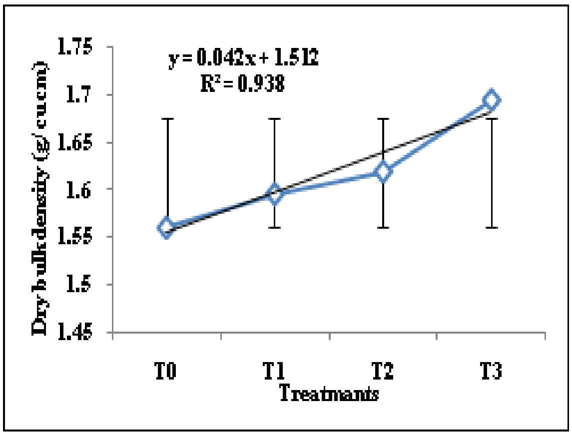

Fig. 3. Average and standard deviation values for dry bulk density readings in all treatments at field experiment.

The wooden ash application in soil, a reduction in micro porosity of the soil because the settlement of ash particles in soil pores. The fine pores contribute to having more water that is uneasily conducted and readily available in the soil.

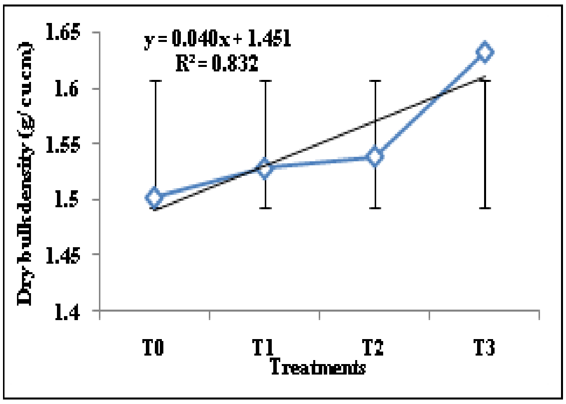

Fig. 4. Average and standard deviation values for dry bulk density readings in all treatments at Laboratory experiment.

Water holding capacity of the soil

After both experiments, on average, the water holding capacity of the soil was 21 and 22 % at 0-15 cm depth under T_0 in field and laboratory experiments respectively.

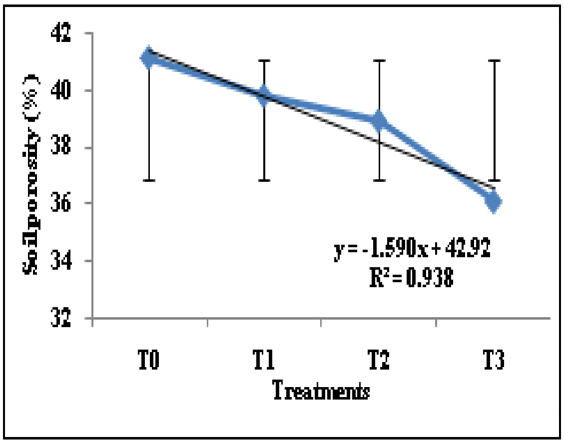

Fig. 5. Average and standard deviation values for soil porosity readings in all treatments at field experiment.

In field experiment, the average water holding capacity of the soil at desired depths was slightly increased to 33, 36 and 41 % under T_1, T_2 and T_3 respectively as shown in Fig. 7. Another hand, the average water holding capacity of the soil at desired depths was slightly increased to 31, 45 % under T_1, T_2 and T_3 respectively in laboratory experiment and reading as shown in Fig. 8. Statistically, it is observed that difference in the values of soil porosity is significant under all treatments with R^2 value was 0.937 and 0.911 in both experiments. The results are presented in Fig. 5 and 6 which revealed that the variation in water holding capacity ranged from 20 to 23 percent under all treatments at both experimental sites.

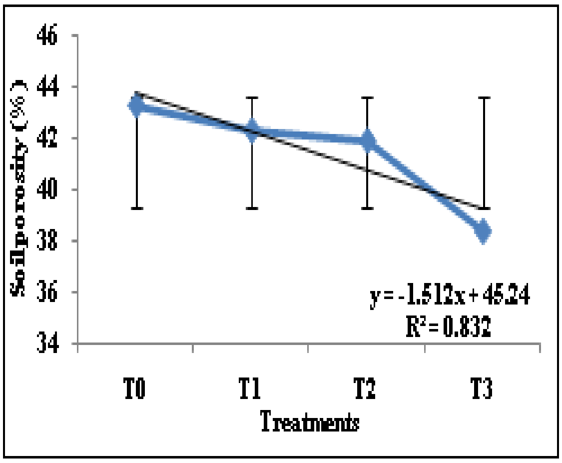

Fig. 6. Average and standard deviation values for soil porosity readings in all treatments at Laboratory experiment.

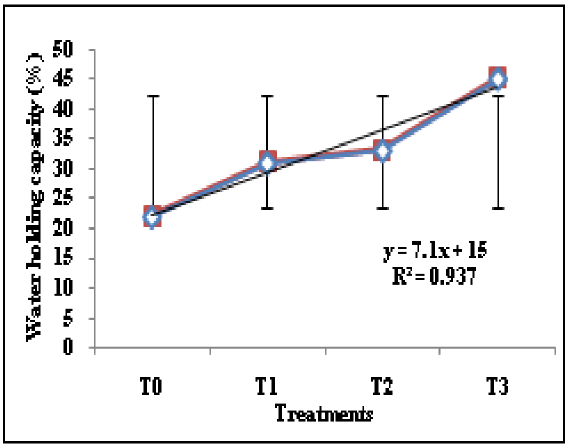

Fig. 7. Average and standard deviation values for water holding capacity readings in all treatments at field experiment.

The effect of ashes addition on physical properties of California soils has been studied by Chang *et al.* (1977). They have found that the increasing hydraulic conductivity of the soil at low ash amendments and an increasing water holding capacity, but without subsequent increase in plant-available water. At normal agronomic rates (<2.5% by volume) the impact on water release was very small. Etiegni and Campbell (1991) have shown that wood ash particles swell in contact with water and can obstruct soil pores. Consequently, this may reduce the aeration and increase the water holding capacity.

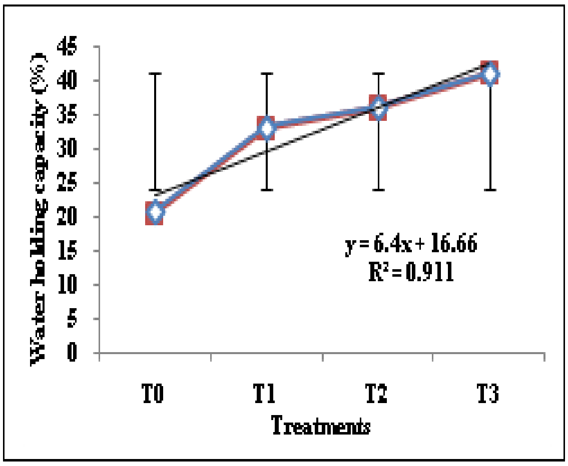

Fig. 8. Average and standard deviation values for water holding capacity readings in all treatments at Laboratory experiment.

Soil chemical proprieties

The application of wooden ash and groundwater to apply in the field and laboratory experiment, also bring the dissolved salts which may be accumulated in the derived depth as well as plant root zone area and affected the soil chemical properties.

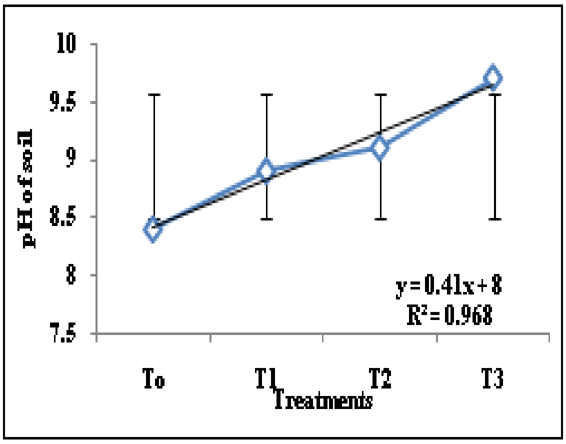

Fig. 9. Average and standard deviation values for soil pH readings in all treatments at field experiment.

The effects of wooden ash application in soil are may be possible to give better or negative results of crop growth at designed treatments in sandy soil.

The soil chemical proprieties were measured in terms of soil pH, EC of soil, organic matter (%), phosphorus (P) and nitrogen (%) after experiment.

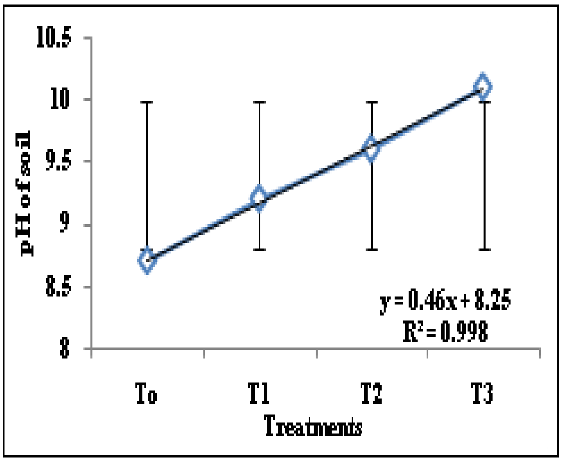

Fig. 10. Average and standard deviation values for soil pH readings in all treatments at Laboratory experiment.

Soil pH

After experiment, the values of the soil pH in field experiment were 8.4, 8.9, 9.1 and 9.2 at the depth of 0-15 cm under T_o, T_1, T_2 and T_3, respectively (Fig. 9). Similarly, the pH values of the soil sample collected from the same depth for Laboratory experiment under T_1, T_2 and T_3.

The average soil pH values under T_o, T_1, T_2 and T_3were 8.7, 9.2, 9.6 and 10.1 respectively in irrigated plot (Fig. 10). These trends revealed that the wooden ash treatments effect on increase of soil pH due to chemical reaction of soluble salts present in the ash at both experimental sites.

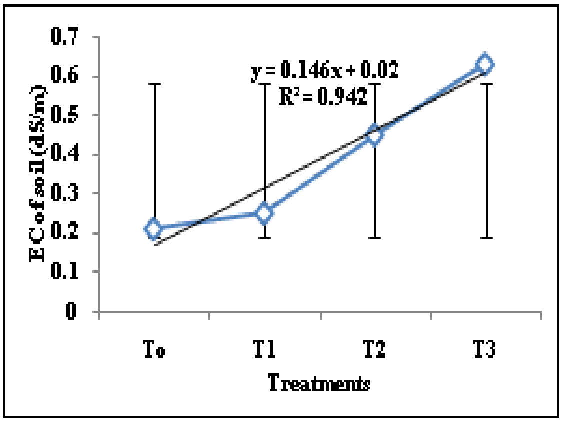

Fig. 11. Average and standard deviation values for EC of soil readings in all treatments at field experiment.

It was observed that the pH increased significantly with the application of different levels of wood-ash. According to Haynes and Naidu (1998) reported that at low pH acid soils are normally flocculated. As pH is raised by addition of wood-ash the net negative change on soil surface is increased and the ratio of negative to positive (+ve) charges also increases.

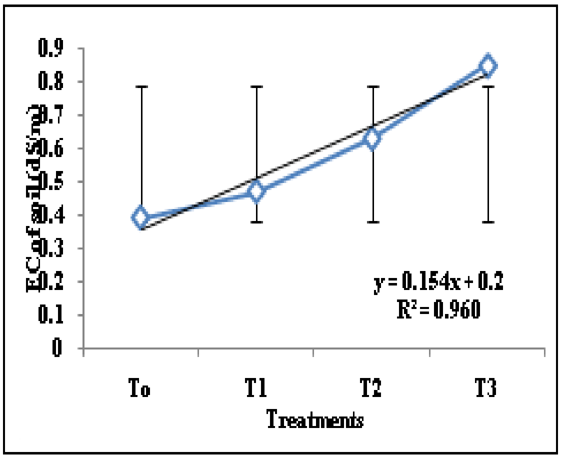

Fig. 12. Average and standard deviation values for EC of soil readings in all treatments at Laboratory experiment.

The experimental results are similar to those given by Ayeni *et al.* (2008) they concluded that the increased pH of soil relative to non-ash treated soil.

Results from this study show that wood-ash when used as soil amendment reduced soil acidity to levels required for crop productions. Similarly, Odedina *et al.* (2001) reported reduced acidity and increased cation availability in soils amended with wood-ash.

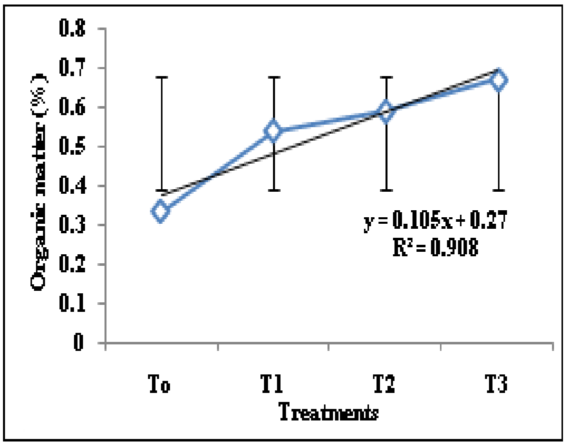

Fig. 13. Average and standard deviation values for organic matter readings in all treatments at field experiment.

Electrical conductivity of soil

After experiment, the values of the soil EC in field experiment were 0.21, 0.25, 0.45 and 0.63 at the depth of 0-15 cm under T_o, T_1, T_2 and T_3respectively (Fig. 11). Similarly, the EC values of the soil sample collected from the same depth for Laboratory experiment under T_1, T_2 and T_3. The average soil pH values under T_o, T_1, T_2 and T_3were 0.39, 0.47, 0.63 and 0.85 dS/m respectively in irrigated plot (Fig. 12). The results are shown in Figure 9 and 10.

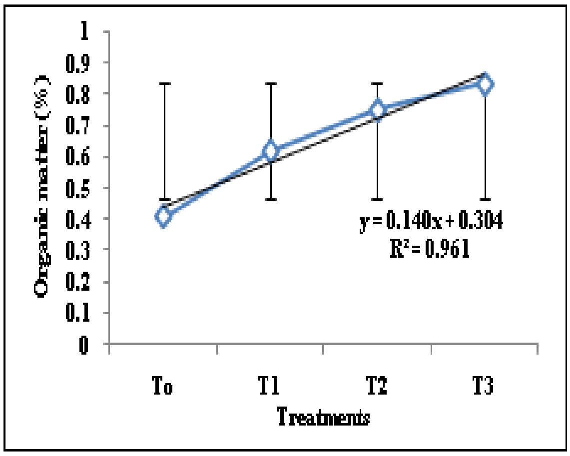

Fig. 14. Average and standard deviation values for organic matter readings in all treatments at Laboratory experiment.

The above results showed that the different level of wooden ash amendments in soil increased soil salinity and approximately same trend was observed under both experiments it shows the impact of different wooden ash application on the soil salinity. According to Clapham and Zibilske (1992), the electrical conductivity of the soil solution increases linearly with wood ash dose and may cause salinity problems.

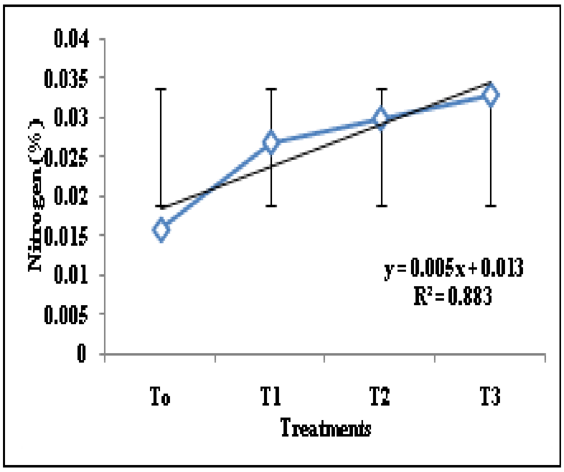

Fig. 15. Average and standard deviation values for nitrogen (%) readings in all treatments at field experiment.

Organic matter

The average organic matter in soil was 0.34 and 0.41 % under T_0 after field and laboratory experiments respectively. Similarly, in field experiment, the average organic matter at desired depths increased to 0.54, 0.59 and 0.67 %under T_1, T_2 and T_3respectively as shown in Fig.13. However, the average organic matter at desired depths increased to 0.62, 0.75 and 0.84 % under T_1, T_2 and T_3 respectively under laboratory experiment and reading as shown in Fig. 14.

It is clear from above data that the wooden ash increased organic matter in soil. Baath and Arnebrant (1994) observed the increased soil nutrient due to wood-ash application could be due to enhance microbial activities in the soils and production of organic matter be attributed to higher organic matter in the wood ash amended plots.

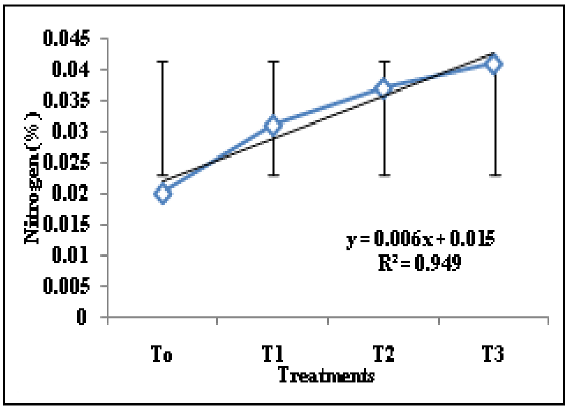

Fig. 16. Average and standard deviation values for nitrogen (%) readings in all treatments at Laboratory experiment.

Nitrogen (%)

After experiment, the nitrogen (%) available in field experiment was 0.016, 0.027, 0.03 and 0.033 % at the depth of 0-15 cm under T_0, T_1, T_2 and T_3respectively (Fig. 15). Similarly, the nitrogen (%) available values of the soil sample collected from the same depth for Laboratory experiment under T_1, T_2 and T_3. The average nitrogen (%) available values under T_0, T_1, T_2 and T_3were 0.02, 0.031, 0.037 and 0.041 % respectively in irrigated plot (Fig. 16). These trends revealed that the wooden ash treatments effect on increase of nitrogen percentage in the soil due to chemical reaction of soluble salts present in the ash with R^2 value was 0.88 and 0.94 at both experimental sites. According to Tisdale *et al.* (1993) suggested that the nitrogen (%) and organic matter play a vital role in nutrient availability and soil fertility.

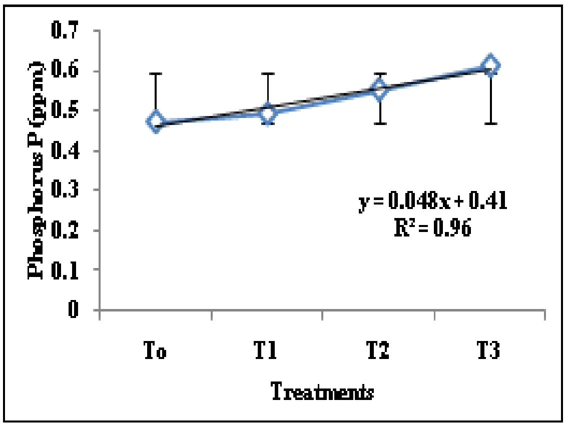

Fig. 17. Average and standard deviation values for phosphorus (P) readings in all treatments at field experiment.

Phosphorus (P)

The average phosphorus in soil was 0.47 and 0.46 ppm under T_0 after field and laboratory experiments respectively. Similarly, in field experiment, the average phosphorus at desired depths increased to 0.49, 0.55 and 0.91 ppm under T_1, T_2 and T_3 respectively as shown in Fig.17. However, the average phosphorus at desired depths at increased to 0.47, 0.59 and 0.75 ppm under T_1, T_2 and T_3respectively under laboratory experiment and reading as shown in Fig. 18.

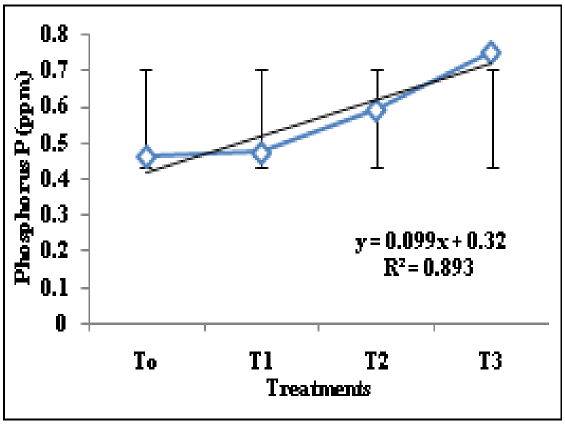

Fig. 18. Average and standard deviation values for phosphorus (P) readings in all treatments at Laboratory experiment.

These results of the experiment are similar to those reported by many researcher, who reported that the increased available P could be attributed to traces of P released from Al3+ in line with the observation. Similarly, studies by Owolabi *et al.* (2003) and Odedina *et al.* (2001)) showed that plant derived ash increased soil nutrient content.

Conclusion

It was concluded that the wooden ash application increased soil physico-chemical characteristics under all treatments. Wooden ash had a profound effect on the water-holding capacity when amended with a medium to fine textured sandy soil. T_3 increased soil nutrient content and beneficial for crop productivity, because wooden ash supplied additional nutrients to soil and increased soil physical properties.

Recommendation

The present study needs to be continued to observe the long-term effects on hydrophilic behavior of sandy soil and crop yield.

It is dire need to improve soil properties with applied wooden ash in the irrigated areas and device the concrete recommendations.

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