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# Effect of chicken manure on soil infiltration rate, soil moisture retention and wheat (*Triticum aestivum* L.) Yield of desert soil in the Northern State, Sudan

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## ABSTRACT
This study was conducted for two successive seasons 2014/15 and 2015/16 on desert soil with the aim to investigate the effect of chicken manure on infiltration rate and soil moisture retention of desert plain soils and wheat yield in the Northern State of Sudan as well. The chicken manure was used with four levels (0, 4, 8, and 12 ton $ha^{-1}$). The treatments were arranged in a randomized complete block design with three replications. The results showed that the effect of chicken manure was effective in improving the soil physical properties under investigation. The chicken manure application decreased soil infiltration rate on average across the two seasons varied from 3.5 cm $hr^{-1}$ for the control to 1.2 cm $hr^{-1}$ in the chicken manure treatments and improved the soil moisture retention as well and also, increased available water on average across both seasons varied form 15 mm in the control to 31mm in the chicken manure treatments. The result also showed that the effect of chicken manure obtained very highly significant ($P \leq 0.001$) increase in the grain yield of wheat on the average across the two seasons varied from 0.71 ton $ha^{-1}$ in the control treatment to 3.75 ton $ha^{-1}$ in the chicken manure treatments. The results showed that there were no significant differences among the levels of chicken manure. It is recommended that 4 ton $ha^{-1}$ chicken manure is the optimum dose can be applied to reclaim these desert plain soils and increase wheat yield in Northern Sudan

***Keywords:*** desert soil, chicken manure, soil infiltration rate, soil moisture retention, wheat

## 1. Introduction
Organic matter plays such a key role in soil productivity by affecting almost all physical, chemical and biological properties. Successful land reclamation depends on recreating a surface horizon with enough soil organic matter to sustain productivity
(Larney and Angers, 2012).

Wheat (*Triticum aestivum* L) is the most important cereal crop in the world trade and is one of the main sources of carbohydrates and also contains a considerable amount of protein, minerals and vitamins. There is a need to increase the yield of wheat per unit area in the world to fulfill its demands resulting from the rapid growth of the world population. The use of modern varieties of wheat and judicious fertilization are important factors which can help to increase wheat production (Rasul, 2015).

Organic fertilizers have positive effects on wheat grain yield and some soil properties (Ali, 2001). Ahmed (2010) evaluated the effect of green and farmyard manures on the properties of desert plain soil in Northern Sudan. His study showed that each of the tested manures was effective in improving the soil physical properties. The grain yield of wheat crop was high to very highly significantly increased in response to the application of each of the green and farmyard manures.

Adeleye *et al.* (2010) investigated the effect of poultry manure on soil physico-chemical properties of sandy loamy soil in Southwestern Nigeria. Their study showed that poultry manure application improved soil physical properties; it reduced soil bulk density, temperature and also increased total porosity and soil moisture retention capacity.

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Elia and Boulos (2019) investigated the effect of different rates of bentonite, chicken manure and their combination on salts affected sandy soil in Ismailia Governorate, Egypt. Their study showed the application rates of chicken manure 5, 10 and 15 ton/fed lead to, increasing the values of water-holding pores (WHP) by 9.21, 10.43 and 11.27% respectively, and also decreased the infiltration rate significantly compared to the control.

Rawls *et al.* (2003) studied the effect of soil organic carbon on soil water retention. They used the U.S. National Soil Characterization database and the database from pilot studies on soil quality as affected by long-term management. They found that increase in organic matter content led to increase of water retention in sandy soils.

Cercioglu *et al*. (2014) studied the changes in physical conditions of a coarse textured soil by the addition of organic wastes (composted tobacco waste, chicken manure and bio-humus) in Izmir, Turkey. They reported that the addition of organic wastes resulted in a significant ($p \leq 0.05$) decrease in bulk density (BD); increase in porosity (PO), field capacity (FC), wilting point (WP), available water content (AWC) and structure stability index (SSI) of soil samples when compared to the control.

Khalid *et al*. (2014) investigated the influence of poultry manure and NPK fertilizer on the hydraulic properties of sandy soil in Ghana. Their study showed that poultry manure was improved the hydrological properties of the sandy soil. The significant decreases in water entry (infiltration rate) and movement suggest that poultry manure application can minimize excessive leaching of plant nutrients in sandy soil.

The spread of the electrical power after the construction of Merrowi dam encourages investment in poultry farms in various localities in the Northern State, therefore chicken manure is expected to increase in the future. The lack of knowledge of many farmers who used chicken manures lead to failure of many cultivated crops. For the previously mentioned reason and the availability of manures, this situation necessitates more investigation on the application of manure. Hence, chicken manure may pose a solution to the problem of soil fertility.

This study was conducted with the aim to assess the effect of chicken manure on soil infiltration rate, soil moisture retention and wheat yield in desert plain soils of El Multaga soil series.

## 2. Materials and Methods

The experiment was carried out during the two successive seasons 2014/15 and 2015/16 at the National Institute of Desert Studies Research Farm, New Hamdab Scheme, in the Northern State of Sudan. The study area lies at the intersection of latitude 17º 55' N, and longitude 31º 10' E in the desert climate.

The soil of the study area belongs to the El Multaga soil series which classified as Vertic Haplocambids, fine loamy, mixed, supper active, hyperthermic. The soil structure is moderate subangular blocky. It is non-saline ECe ≥ 4 d $Sm^{-1}$ (soil ECe 0.35, 0.37 and 0.42 d $Sm^{-1}$ at 0 – 23, 23 – 65 and 65 - 80 cm soil depth, respectively) and non-sodic ESP ≥ 15 (ESP = 3, 3 and 4 for 0 – 23, 23 - 65 and 65 - 80 cm soil depth, respectively). Generally, the soil chemical fertility is low and mostly these soil deficient in nitrogen, phosphorus and organic carbon for optimum yield production of different cultivated crops. The physical and chemical properties of the soil are shown in Table 1 (LWRC, 1999). Chicken manure was manually broadcasted six weeks before planting on the designated experimental units at the rates of 0, 4, 8 and 12 ton $ha^{-1}$. The manure was mixed into the soil using a disk plow. Then the soil was watered and the subsequent watering was carried out at ten- day interval for six weeks before sowing of wheat crop.

Wheat variety Wadi Elneel was sown manually on 20$^{th}$ November 2014 and on 20$^{th}$ November 2015 for first and second seasons by dibbing, using seed rate of 120 kg $ha^{-1}$, at 0.2 m inter-row spacing. Nitrogen and phosphorus were added as recommended (86 kg N $ha^{-1}$ plus 43 kg P2O5 $ha^{-1}$) by (ARC). The irrigation was carried out every ten days. During all experimental periods observations on soil infiltration rate, soil moisture retention, available moisture and grain yield of wheat were taken.

**Table 1:** Some soil properties of the experimental site

| Soil properties | Soil depth (cm) | | | | |
|---|---|---|---|---|---|
| | **0 - 23** | **23 – 65** | **65 - 80** | **80 - 105** | **105 - 125** |
| **FS (%)** | 40 | 23 | 22 | 21 | 24 |
| **CS (%)** | 37 | 33 | 43 | 42 | 40 |
| **Silt (%)** | 15 | 25 | 11 | 19 | 8 |
| **Clay (%)** | 8 | 19 | 24 | 18 | 28 |
| **Texture** | **LS** | **SL** | **SL** | **SL** | **SCL** |
| **pH (paste)** | 7.5 | 7.3 | 8.1 | 7.8 | 7.5 |
| **ECe** | 0.35 | 0.37 | 0.42 | 1.1 | 3.2 |
| **ESP** | 3.0 | 3.0 | 4.0 | 5.0 | 8.0 |
| **$CaCO_3$ (%)** | 0.8 | 2.6 | 10.4 | 0.2 | 27.5 |
| **O.C (%)** | 0.052 | 0.066 | 0.078 | 0.061 | 0.052 |
| **C/N ratio** | 4 | 4 | 5 | 5 | 5 |

LS =loamy sand, SL = sandy loam, SCL= sandy clay loam

### 2.1. Infiltration rate method:

Infiltration rate was determined after the application of treatments and at the end of the season. A double ring infiltrometer as described by Landon (1984) was used. The two cylinders were driven into the soil to 12 cm- depth, and then a plastic sheet was placed into the inner cylinder to prevent infiltration of water into the soil before time zero. At time zero the plastic sheet was removed and the rate of water height drop was measured.

### 2.2. Soil moisture retention method:

Composite soil samples were collected from the top 30 cm of the soil surface using an auger from each experimental unit for soil moisture retention after the termination of the experiment immediately after harvesting (at the laboratories of the Faculty of Agricultural Studies, Sudan University for Science and Technology).

In the method used, two types of pressure plates were used; 1 bar and 15 bar ceramic plates, compressors giving pressure up to 250 psi, air- tight extractors, and two manifold assemblies, with values and gauges, one operating up to 15 psi and the other in the range 15 to 250 psi (Klute,1986).

In the procedure, saturated soil is placed in a closed chamber, subjected to the required air pressure and allowed to stand while water is forced out of it through the porous plate to a graduated burette outside the chamber. After equilibrium has been reached, the moisture content of the sample is determined by oven- drying at 105°C for 24 hours. The pressures used included 0.3,5,10, and 15 bar (4.5- 220 psi) corresponding to pF 2.5-4.2.

## 3. Results and Discussion

### 3.1. Soil infiltration rate (cm hr-1):

Fig. 1 shows the infiltration rate for the control and the chicken manure treatments for season 1. The rate started higher from about 14 - 23 cm $hr^{-1}$ and then decreased clearly and progressively down the profile to about 1.1 - 4 cm $hr^{-1}$.

The result showed that the highest rates during all time was obtained by the control, while the lowest (1.1 $cmhr^{-1}$) was found for chicken manure treatment 12 ton $ha^{-1}$.

Fig. 2 shows the infiltration rate for the control and the chicken manure treatments for season 2. The rate started higher from about 16 - 20 cm $hr^{-1}$ and then decreased clearly and progressively down the profile to about 1.2 - 3 cm $hr^{-1}$.

The result showed that the highest rates during all time was obtained by the control, while the lowest (1.2 $cmhr^{-1}$) was found for chicken manure treatment 12 ton $ha^{-1}$. This result almost similar to that of the first season.

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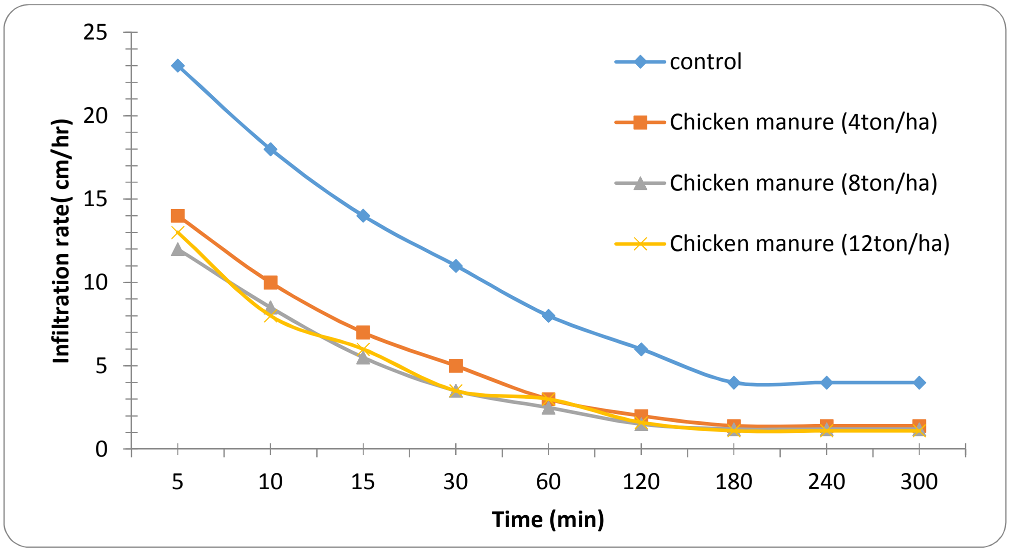


**Fig.1:** Average infiltration rate for the control and the effect of chicken manure after harvesting (season 1).

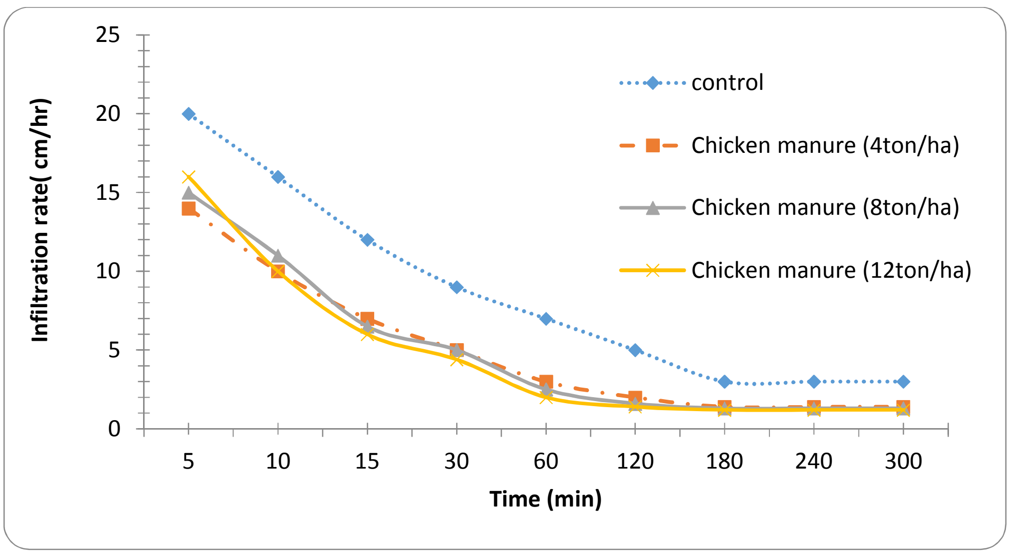


**Fig. 2:** Average infiltration rate for the control and the effect of chicken manure after harvesting (season 2).

Table 2 revealed that chicken manure treatments positively decreased the final infiltration rate from 4 cmha$^{-1}$ for the control to 1.1 – 1.4 cmhr$^{-1}$ for the chicken manure treatments in season 1 and from 3 cmhr$^{-1}$ for the control to 1.2 – 1.4 cmhr$^{-1}$ for the chicken manure treatments in season 2. This result agrees with that of Khalid *et al*. (2014), and Elia and Boulos, (2019) who found that soil infiltration rate positively was decreased in response to chicken manure application.

Fig. 3 showed that the wetting front for the control and chicken manure treatments. The result showed that the deepest wetting front was recorded for the control (58cm for season1 and 55cm for season2) and the lowest for the chicken manure (12 ton ha$^{-1}$) treatment (37cm for season1 and 36cm for season2).

The reduction in water infiltration rate as a result of the addition of the chicken manure could be attributed to the increase in the moisture retention in the root zone which decreases the deep percolation and wetting front depth.

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**Table 2:** Average final infiltration rate ($cmhr^{-1}$) for the control and the effect of chicken manures after harvest.

| Treatments | Season 1 | Season 2 |
|---|---|---|
| **Control** | 4.0 | 3.0 |
| **Chicken manure (4 ton $ha^{-1}$)** | 1.3 | 1.4 |
| **Chicken manure (8 ton $ha^{-1}$)** | 1.2 | 1.3 |
| **Chicken manure (12 ton $ha^{-1}$)** | 1.1 | 1.2 |

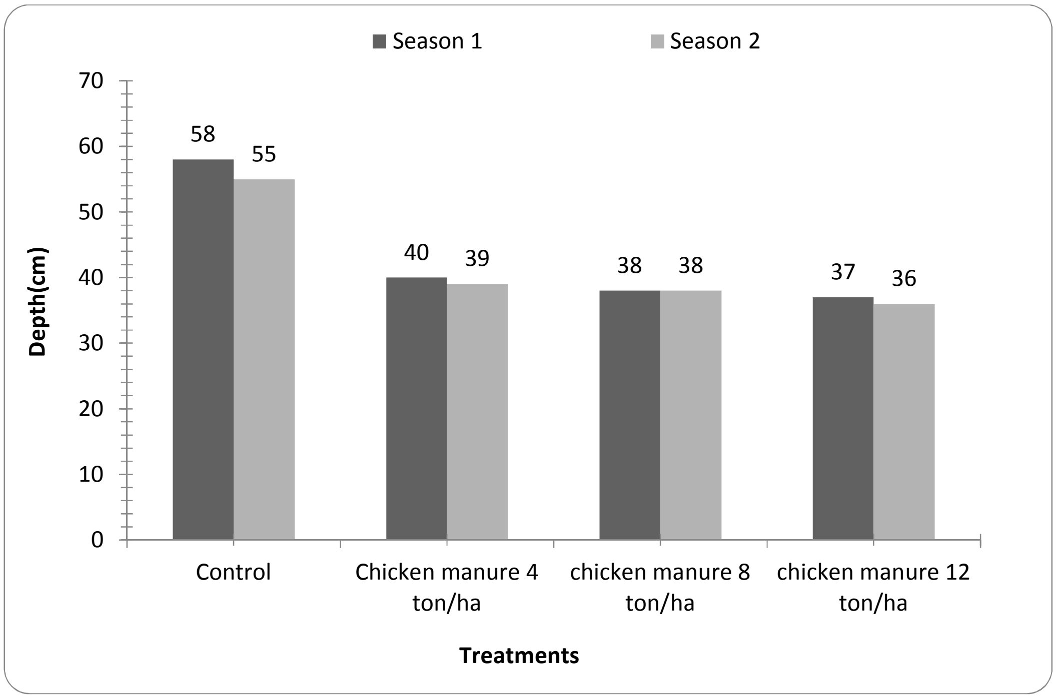


**Fig. 3:** Average wetting front (cm) for the control and the effect of chicken manure after harvesting.

### 3.2. Soil water retention:

The curves are drawn by plotting the % volumetric water (Ø) against suction (Ψm). Volumetric water content is obtained by multiplying the moisture weight by soil density. Water retention characteristics of the effect of chicken manure at different pressure for the two seasons are presented in Figs. 4 and 5. The moisture content of all treatments except the control treatments when plotted against suction equivalent to (0.3 to 15 bar) has shown a rapid decrease in moisture content between $\frac{1}{3}$ and 5 bar. The general shape of all curves indicates that as the moisture content (Ø) decreases binding of water becomes stronger, and the water retained between $\frac{1}{3}$ and 15 bar is of special interest as it is considered to represent the amount of water available to plant. It correlates well with the moisture remaining in the soil under field conditions, 2-3 days after irrigation. However, a number of limitations might be considered in the evaluation of plant available water. The wilting point at 15 bar varies between 3-5 percent for all samples of treatment.

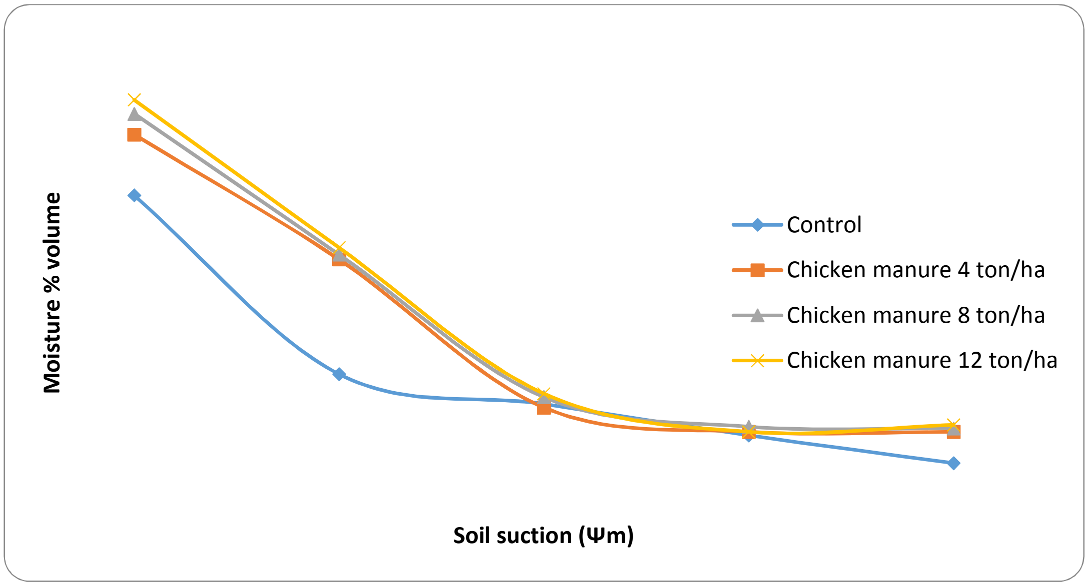


**Fig. 4:** Water retention curves of the effect of chicken manures and the control between 1/3 and 15 bar tension as a function of volumetric water content (season 1).

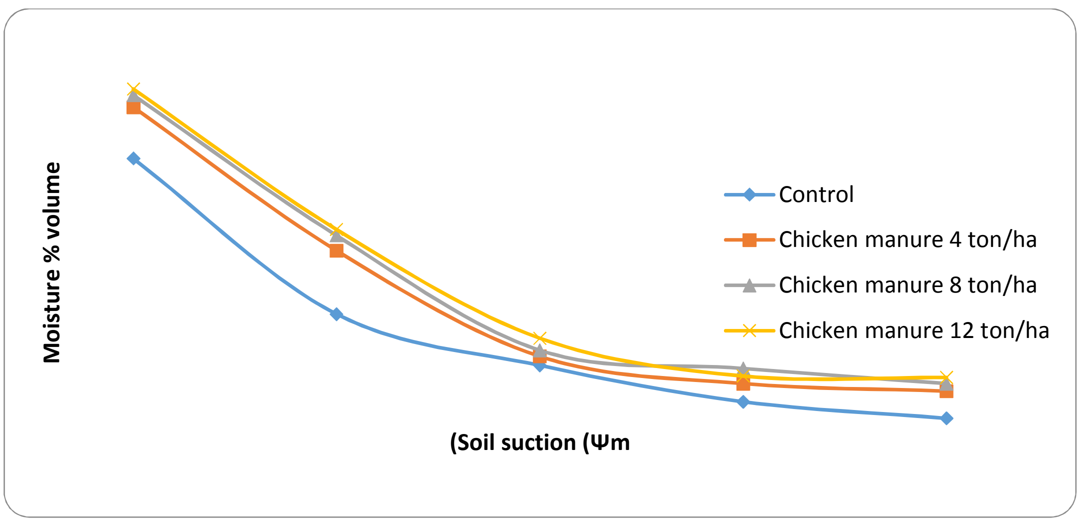


**Fig. 5:** Water retention curves of the effect of chicken manures and the control between 1/3 and 15 bar tension as a function of volumetric water content (season 2).

Table 3: shows that the chicken manure increased soil available water (soil equivalent depth) as compared with the control. In season one the lowest value (14 mm) of available soil water was recorded for the control treatment and the highest (34 mm) on chicken manure treatment (12 ton $ha^{-1}$). On the other hand, for the second season the lowest value (20 mm) of available soil water was recorded for the control treatment and the highest (37 mm) on chicken manure treatment (12 ton $ha^{-1}$). The available soil water recorded on the first level of chicken manure is not far from that recorded for the second and the third levels of organic manure. The improvement of soil moisture retention in response to application of organic manures has already been reported by Rawls *et al*. (2003), Adeleye *et a*l.(2010) and Cercioglu *et al*. (2014) who reported that organic manures improved the soil moisture retention and increased soil available water.

**Table 3:** Effects of chicken manure on soil moisture equivalent depth (30cm) of available Water (mm) in the Northern State, Sudan.

| Treatments | $\frac{1}{3}$ bar (%) | 15bar (%) | Av. Water (%) | Av. Water (mm) |
|---|---|---|---|---|
| **Season 1** | | | | |
| **Control** | 7 | 4 | 3 | 14 |
| **Chicken manure(4ton ha-1)** | 12 | 5 | 7 | 30 |
| **Chicken manure(8ton ha-1)** | 12 | 5 | 7 | 26 |
| **Chicken manure (12ton ha$^{-1}$)** | 12 | 4 | 8 | 34 |
| **Season 2** | | | | |
| **Control** | 8 | 4 | 4 | 20 |
| **Chicken manure(4ton ha-1)** | 10 | 3 | 7 | 30 |
| **Chicken manure(8ton ha-1)** | 11 | 3 | 8 | 31 |
| **Chicken manure (12ton ha$^{-1}$)** | 12 | 3 | 9 | 37 |

### 3.3. Grain yield of wheat crop:

The average grain yield for all seasons as influenced by the chicken manure is shown in Table 4. The results revealed that there were no significant differences among the levels of chicken manure in both seasons. The analyses of data in the two seasons revealed that there were very highly significant differences ($P \leq 0.001$) in grain yield between the control and the chicken manure treatments. The lowest grain yield was obtained by the control 0.52 to 2.05 ton ha$^{-1}$ while the highest grain yield (3.18 to 5.81 ton ha$^{-1}$) was recorded in chicken manure treatments for both seasons.

High wheat grain yield due to the application of organic fertilizers is reported by many researchers, Ali (2001), Ahmed (2010), and Rasul et al.(2015) who found that organic manure significantly increa the sed grain yield of wheat crop.

**Table 4:** Effect of chicken manure on grain yield of wheat crop.

| **Chicken manure levels** | First season 2014/5 | Second season 2015/6 |
|---|---|---|
| 0 ton ha$^{-1}$ (control) | 0.51$^{b}$ | 0.92$^{b}$ |
| 4 ton ha$^{-1}$ | 3.18$^{a}$ | 4.21$^{a}$ |
| 8ton ha$^{-1}$ | 3.16$^{a}$ | 4.29$^{a}$ |
| 12 ton ha$^{-1}$ | 3.28$^{a}$ | 4.39$^{a}$ |
| **Grand mean** | **2.52** | **3.53** |
| Sign. level | *** | *** |
| SE± | 0.286 | 0.465 |
| C.V | 19.52 | 11.70 |

Means followed by different letters in the same column are significantly different at $P \leq 0.05$.
*** and ** = significant level at $P \leq 0.001$ and $P \leq 0.01$.

## Conclusion

From the above mentioned results, it can be concluded that the application rates of chicken manure led to improve the soil physical properties under investigation. The results showed clearly that some soil properties and wheat yield were improved due to the application of chicken manure. It is positively decreased soil infiltration rate and increased soil moisture retention and consequently increased grain yield of wheat. The results revealed that there were no significant differences among the levels of chicken manure. It is recommended that 4 ton ha$^{-1}$ chicken manure is the optimum dose can be applied to reclaim these desert plain soils and increase wheat yield in Northern Sudan

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