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Direct and Residual Effects of Green and Farmyard Manures on some Physical Properties of Sandy Soil and Wheat (*Triticum aestivum* L.) Yield in El Multaga Area of Northern Sudan

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ABSTRACT

Soil characteristics are important indicators of the potential for agricultural production. This study investigates the direct and residual effects of green and farmyard manures on soil dry bulk density, total porosity, soil moisture percentage, infiltration rate and wheat grain yield of a desert plain soil in Northern Sudan during three successive seasons 2007/08 (direct effect), 2008/09 (direct and residual effects) and 2009/10 (residual effect). Treatments consisted of green manure produced from green gram (*Vigna radiate*) with two seed rates (0 and 12 kg ha^{-1}), and farmyard manure with two levels (0 and 10 ton ha^{-1}) arranged in a split plot design with three replicates. The results revealed that all studied treatments significantly decreased soil bulk density and infiltration rate ($P \leq 0.01$), and increased total soil porosity and soil moisture percentage ($P \leq 0.001$), as compared to the control in response to the application of the two types of manures. The results also showed that the direct and residual effects of manures caused significant increase in the wheat grain yield of the desert plain soils. It can be concluded that green and farmyard manures had continuing positively effects on the desert plain soil to produce higher grain yield of wheat. Green manure, therefore, may be used in vast desert plain soils areas as it may pose a solution to the problems of the infertility and unavailability of organic manure and farmyard manure may be useful in small areas in the Northern State of Sudan.

***Keywords*:** Desert soil, green manure, farmyard manure, wheat yield, *Triticum aestivum, Vigna radiate*

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1. INTRODUCTION

Most of the agricultural soils in the Northern State are located in the marginal lands (desert plain soils). The horizontal agricultural expansion in this state is expected to be carried out in these lands particularly after the construction of Merowe dam. Studies and surveys done showed that most of these soils are unsuitable for agricultural purposes unless soil chemical and physical fertility is cured through reclamation (LWRC, 1999). Previous investigations in organic matter were done in these soils for reclamation purposes rather than fertilization, but the source of organic matter in the Northern State is very limited. This is in addition to the low vegetation cover (Ahmed, 2017).

Wheat (*Triticum aestivum* L.) is the most important cereal crop in the world trade and is one of the main sources of carbohydrate 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 meet the increasing demands resulting from the rapid growth of the world population. The use of modern varieties of wheat and judicious fertilization are the important factors which can help to increase wheat production,(Rasul, 2015).

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.

In crop production, nutrient availability from manure has been recognized for many centuries. Before the introduction of chemical fertilizers, manure was the primary source of nutrients for crop production. Beneficial effects of organic matter for physical soil properties are: enhancing aggregate stability, improving water infiltration and soil aeration, reducing runoff, improving water holding capacity, reducing the stickiness of clay soils making them easier to till and reducing surface crusting and facilitating seedbed preparation (Kuoe and Joñczyk 2008).

Humus exhibits low cohesion and adhesion compared to mineral colloids. Nevertheless these forces do influence soil structure when an appreciable quantity of humus is present. The capacity of humus to absorb large quantity of water is one of its outstanding characteristics. The organic fraction of mineral soils is usually capable of taking up from 4 to 6 times its weight of water (Millar, 2004).

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

Ahmed *et al*. (2018) evaluated the direct and residual effects of green manure on some soil physical properties of desert soil grain yield of wheat in Northern State of Sudan. They reported that the direct and residual effects of green manure were significantly effective in improving the soil physical properties under investigation. The soil bulk density was significantly ($P \leq 0.001$) reduced while the soil total porosity, percentage of soil moisture and grain yield of wheat were significantly ($P \leq 0.001$) increased in response to the application of green manure.

Adeleye *et al*. (2010) investigated the effect of poultry manure on physico-chemical properties of a sandy loam 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.

In a study on the effect of different cultural practices and farmyard manure on soil properties and wheat production on Mukabrab soil series in Northern Sudan, Awad Elkarim (2007) found that the addition of farmyard manure invariably resulted in a reduction of the soil bulk density and hence in an increase in soil moisture content.

Cercioglu *et al*. (2014) studied the changes in the physical conditions of a coarse textured soil by 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.

This study was conducted to assess the direct and residual effects of green and farmyard manures on some soil physical properties and wheat yield on a desert plain soil of El Multaga soil series in the Northern Sudan.

2. MATERIALS AND METHODS

2. 1. Study area and experimental design

The experiment was carried out during three consecutive seasons 2007/08 (direct effect, season1), 2008/09 (direct effect, season2 and residual effect season1), 2009/10 (residual effect season2) at the National Institute of Desert Studies Research Farm, New Hamdab Scheme, Northern State, Sudan. The study area lies at the intersection of latitude 17º55' N, and longitude 31º10' E in the desert zone.

The soil of the study area belongs to El Multaga soil series which is classified as typic, haplocambids, coarse loamy, mixed, superactive, hyperthermic. It is non-saline 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 inTable 1.

The design was a split plot with three replicates. The main plots were assigned to GM (green gram crop) with two seed rates: 0 kg $ha^{-1}$and 12 kg ha^{-1}. The sub plots were assigned to FYM with two rates: 0 ton $ha^{-1}$and 10 ton ha^{-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
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

(Source: LWRC, 1999)

In the first application of GM and FYM for seasons 2007/2008 and 2008/2009, green gram, (*Vigna radiate*), was selected as a green manure crop. It was planted early in the summer season (20th July) on the designated experimental units. After two months and before flowering phase, the crop (the average biomass production of 5 ton ha^{-1}) was incorporated into the soil six weeks before wheat planting using disk plough. Then the soil was watered and the subsequent watering was carried out at a ten - day interval before the sowing of wheat, as an indicator crop. FYM was hand broadcast six weeks before planting on the designated experimental plots. The manure was mixed with the soil using disk plough. The plots were watered as for the green manure treatments. Land preparation was done manually for the residual effects of GM and FYM lest to disturb the treatments which were fixed in the same plots of the first application of manures.

Wheat variety Wadi Elneel was sown manually in seasons 2007/08, 2008/09, 2008/09 and 2009/10 on 20th November using a seed rate of 120 kg ha^{-1}, at 0.2 m inter-row spacing. Basal doses of nitrogen of 86 kg N ha^{-1} and phosphorus (43 kg P_2O_5 ha^{-1}) were added to all plots (Ibrahim, 1990). Irrigation was carried out every ten days. In all seasons, soil bulk density, soil moisture percentage, soil infiltration rate and grain yield (kg ha^{-1}) were measured. Data were statistically analyzed using MSTAT program. Duncan's Multiple Range Test (DMRT) was used to compare the means.

2. 2. Measurements of soil physical properties

2. 2. 1. Soil dry bulk density (ρd)

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 0-20 cm soil depth for each of experimental units at 80 days after sowing (DAS). The soil was oven dried at 105 ºC for 24 hours, and weighed. The soil dry bulk density (ρd) for all soil samples was calculated by the following equation:

$$\rho d = Ms/Vt \quad \ldots\ldots\ldots 1$$

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

2. 2. 2. Soil moisture

Measurements of the soil moisture were done at 0 - 25 and 25 - 50 cm soil depths. Soil samples were taken by an auger. Readings were taken in the field two days after irrigation at 80 DAS. The volumetric moisture content (ϴ) was calculated by the following relationship:

$$\Theta = \rho d \times (Mm-Md)/Md \quad \ldots\ldots 2$$

where Mm is the moist soil mass and Md is the oven dry soil mass.

2. 2. 3. Total soil porosity

The total soil porosity (P) was calculated using the following equation:

$$P\ (\%) = 100 \times (1 - \rho d / \rho s) \quad \ldots\ldots 3$$

where P = soil total porosity, ρd = soil dry bulk density, ρs = soil particle density which is taken as 2.65 g cm^{-3}.

2. 2. 4. Infiltration rate

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 to measure the infiltration rate. Two cylinders were driven into the soil to a 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.

3. RESULTS AND DISCUSSIONS

3. 1. Soil bulk density(ρd)

The soil bulk density and soil density are important indicators of soilphysical properties and the constraining factors that affect soil fertility and crop productivity. Data in Table 2 showed the soil bulk density at 80 DAS for the 0 - 20 cm soil depth for all seasons. The results showed significant effects of both direct and residual manures ($P \leq 0.01$) on soil dry bulk density while it showed no significant differences between green and farmyard manures and their interaction. The direct and residual green and farmyard manures reduced the soil dry bulk density with highly significant differences ($P \leq 0.01$) as compared to that of control, for all seasons. The highest soil bulk density value was obtained in the control (1.80 gcm^{-3}) in direct effect of manure and the lowest value (1.16 gcm^{-3}) was for the interaction of green and farmyard manures treatments in the residual effect of the first season.

Generally, the residual effect of green and farmyard manures recorded lower soil bulk density value than that of the direct effect in all seasons. This supports the general concept that manures have more beneficial residual effect in comparison to their direct effect. The decrease in the bulk density refers to higher soil organic carbon content of soil, in addition, the bulk density improves aggregation. Polysaccharides, cellulose and humus released during the decomposition of organic manure are responsible for firm binding among soil particles in more stable aggregates, causing bulk density reduction (Pareek and Yadav 2011).

These findings are very close to that obtained by Ahmed *et al*. (2018), Agbede *et al*. (2008), Cercioglu *et al*. (2014) and Elkarim (2007) who found that the soil bulk density decreased significantly in response to organic manure application.

Table 2. Direct and residual effects of green and farmyard manures on soil dry bulk Density (g cm^{-3}).

Green Manure Levels	FYM Levels	Direct effect 2007/08	Residual effect 2008/09	Direct effect 2008/09	Residual effect 2009/10
		Season 1		Season 2	
0 kg/ha	0 ton/ha	1.80[a]	1.70[a]	1.80[a]	1.73[a]
	10 ton/ha	1.40[b]	1.23[b]	1.40[b]	1.26[b]
12kg/ha	0 ton/ha	1.40[b]	1.26[b]	1.43[b]	1.26[b]
	10 ton/ha	1.33[b]	1.16[b]	1.36[b]	1.26[b]
Grand mean		1.48	1.34	1.50	1.38
C.V (%)		6.15	6.80	3.85	5.52
SE±		0.053	0.052	0.033	0.044
P ≤		0.034	0.01	0.001	0.01

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

3. 2. Soil total porosity (T.P.)

Results in Table 3 showed the soil total porosity of the 0 - 20 cm soil depth for all seasons. Green and farmyard manures increased soil total porosity. There were no significant differences in the soil total porosity among the type of manure and their interaction. However, there were highly significant difference (P≤ 0.01) between the control and that of the green and farmyard manures treatments in all seasons. The most positively affected categories of pores were the quickly drainable pores and the water-holding pores. These two categories also represent major portions of soil porosity, and they had a very important significance in soil fertility and plant growth. Green and farmyard manures leads to significant change in pore size distribution due to high organic matter which may leads to an increase in fine capillary pores on the expense of quickly drainable pore and consequently, an increase of the soil moisture percentage in sandy soil. This result was in conformity with that of Agbede *et al.* (2008), Ahmed *et al*. (2018) and Elkarim (2007who stated that the soil total porosity was significantly increased in response to organic manure application.

Table 3. Direct and residual effects of green and farmyard manures on soil porosity (%)

Green Manure Levels	FYM Levels	Direct effect 2007/08	Residual effect 2008/09	Direct effect 2008/09	Residual effect 2009/10
		Season 1		Season 2	
0 kg/ha	0 ton/ha	32.0^{b}	36.00^{b}	30.7^{b}	34.66^{b}
	10 ton/ha	46.7^{a}	53.66^{a}	46.7^{a}	52.33^{a}
12 kg/ha	0 ton/ha	46.7^{a}	52.33^{a}	45.3^{a}	52.33^{a}
	10 ton/ha	49.7^{a}	56.00^{a}	48.3^{a}	52.33^{a}
Grand mean		43.7	49.50	42.7	47.91
C.V (%)		7.52	7.12	3.38	6.38
SE±		1.9	2.03	1.1	1.76
P≤		0.037	0.05	0.003	0.01

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

3. 3. Soil moisture percentage (Ө%)

Data in Table 4 showed the soil moisture percentage at 80 DAS for the 0 - 25 cm soil depth for all seasons. The data showed that both green and farmyard manures generally increased soil moisture percentage. There were no significant differences in moisture percentage among the types of organic manures and their interaction. There was a highly significant difference in soil moisture percentage (P≤ 0.01) between the control and that of the green and farmyard manures treatments in all seasons.

The control recorded the lowest moisture % value of 9 %while the highest value of 19.7% was recorded for the interaction of combination of the manure treatments of residual effect in season 2. Green and farmyard manures positively increased soil moisture percentage. These results may be attributed to the redistribution of solid particles after the addition of green and farmyard manures. In such case soil aggregates can be established, the water holding pores increased and consequently the available moisture in the treated soils. In addition, the organic fraction of mineral soils is usually capable of taking up from 4 to 6 times its weight of water (Millar, 2004).

This result was in conformity with that of Ahmed *et al*. (2018), Agbede *et al*. (2008) and Elkarim (2007) who found that moisture percentage increased significantly in response to organic manure application. Soil moisture percentages at 80 DAS of the 25 – 50 cm soil depth for all seasons are shown in Table 5. There were no significant differences in soil moisture percentage among the organic manure and their interaction. However, there were highly significant differences in soil moisture percentage ($P \leq 0.001$) between the control and that of green and farmyard manure treatments in all seasons.

Table 4. Direct and residual effects of green and farmyard manures versus moisture percentage for 0 – 25 cm soil depth at 80 DAS

.

Green Manure Levels	FYM Levels	Direct effect 2007/08	Residual effect 2008/09	Direct effect 2008/09	Residual effect 2009/10
		Season 1		Season 2	
0 kg/ha	0 ton/ha	11.33[c]	10.30[b]	11.33[b]	9.00[c]
	10 ton/ha	17.67[b]	18.60[a]	17.67[a]	18.00[b]
12kg/ha	0 ton/ha	16.67[b]	18.30[a]	18.00[a]	18.00[b]
	10 ton/ha	19.00[a]	19.00[a]	18.00[a]	19.70[a]
Grand mean		16.20	16.60	16.30	16.20
C.V (%)		6.68	4.61	12.05	9.45
SE±		0.006	0.004	0.011	0.009
P≤		0.032	0.001	0.048	0.01

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

The highest value of 19 % was recorded for the control in residual effect of season two, while the lowest soil moisture values (11%) were obtained for the interaction of manures in residual effect for season one. Organic manure was applied and incorporated in the top soil (0-25 cm) and its positive effect on soil moisture retention was evident but when looking at the soil moisture content at 25 – 50 cm, the data indicated that the values were lower than their respective counterparts of 0 -25 cm. These lower values were related to soil texture only because the influence of the organic manure did not go down below 25 cm from the soil surface. Generally, the moisture percentage at the 25 –50 cm was higher than that of the 0 – 25 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 surface.

3. 4. Soil Infiltration rate (IR):

Figs. 1 and 2 show the infiltration rate for the control , direct and residual effects of manure treatments for both seasons. The rate started higher from about 14 - 23 cm hr^{-1} and then decreased clearly and progressively down the profile to 1.4 - 3cm hr^{-1}. The result showed that the highest rates during all time were recorded for the control, while the lowest was found for green and farmyard manures treatments. The result revealed that green and farmyard manures treatments positively decreased the final infiltration rate from 4 $cmhr^{-1}$ in season one and 3 $cmha^{-1}$ in season two for the control to 1.4 – 3 $cmhr^{-1}$ for the green manure treatments.

The studied green manures can be ranked according to their positive effect in decreasing the final infiltration rate as follows: the interaction of green and farmyard manures treatments, farmyard manure treatments and green manure treatments for both seasons.

Table 5. Direct and residual effects of green and farmyard manures on soil moisture percentage for 25 – 50 cm soil depth at 80 DAS.

Green Manure Levels	FYM Levels	Direct effect 2007/08	Residual effect 2008/09	Direct effect 2008/09	Residual effect 2009/10
		Season 1		Season 2	
0 kg/ha	0 ton/ha	18.67[a]	18.7[a]	18.33[a]	19.0[a]
	10 ton/ha	14.33[b]	12.3[b]	13.00[b]	13.0[bc]
12kg/ha	0 ton/ha	14.33[b]	13.0[b]	13.33[b]	12.3[b]
	10 ton/ha	13.00[c]	11.0[c]	12.33[b]	11.6[c]
Grand mean		15.10	13.7	14.20	14.0
C.V (%)		9.76	5.94	12.81	9.22
SE±		0.008	0.005	0.005	0.008
P≤		0.01	0.01	0.01	0.02

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

Fig. 3. shows the wetting front for the control and direct and residual effects of green and farmyard manures treatments. The result showed that the deepest wetting front was recorded for the control (59 cm in direct effect and 57 cm in residual effect) and the lowest of (40 cm) for residual effect of the interaction of green and farmyard manures treatments. It is also evident that the rate of water entry into the soil treated with green and farmyard manures and their combination is relatively lower than that in the control.

This behavior may be ascribed to the relatively of green and farmyard manures and their combination, which may result in partial blocking of soil pores with modification of the pore size distribution, which is affected in increasing the micro pores and thus decrease in the basic infiltration rates of treatments compared to control.

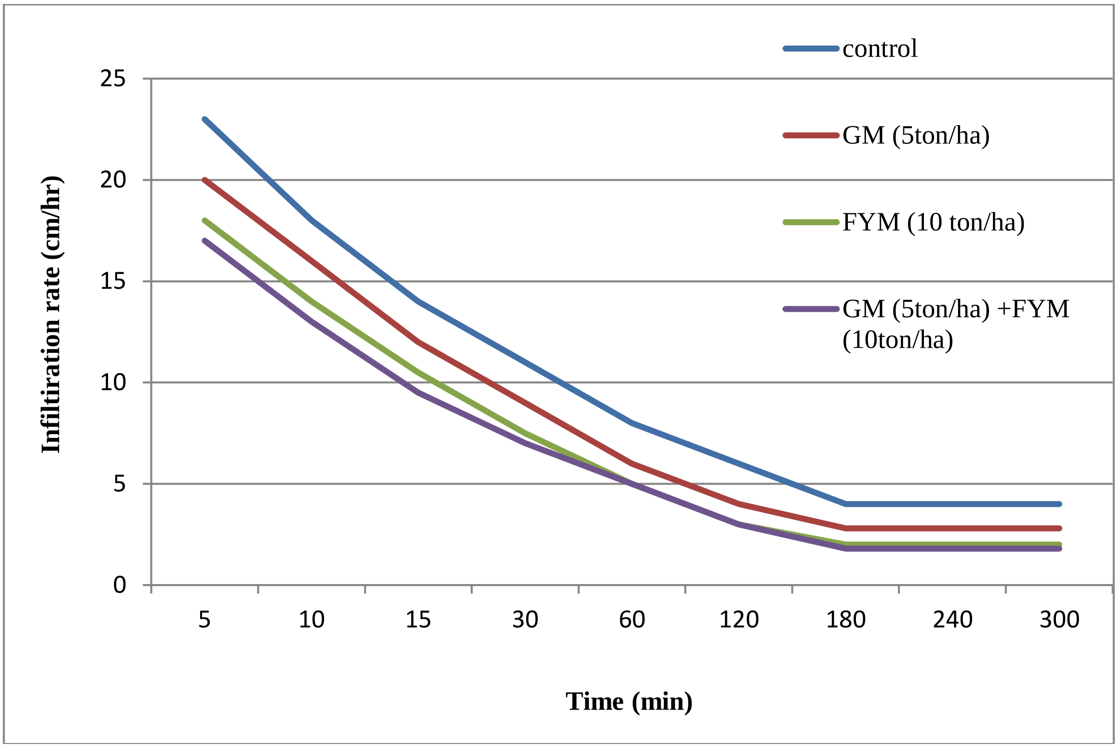

Fig. 1. Average infiltration rate for the control and the direct effect of green and farmyard manures after harvesting

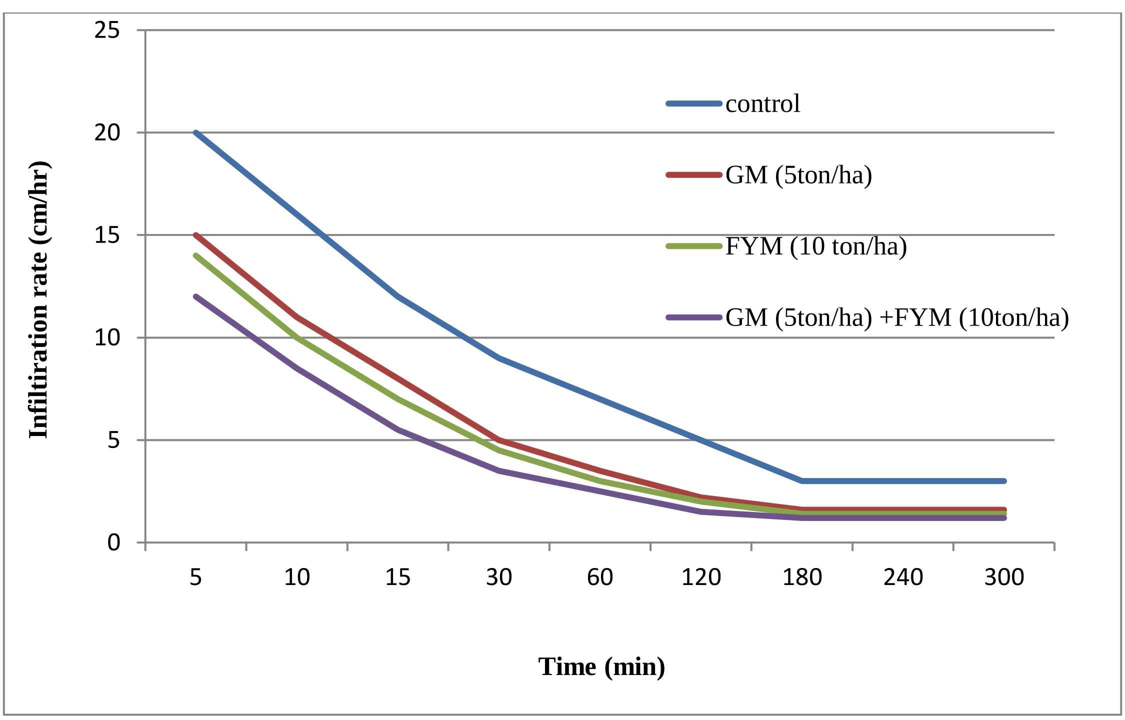

Fig. 2. Average infiltration rate for the control and the residual effect of green and farmyard manures after harvesting**.**

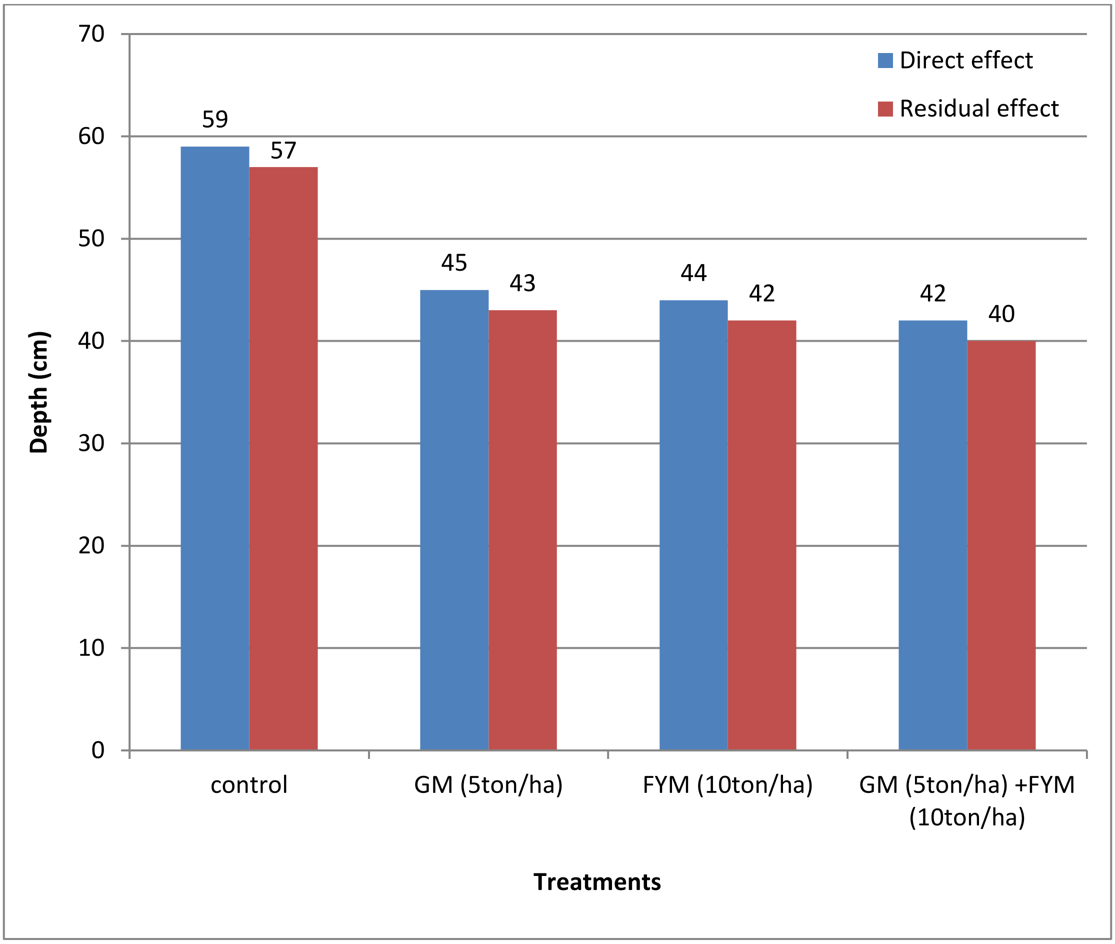

Fig. 3. Average wetting front (cm) for the control and the direct and residual effects of green and farmyard manures after harvesting.

3. 5. Grain yield of wheat

As shown Table 6 there were very highly significant differences ($P \leq 0.001$) in grain yield between each of GM, FYM, and their interaction during the first application of manures and that of the control. Also similar results were found due to the residual effects of GM and FYM. In the direct effect of organic manure the interaction of GM and FYM treatments produced the highest grain yield followed by that of FYM treatments and then that of GM treatments. However, regarding the residual effect of both seasons, GM gave higher grain yields than that of FYM due to its slower decomposition rate compared with farmyard manure. This observed increase in grain yield could be attributed to that the manures and their residues added some of the essential plant nutrients, improved their availability and substantially improved the physical conditions of the soil. The residual effect1 of GM and FYM treatments gave higher grain yield than that of their respective direct effects. High wheat grain yield due to application of organic manures has been reported by many investigators(Ahmed *et al*. 2018 and Awad Elkarim, 2007). The increment ingrain yield of wheat could be attributed to either addition or improved availability of some essential plant nutrients and/or improved physical conditions of the soil.

Table 6. Direct and residual effects of green and farmyard manures on grain yield of wheat crop.

Green Manure Levels	FYM Levels	Direct effect 2007/08	Residual effect 2008/09	Direct effect 2008/09	Residual effect 2009/10
		Season 1		Season 2	
0 kg/ha	0 ton/ha	1.13^{b}	2.62^{b}	1.51^{b}	2.42^{b}
	10 ton/ha	4.47^{a}	4.85^{a}	3.85^{a}	4.69^{a}
12kg/ha	0 ton/ha	3.03^{a}	5.04^{a}	3.58^{a}	5.03^{a}
	10 ton/ha	4.66^{a}	5.08^{a}	5.11^{a}	5.06^{a}
Grand mean		3.32	4.39	3.51	4.30
C.V (%)		15.02	8.93	15.16	3.23
SE±		2.88	1.96	3.07	0.80
P≤		0.001	0.001	0.001	0.001

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

4. CONCLUSIONS

This study concluded that application of green and farmyard manures and their residuals positively decreased soil dry bulk density, infiltration rate and increased total soil porosity, soil moisture percentage and consequently increased the grain yield of wheat. GM and FYM had continuing positively effects on the desert plain soil to produce higher grain yield of wheat at least for the duration of this experiment. Green manure, therefore, may be used in vast desert plain soils areas, as it may pose a solution to the problems of the infertility and unavailability of organic manure, and FYM may be used in small areas in the Northern State of Sudan.

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