Direct and residual effects of chicken manure on soil air dry bulk density and moisture content of a desert plain soil and wheat (*Triticum aestivum* L.) yield, Northern State, Sudan

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ABSTRACT

This study was conducted for three consecutive seasons 2014/15 (direct effect), 2015/16 (direct and residual effects) and 2016/17 (residual effect) on a desert soil with the aim to investigate direct and residual effects of chicken manure on air dry bulk density and moisture content of a desert plain soil as well as grain yield of wheat in the Northern State, Sudan. The chicken manure was used at four levels (0, 4, 8, and 12 ton ha^{-1}). The treatments were arranged in a randomized complete block design with three replicates. Land preparation was done manually for the residual effects of chicken manure so as not to mix the treatments which were fixed in the same plots of the first application of the manure. The results showed that the direct and residual effects of chicken manure were effective in improving soil physical properties. The soil air dry bulk density was very highly significantly ($P \leq 0.001$) reduced on the average across the two seasons and varied from 1.67 g cm^{-3} for the control treatment to 1.39 g cm^{-3} for the chicken manure treatments in the direct effect and from 1.60 g cm^{-3} to 1.33 g cm^{-3} for the residual effect. The total pore space (porosity) increased very highly significantly($P \leq 0.001$) on average across the seasons and varied from 36 % for the control treatment to 47.1% for the chicken manure treatments for the direct effect and from 38% to 49.1% for the residual effect in response to the application of the organic manure. The direct and residual effects of chicken manure very highly significantly ($P \leq 0.001$) increased the soil moisture percentage on the average across both seasons and varied from 9.4% in the control to 16.9% for the direct effect and from 10.5% to 19.6% for the residual effect in the top soil (30 cm soil depth).The results indicated that the direct and residual effects of chicken manure gave very highly significant ($P \leq 0.001$) increases in the grain yield of wheat on the average across the seasons and varied from 0.72 in the control treatment to 3.75 ton ha^{-1} in the direct effect and 1.87 to 5.54 ton ha^{-1} for the residual effect in this desert plain soil. It is recommended that 4 ton ha^{-1} of chicken manure can be applied to reclaim these desert plain soils and increase wheat yield in the Northern Sudan

INTRODUCTION

Regular addition of organic manures, such as animal, poultry and green manures and crop residues is very important in maintaining the tilth, fertility and productivity of agricultural soils and in protecting them from wind and water erosion. It also prevents nutrient losses through runoff and leaching. These materials have predictable beneficial effect on soil physical properties, such as increasing water-holding capacity, soil aggregation, soil aeration and permeability and decreased soil crusting and bulk density (Hornik and Parr, 1987).

Wheat (*Triticum aestivum* L) is one the most important cereal crops in the world trade. The use of improved wheat cultivars and fertilization are important factors which can increase wheat production (Rasul *et al.*, 2015). Organic fertilizers have positive effects on wheat grain yield and some soil properties (Ali, 2001).

In a study on the effect of different cultural practices and animal manures on soil properties and wheat production in the Mukabrab soil series in Northern Sudan, Awad Elkarim (2007) found that the addition of animal manure invariably resulted in a reduction of the soil bulk density and hence in an increase in soil moisture content. Ali (2001) showed that the addition of organic manures to Khashm Elgirba soil series was effective in improving the soil physical properties. The soil bulk density was highly significantly ($P \leq 0.01$) reduced while each of total soil porosity and the percentage of soil moisture were highly significantly ($P \leq 0.01$) increased in response to application of increasing rates of the studied manures.

Agbede *et al.* (2008) evaluated the effect of poultry manure on soil physical and chemical properties, growth and grain yield of sorghum in Southwest Nigeria. They found that the poultry manure significantly ($P \leq 0.05$) reduced soil bulk density and temperature and increased porosity and moisture content.

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

Ahmed (2010) evaluated the effect of green and farmyard manures on the properties of a desert plain soil in northern Sudan. His study showed that each of the tested manures was effective in improving the soil physical properties. The soil bulk density was highly to very highly significantly reduced while the percentage of soil moisture and grain yield of wheat were highly to very highly significantly increased in response to the application of each of the green and farmyard manures.

In a study at New Hamdab, Awad Elkarim and Younis (2008) evaluated the effect of farmyard manure, nitrogen and phosphorus on wheat growth and productivity for three consecutive seasons. They reported that farmyard manure and nitrogen had very highly significant ($p \leq 0.001$) effects on yield components and total yield of wheat in all seasons.

This study was conducted to assess the direct and residual effects of chicken manure on some soil physical properties and wheat yield on a desert plain soil of El Multaga soil series.

MATERIALS AND METHODS

The experiment was carried out during three consecutive seasons 2014/15 (direct effect), 2015/16 (direct and residual effect) and 2016/17 (residual effect) at the National Institute of Desert Studies Research Farm, New Hamdab Scheme, Northern State, 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 El Multaga soil series which is classified as Haplocambids, coarse loamy, mixed, hyperthermic. The soil structure is moderate subangular blocky (Table 1). It is non-saline and non-sodic (LWRC, 1999). Generally, the soil chemical fertility is low and deficient in nitrogen, phosphorus and organic carbon. The physical and chemical properties of the soil are shown in Table 1.

Table 1. Some soil properties of the experimental site.

Soil properties	Soil depth (cm)				
	0 - 23	23 – 65	65 – 80	80 - 105	105 - 125
CS (%)	37	33	43	42	40
FS (%)	40	23	22	21	24
Silt (%)	15	25	11	19	8
Clay (%)	8	19	24	18	28
Texture	LS	SL	SL	SL	SCL
CEC	6	14	26	24	26
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

L S = loamy sand, SL = sandy loam, SCL= sandy clay loam

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 incorporated into the soil using a disc plough. Then the soil was watered and the subsequent watering was carried out at ten-day interval for six weeks before sowing of the wheat crop.

Seeds of wheat (Wadi Elneel cultivar) were sown at the rate of 120 kg ha^{-1} on the 20th of November in all seasons at 0.2 m inter-row spacing. Nitrogen and phosphorus were added as recommended (86 kg N ha^{-1} plus 43 kg P_2O_5 ha^{-1}) by the Agricultural Research Corporation. Irrigation was carried out every ten days. During all experimental period, observations on soil dry bulk density, soil moisture content, soil total porosity and grain yield of wheat were taken.

Methods of soil physical analyses

The core sample method as described by Black (1965) and Landon (1984) was used to determine the soil dry bulk density (ρd). Soil core was obtained from 0 -15 cm soil depth for each of experimental units at 80 days after sowing (DAS). The soil was oven dried at 105º C for 24 hours, and weighed. The soil dry bulk density (ρd) for all soil samples was calculated in the laboratory using the equation below:

$$\rho d = \frac{Ms}{Vt}$$

where Ms is dry soil mass and Vt is the total soil volume or the core volume.

Measurements of the soil moisture were done at 0 - 30 and 30 - 60 cm soil depths. Soil samples were taken by an auger. Readings were taken in the field, two days after irrigation at 80 DAS. Gravimetric method was used to determine the soil moisture percentage (ϴ) as described below:

$$\Theta = \frac{(Mm - Md)}{Md}$$

where Mm is the moist soil mass and Md is the oven dry soil mass.
The soil total porosity (T.P.) was calculated using the following equation:

$$T.P. = 1 - \frac{\rho d}{\rho s}$$

T.P. = soil total porosity.
ρd = soil air dry bulk density.
ρs = soil particle density (taken as 2.65 g cm^{-3}).

Data were statistically analyzed using MSTAT program. Duncan's Multiple Range Test was used for means separation.

RESULTS AND DISCUSSION

Soil bulk density (ρd)

Data in Table 2 showed the soil bulk density at 80 DAS for the 0 - 15 cm soil depth for all seasons. The results showed no significant differences in air dry bulk density among the chicken manure levels for all seasons. However, the direct and residual effects of chicken manure reduced the soil air dry bulk density with very highly significant differences ($P \leq 0.001$) as compared to that of control, for all seasons. The highest soil bulk density value was obtained in the control (1.74 gcm^{-3}) and the lowest value (1.30 gcm^{-3}) was in chicken manure treatments (12 ton ha^{-1}) in the residual effect of the second season. Reduction in soil bulk density in response to manure application had already been documented (Awad Elkarim, 2007; Ali, 2001; Agbede *et al*., 2008; Adeleye *et al*., 2010).

Soil total porosity (T.P.)

Results in Table 3 showed the soil total porosity of the 0 - 15 cm soil depth for all seasons. Chicken manure increased soil total porosity. There were no significant differences in the soil total porosity among chicken manure levels. However, there was a very highly significant difference ($P \leq 0.001$) between the control and that of the chicken manure treatments in all seasons. This result was in conformity with that of Agbede *et al.* (2008) and Adeleye *et al.*(2010) who reported that the soil total porosity was significantly increased in response to poultry manure application.

Table 2. Direct and residual effects of chicken manure on soil air dry bulk density (g cm^{-3}) of the 0 – 15 cm depth.

Chicken manure levels (t/ha)	Direct effect 2014/15	Residual effect 2015/16	Direct effect 2015/16	Residual effect 2016/17
0 (control)	1.61[a]	1.66[a]	1.74[a]	1.60[a]
4	1.39[b]	1.33[b]	1.40[b]	1.38[bc]
8	1.40[b]	1.33[b]	1.40[b]	1.38[bc]
12	1.38[b]	1.31[b]	1.39[b]	1.30[c]
Mean	1.44	1.40	1.48	1.41
C.V (%)	1.65	1.99	2.44	4.62
SE (±)	0.018	0.018	0.018	0.018

Means followed by different letters in the same column are significantly different at P≤ 0.05.

Table 3. Direct and residual effects of chicken manure on soil total porosity (%) of the 0 – 15 cm depth **.**

Chicken manure levels (t/ha)	Direct effect 2014/15	Residual effect 2015/16	Direct effect 2015/16	Residual effect 2016/17
0 (control)	39.2[b]	37.3[b]	34.3[b]	39.6[b]
4	47.6[a]	49.8[a]	47.2[a]	47.9[a]
8	47.2[a]	49.8[a]	47.2[a]	47.9[a]
12	47.9[a]	50.5[a]	47.6[a]	50.9[a]
Mean	45.1	47.1	44.1	46.2
C.V (%)	2.59	2.45	2.68	5.72
SE (±)	0.673	0.659	0.659	0.673

Means followed by different letters in the same column are significantly different at P≤ 0.05.

Soil moisture percentage (ϴ%)

Data in Table 4 showed the soil moisture percentage at 80 DAS for the 0 - 30 cm soil depth for all seasons. The data showed that chicken manure generally increased soil moisture percentage. There were no significant differences in moisture percentage among chicken manure levels. However, there was a very highly significant difference in soil moisture percentage (P≤ 0.001) between the control and that of the chicken manure treatments in all seasons. The control recorded the lowest value in soil moisture percentage (9.6% in direct effect and 10 % in residual effect) and the highest value for the chicken manure treatments ranged from 15.3% to 20.3% in all seasons. Chicken manure positively increased soil moisture percentage. This result was in conformity with that of Ali (2001) and Adeleye *et al.*(2010) who found that moisture percentage increased significantly in response to organic manure application.

Table 4. Direct and residual effects of chicken manure on soil moisture percentage for 0 – 30 cm soil depth at 80 DAS.

Chicken manure levels (t/ha)	Direct effect	Residual effect	Direct effect	Residual effect
	2014/15	2015/16	2015/16	2016/17
0 (control)	9.6[b]	11.0[b]	9.3[b]	10.0[b]
4	15.3[a]	19.0[a]	17.7[a]	19.0[a]
8	15.6[a]	20.0[a]	17.7[a]	19.3[a]
12	16.3[a]	20.3[a]	19.0[a]	20.0a
Mean	14.2	17.57	15.92	17.1
C.V (%)	6.51	7.03	6.19	10.26
SE (±)	0.535	0.72	0.569	1.01

Means followed by different letters in the same column are significantly different at P≤ 0.05.

Soil moisture percentages at 80 DAS of the 30 - 60cm soil depth for all seasons are shown in Table 5. There were no significant differences in soil moisture percentage among the chicken manure levels. However, there were very highly significant differences in soil moisture percentage (P≤ 0.001) between the control and that of chicken manure treatments.

Table 5 .Direct and residual effects of chicken manure on soil moisture percentage for 30 –60 cm soil depth at 80 DAS.

Chicken manure levels (t/ha)	Direct effect	Residual effect	Direct effect	Residual effect
	2014/5	2015/6	2015/6	2016/7
0 (control)	36.3[a]	20[a]	21.0[a]	21.0[a]
4	16.3[b]	11.3[b]	12.0[b]	12.0[b]
8	16.3[b]	11.3[b]	11.0[b]	11.0[b]
12	17.3[b]	12.0[b]	11.6[b]	11.0[b]
Mean	21.58	13.6	13.9	13.7
C.V (%)	11.02	9.98	7.48	12.6
SE (±)	1.37	0.787	0.601	0.621

Means followed by different letters in the same column are significantly different at P≤ 0.05.

The highest values were recorded for the control (36.3 %) in the direct effect for season one, while the lowest soil moisture values (11%) were recorded for chicken manure (12 ton/ha) in residual effect for season two. Chicken manure was applied and incorporated in the top soil (0- 30cm) and its positive effect on soil moisture retention was evident but when looking at the soil moisture content at 30 – 60 cm, the data indicated that the values were lower than their respective counterparts of 0 - 30 cm. These lower value were related to soil texture only because the influence of the chicken manure did not go down below 30 cm from the soil surface.

Generally, the moisture percentage at the 30 – 60 cm was higher than that of the 0 – 30 cm. This result might be attributed to the nature of the soil texture which was loamy sand on the top but varied to sandy loam in some places below and to sandy clay loam in other places. Also, it might be due to the higher rate of evaporation from the top soil.

Grain yield of wheat

Grain yield of wheat for all seasons as influenced by chicken manure is shown in Table 6. The results revealed no significant differences in grain yield of wheat among the levels of chicken manure in all seasons. However, there were very highly significant differences ($P \leq 0.001$) in grain yield between the control and that of 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 all seasons. Generally, the residual effect of chicken manure recorded higher grain yield than that of the direct effect in all seasons. This supports the general concept that chicken manure had more beneficial residual effects in comparison to its direct effects. High wheat grain yield due to application of organic fertilizers was reported by many researchers, (Ali, 2001; Awad Elkarim and Younis, 2008; Ahmed, 2010; Rasul *et al.*,2015) who found that organic manure significantly increased grain yield of wheat.

Table 6. Direct and residual effects of chicken manure on grain yield of wheat crop.

Chicken manure levels (t/ha)	Direct effect	Residual effect	Direct effect	Residual effect
	2014/5	2015/6	2015/6	2016/7
0 (control)	0.51^{b}	2.05^{b}	0.92^{b}	1.69^{b}
4	3.18^{a}	5.51^{a}	4.21^{a}	5.41^{b}
8	3.16^{a}	5.71^{a}	4.29^{a}	5.40^{a}
12	3.28^{a}	5.81^{a}	4.39^{a}	5.41^{a}
Mean	2.52	4.82	3.53	4.48
C.V (%)	19.52	13.74	11.70	13.71
SE (±)	0.286	0.375	0.465	0.252

Means followed by different letters in the same column are significantly different at $P \leq 0.05$.

CONCLUSIONS

Application of chicken manure markedly decreased soil dry bulk density and hence increased total soil porosity , soil moisture percentage and consequently grain yield of wheat. The optimum rate of chicken manure was 4 ton ha^{-1}. Chicken manure proved to have a continuing positive effect on this desert plain soil to produce higher grain yield of wheat at least for the duration of this experiment. It is recommended that 4 ton ha^{-1} of chicken manure can be applied for improving the studied soil physical properties and increased wheat yield in the Northern Sudan.

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الأثر المباشر والباقي لسماد زرق الدواجن على الكثافة الظاهرية ومحتوى الماء لتربة في السهل الصحراوي و إنتاجية القمح بالولاية الشمالية بالسودان

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الخلاصة

تضمنت الدراسة تجربة نفذت خلال ثلاثة مواسم متتالية 15/2014 (الأثر المباشر) و16/2015 (الأثر المباشر والباقي) و17/2016 (الأثر الباقي) في تربة صحراوية بهدف معرفة الأثر المباشر والباقي لسماد زرق الدواجن بأربعة مستويات (0 و 4 و 8 و 12 طن/ هكتار) على الكثافة الظاهرية ومحتوى الماء لتربة السهل الصحراوي وإنتاجية القمح بالولاية الشمالية بالسودان. نفذت التجربة على نظام القطاعات العشوائية الكاملة لثلاث مكررات. تم تحضير ارض التجربة يدويا حتى تحتفظ وحدات التجربة بنفس معاملات السنة الأولى وذلك لمعرفة الأثر الباقي لسماد زرق الدواجن. أوضحت النتائج أن الأثر المباشر و الباقي لسماد زرق الدواجن فعال في تحسين الخواص الطبيعية للتربة. وجد تناقص معنوي عال جدا ($P\leq0.001$) في قيمة الكثافة الظاهرية للتربة في المتوسط للموسمين من 1.67 في الشاهد إلى 1.39 جرام/ سم^3 في معاملات سماد زرق الدواجن بالنسبة للأثر المباشر لسماد زرق الدواجن حيث تناقصت الكثافة الظاهرية من 1.60 إلى 1.33 جرام/ سم^3 بالنسبة للأثر الباقي لسماد زرق الدواجن. بينما حدثت زيادة معنوية عاليه جدا ($P\leq0.001$) في مسامية التربة في المتوسط للموسمين من 36 % في الشاهد إلى 47.1 % للأثر المباشر لمعاملات سماد زرق الدواجن أما بالنسبة للأثر الباقي كانت الزيادة في المتوسط للموسمين من 38% في الشاهد إلى 49% لمعاملات سماد زرق الدواجن. و أيضا أن سماد زرق الدواجن و أثره الباقي له اثر معنوي عالي جدا في زيادة النسبة المئوية لماء التربة حيث كانت الزيادة في المتوسط للموسمين من 9.4 % في الشاهد إلى 16.9 % للأثر المباشر لسماد زرق الدواجن ومن 10.5 % في الشاهد إلى 19.6 % للأثر الباقي لسماد زرق الدواجن في عمق 30سم من سطح التربة. أظهرت نتائج البحث أن الأثر المباشر والباقي لسماد زرق الدواجن له أثر معنوي عال جدا ($P\leq0.001$) في زيادة إنتاجية محصول القمح في المتوسط للموسمين من 0.72 طن/هكتار في الشاهد إلى 3.75 طن/هكتار للأثر المباشر لمعاملات سماد زرق الدواجن ومن 1.87 طن/هكتار في الشاهد إلى 5.54 طن/هكتار للأثر الباقي لسماد زرق الدواجن بتربة السهل الصحراوي. توصى الدراسة بان إضافة 4 طن/هكتار من سماد زرق الدواجن هي الأفضل لاستصلاح ترب السهل الصحراوي وزيادة إنتاجية القمح بشمال السودان.