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Original Article

Effects of non-digested and anaerobically digested farmyard manures on wheat crop cultivated in desert soil

Jamal Abubaker[1]*, Nazar Elnesairy[1,2], Sanussi Ahmad[1]

[1]Department of Soil and Water, Faculty of Agriculture, Sabha University, Sabha, Libya, [2]Department of Soil and Water, Faculty of Agricultural Sciences, University of Gezira, Wad Medani, Sudan

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***Address for correspondence:**
Jamal Abubaker, Department of Soil and Water, Faculty of Agriculture, Sabha University, Sabha, Libya. E-mail: Jamal_Abubaker@hotmail.com

ABSTRACT

Digesting animal manure anaerobically before applying it as fertilizer may be affected crop production differently compared to non-digested, particularly in desert soils. A pot experiment was carried out to evaluate three non-digested dry matter (NDM) and digested dry matter (DM) farmyard manures (cattle, poultry, and sheep) and their combinations with urea on the wheat crop cultivated in desert soil. Fertilizers were applied at rates corresponding to 50, 150, and 250 kg total nitrogen ha^{-1}. During the growing period, seed germination percentage (SGP), plant height, plant tillering percentage (PTP), and deficiency symptoms were assessed. Furthermore, total biomass yield and relative yields of ear, straw, and root fractions were measured at harvest. Results showed that high application of DM reduced SGP significantly ($P < 0.05$), especially at the combination with urea. PTP was higher in non-digested manure treatments of sheep and poultry than DM, and also higher in digested cattle manure treatments than NDM, while it was zero in all urea treatments and control. Deficiency symptoms were seen in the treatments of low application rate as well as in all urea treatments and control. Plant height and biomass yield generally increased in NDM and DM treatments compared with urea treatments and the control. Beneficial of DM was seen in cattle and poultry manure (PM) treatments where they significantly ($P < 0.05$) yielded higher root, ears, and total biomass compared to NDM. However, non-digested sheep and PM yielded higher straw biomass than DM. The combination of non-digested and digested manure with urea gave the maximum biomass yield, especially in combination with digested PM.

KEY WORDS: Cattle manure, digestate, poultry manure, sheep manure, urea, wheat crop

INTRODUCTION

Cultivation of grain crops has developed considerably in Libya resulted in higher demands for the application of fertilizers. Using animal manures as fertilizer has become an important approach to increase and sustain soil fertility, especially in the southern part of Libya (Fezzan region) where desert soils are dominant. Desert soils cover vast areas in the middle east and North Africa regions that characterized by low rainfall and high temperatures (Wheida and Verhoeven, 2007). The previous studies on these soils have shown their productivity is low and costly (Allan, 2015; Henao and Baanante, 2006). This is attributed mainly to their low fertility as well as to the loss of water and applied nutrient, especially nitrogen (N) by leaching. Therefore, applying slow N release materials such as animal manure is a necessary practice for this kind of soils (Rezig *et al*., 2012). Animal manures contain a considerable amount of macro and micronutrients that bound to the organic molecules and hence not immediately available to the plant unless the mineralization process occurred (Eghball *et al*., 2002). In contrast, desert soils have a low biological activity to breakdown complex components that found in animal manures and release plant nutrients. Therefore, digesting animal manures anaerobically before application might be a useful approach for sustaining crop production in these soils. The interest in using anaerobic digestion for treating animal manure is increasing worldwide since it yields valuable degraded organic materials that rich in plant nutrients (Mata-Alvarez *et al*., 2000) and biogas (Makádi *et al*., 2012). In addition, anaerobic digestion also removes pathogens and parasites from digestate and prevents natural CH_4 -emissions by capturing biogas (Makádi *et al*., 2012). Anaerobic digestion is a process by which anaerobic microorganisms break down biodegradable material in the absence of oxygen mainly through four stages, i.e., hydrolysis, acidogenesis, acetogenesis, and methanogenesis (Adekunle and Okolie, 2015; Angelidaki *et al*., 2011). In the first stage carbohydrates, fats and proteins in the manure are hydrolyzed by extracellular enzymes to monomeric simple sugars, fatty acids, and amino acids. In the second and third stage, further degraded of the monomers are made by fermenting and acetogenic bacteria to form hydrogen gas (H_2), carbon dioxide (CO_2), alcohol, organic acids (including acetate), ammonia (NH_3), and hydrogen sulfide (H_2S). In the last stage, strictly anaerobic methanogenic archaea produce methane (CH_4) mainly from CO_2 and H_2 but also produce small amounts of dinitrogen (N_2), NH_3, and H_2S (Deublein and Steinhauser, 2008). At the same time, most of the other nutrients are preserved in the residue (Massé *et al*., 2007). Overall, anaerobic digestion will result in a digested material that differs from the "non-digested" in having higher proportion of NH_4^+-N to total N, higher pH, lower dry matter content and total carbon (Tot C), lower carbon to nitrogen (C/N) ratio, but generally no alteration occur in total N, potassium (K), and phosphorus (P) (Field *et al*., 1984; Field *et al*., 1985). That, consequently, it can be expected fertilizing crops with digested manure will lead to different effects compared with non-digested. The main objective of this study was to evaluate and compare the effect of three anaerobic digested farmyard manures (cattle, sheep, and poultry) against that of non-digested and mineral fertilizer (urea) in terms of supporting wheat growth and yield that cultivated in desert soil. Furthermore, the efficiency of combining non-digested and digested manure with mineral fertilizer will be evaluated.

MATERIALS AND METHODS

Soil Sampling and Characteristics

Sandy soil was taken from an arid region of the Libyan Desert, 10 km west of the Sabha city (Fezzan region), a southern part of Libya (22°30′ N and 30°00′ N and between the meridians of 10° E and 18° E). This region has a hot dry climate in the summer and cold in winter, and dryness may continue for several years. The rainfall in the southern part of Libya receives only 10 mm y^{-1} and in some parts, there is no rain (Wheida and Verhoeven, 2007). The collected soil had not been cultivated or fertilized before. At sampling the soil was totally dry and sampled from the top 0-20 cm layer, immediately transported to the laboratory and stored at lab temperature (23°C). Before the experiment starts the soil was sieved (4 mm screen) and thoroughly mixed. Physical and chemical properties of the soil are shown in Table 1. Soil texture (sand, silt, and clay) was measured using hydrometer method described by Bouyoucos (1962). The water holding capacity of the soil was determined according to Forster (1995). Soil pH was determined at a soil to deionized water ratio of 1:2 using a pH meter 3030 (Jenway, Ltd., UK). Electrical conductivity was determined by the conductivity meter (model 4070, ELE, England) using a 1:1 (v/v) water to soil suspension. Organic matter content was determined according to the method described by Ball (1964). Tot C was estimated by a loss-on-ignition method described by Dean (1974). Total nitrogen (Tot N) was determined according to Kjeldahl method modified by Bradstreet (1954). Soil phosphorus (P) was extracted according to the method described by Chapman and Pratt (1962) and determined using Cecil CE 202 spectrophotometer at 420 nm (super aquarius, cecil instruments, and Cambridge, England). Potassium (K) and sodium (Na) were extracted with HCl according to the Protocol: P05-004 A and determined by a flame photometer (Jenway, PFP7, UK). Soil magnesium (Mg) and calcium (Ca) were determined by atomic absorption spectrometer (AAS, Analytik Jena AG 400).

Farmyard Manure and Characteristics

Three farmyard manures (cattle manure [CM], sheep manure (SM), and poultry manure (PM)) were collected from different farmyards that located in Sabha city. Cattle and SM were collected from farmyard where animals were mainly fed with clover and barley straw. Whereas PM was collected from broiler farm that using wood shavings as bedding and feeding with grinded grain consist of wheat, barley, corn, and soybeans. Approximately, 25 kg of each manure was collected and cleaned, portioned into small

Table 1: Physical and chemical properties of the desert soil used for cultivating wheat in pot experiments

Parameters	Values
Physical properties	
Sand (%)	97
Clay (%)	1.3
Silt (%)	1.7
Water-holding capacity (%)	21.6
Chemical properties	
Phpaste	8
Ece (ds m^{-1})	2.99
Om (%)	0.5
Total n (%)	0.2
Total c (%)	1.05
P (g kg^{-1} dw)	0.1
K (g kg^{-1} dw)	0.04
Na (g kg^{-1} dw)	0.25
Mg (g kg^{-1} dw)	0.04
Ca (g kg^{-1} dw)	0.16

burlap bags and stored at room temperature (23°C) until use. All collected manures were nearly dry (% of water content was 1.2, 1.6, and 2 for CM, SM, and PM, respectively). The physical and chemical characteristics of manures are shown in Table 2. The pH was determined at a manure to deionized water ratio of 1:6 using a pH meter 3030 (Jenway, Ltd., UK). Dry matter (DM) was determined according to Klute (1986). Tot C was estimated by a loss-on-ignition method described by Dean (1974). Tot N according was determined according to Kjeldahl method that modified by Bradstreet (1954). Tot K extracted by HCl according to the protocol: P05-004A and determined using a flame photometer (Jenway, PFP7, UK). Tot P was extracted according to the method described by Pungor (1994) and determined using Cecil CE 202 spectrophotometer at 420 nm (Super Aquarius, Cecil Instruments, and Cambridge, England). The urea ($CO(NH_2)_2$) used in the experiment consist of 20% C, 26.6% O, 46.6% N, and 6.7% H.

Anaerobic Digestion of Farmyard Manure

Anaerobic digestion of farmyard manures was carried out in a sealable plastic container (30 L volume) provided with a valve in the lid allowing the flow of air and prevents backflow. The amount of manure and deionized water that was added to each unit is 6 kg and 10 L, respectively, after which the containers sealed. The fermentation was operated in the lab at the mesophilic (42-48°C) and for 30 days retention time. After 30 days containers opened and digested manures portioned into small plastic bags, and stored at −20°C until use. The physical and chemical characteristics of digestate are given in Table 2.

Experiment Setup

The pot experiment was conducted at experimental farm, faculty of agriculture, Sabha University, Libya. The experiment was set up in a random block design with three replicates, resulting in a total of 84 pots. The experiment consists of 14 treatments, showing in Table 3. The non-digested DM (NDM) and DM were applied at three rates, corresponding to 50, 150, and 250 kg Tot N ha^{-1}. At the start, 2 kg of soil was measured into each pot (10-L, 20 cm diam. ×24 cm height). A further portion of 5 kg soil was then mixed with manure, gently packed into the pot to form top soil, and watered to the desired moisture level. The combination with mineral fertilizers was applied only at a rate corresponding to 250 kg Tot N ha^{-1} so that half of the added N originated from the manures and the other half came from the urea (Table 3). The soil moisture in the pots was set to 70% of its water holding capacity and kept at this level during the experimental period.

Planting and Harvesting

Each pot was sown with 20 seeds of wheat (Karim [Bitterns']) at a depth of 2.5 cm. After sowing, all pots were placed on trolleys under field condition (13 h day, 11 h night, and during growing period temperature was between 15°C and 38°C at daytime and 10°C at night-time, and air humidity 22%). During growth and until harvest, the moisture content was checked by weighing each pot every 3 days and when needed adjusting it to 70% WHC. At 7 and 18 days after sowing (DAS) seed germination percentage (SGP) was calculated in each treatment as follows: ([seeds germinated/total sowed seeds] ×100). At 18 DAS, germinated seeds were thinned out to give 9 seedlings per pot, which means 9 plants were allowed to grow in each pot. During the growing period, deficiency symptoms, plant height, and plant tillering were recorded. In the middle of growing period (62 DAS), number of tillering plants per pot was counted and plant tillering percentage (PTP) was calculated as follows: ([number of plants which had tillered in the pot/total plants in the pot] ×100). Plant height was only measured 23, 43, and 64 DAS. The total growing period was 82 days, after which the ear, straw, and root fractions were harvested and weighed separately. The roots were carefully removed from the soil by placing them in large flat pans of water where they could be freed from practically all the larger soil particles with little or no injury to the root. Biomass weight was determined after cutting the biomass fractions into small pieces and drying them at 75°C for 24 h. All biomass fractions expressed in dry weight.

Table 2: Physical and chemical characteristics of farmyard manures used for fertilizing wheat in pot experiment

Farmyard manure	Dm (%)	Ph	Tot n (g kg^{-1} dw)	Parameters			
				Tot c (g kg^{-1} dw)	C/n	Tot P (g kg^{-1} dw)	Tot k (g kg^{-1} dw)
Cattle manure	98.8	7.7	13.8	453	33	5.9	3.5
Sheep manure	98.5	7.3	14.3	385	27	2.1	25.4
Poultry manure	98	9.3	42.6	470	11	14.2	17.3
Digested cattle manure	17.3	8.3	14.2	427	30	5.9	3.9
Digested sheep manure	40.9	7.6	14.5	313	22	2.3	24.3
Digested poultry manure	15.2	9.7	46.2	395	9	13.9	18

Table 3: Treatments used in the pot experiment

Abbreviations	Treatments	Fertilization rate
Control	No fertilization	0
U	Urea	50, 150, 250 kg Tot N ha^{-1}
CM	Cattle manure	50, 150, 250 kg Tot N ha^{-1}
DCM	Digested cattle manure	50, 150, 250 kg Tot N ha^{-1}
CM+U	Cattle manure+urea	250 kg Tot N ha^{-1} (50% CM+50% U)
DCM+U	Digested cattle manure+urea	250 kg Tot N ha^{-1} (50% DCM+50% U)
SM	Sheep manure	50, 150, 250 kg Tot N ha^{-1}
DSM	Digested sheep manure	50, 150, 250 kg Tot N ha^{-1}
SM+U	Sheep manure+urea	250 kg Tot N ha^{-1} (50% SM+50% U)
DSM+U	Digested sheep manure+urea	250 kg Tot N ha^{-1} (50% DSM+50% U)
PM	Poultry manure	50, 150, 250 kg Tot N ha^{-1}
DPM	Digested poultry manure	50, 150, 250 kg Tot N ha^{-1}
PM+U	Poultry manure+urea	250 kg Tot N ha^{-1} (50% PM+50% U)
DPM+U	Digested poultry manure+urea	250 kg Tot N ha^{-1} (50% DPM+50% U)

Statistical Analyses

The data were analyzed using the SPSS (WIN. Version 17) procedure GLM where two-way analysis of variance followed by Tukey (honestly significant difference) multiple comparison tests was used for repeated testing of paired differences between treatments regarding SGP, plant height, PTP, straw, ears, root, and total biomass, where fertilizer type, application rate, and the interaction fertilizer type × application rate were considered as fixed factors. Furthermore, the repeated measures test was used to analyze plant height at day 23, 43, and 64. Differences considered significant at the level ($P < 0.05$) unless otherwise not stated.

RESULTS

Anaerobic Digestion

Anaerobic digestion of farmyard manure generated digestate that different from non-digested manure (Table 2). The dry matter content of the digestate varied between 15.2% and 40.9%, while it was higher in non-digested. Anaerobic digestion, increased pH of digestate compared to non-digested, to 9.7-7.6 in digested and 9.3-7.3 in non-digested, respectively. Total N ranged from 14.2 to 46.2 g kg^{-1} in the digestate and 13.8-42.6 g kg^{-1} in non-digested. Tot C ranged from 313 to 427 g kg^{-1} in digestate and 385-470 g kg^{-1} in non-digestate. In general, the total content of nutrients was not affected by the anaerobic digestion process. This means that the nutrient content of non-digested was more or less the same as that of the digestate. As nutrient addition with fertilizer was calculated on the basis of Tot N level, the non-digested treatments generally received a little more plant nutrients than digestate treatments (Tables 2 and 4).

Seed Germination, Deficiency Symptoms, and Plant Tillering

The growth period of wheat was approximately 12 weeks (82 days), after which harvest was performed. Seeds of wheat start to germinate 7 DAS. The SGP was calculated at 7 and 18 DAS (Table 5). Overall, SGP responded differently to fertilizer type and application rate. The statistical analysis showed significant effects of fertilizer type ($P < 0.05$), application rate ($P < 0.05$) and their interaction ($P < 0.05$) on SGP. At 7 DAS, high application rate of DM reduced SGP (to 5-25%) significantly ($P < 0.05$) compared with NDM (13-40%). Moreover, the high application rate of NDM and DM in combination with urea reduced SGP significantly ($P < 0.05$) to 0-13% and 1.7-10%, respectively, compared with application of sole digestate or sole urea. Moreover, 7 DAS, high application rate of sole urea decreased SGP significantly ($P < 0.05$) to 13% compared with low application (57%) and the control (23%). At 18 DAS, SGP increased in all treatments, especially in NDM, but has not reached to its maximum (Table 5).

At week four plants started to show symptoms, i.e., brown spots, and yellow stripes. The plants fertilizing with urea showed deficiencies first, while the plants fertilizing with NDM and DM at a rate of 50 kg Tot N ha^{-1} also showed early symptoms. Fertilizing with urea gave rise to more severe deficiency symptoms than the NDM and DM. Furthermore, CM and DCM showed more deficiency symptoms compared with SM, DSM, PM, and DPM treatments. The combination with urea showed less deficiency symptoms, particularly in PM and DPM treatments.

At 62 DAS tillers were found in all treatments with the exception of the control where non-tillered plants were found (Table 5). The PTP in SM, DSM, PM, and DPM treatments were significantly ($P < 0.05$) higher (ranged between 55% and 100%) compared with CM and DCM treatments (11-96%). Furthermore, SM (85-100%) and PM (92-100%) increase PTP compared with DSM (78-85%) and DPM (55-92%), while, DCM resulted in higher PTP (26-96%) than the CM (11-41%). The combination of NDM and DM with urea resulted in increasing PTP significantly ($P < 0.05$) (to 89-100%) compared with treatments fertilized with sole urea or manure alone (Table 5).

Table 4: Amount of nutrients added with farmyard manure to each pot at fertilization rate corresponding to 250 kg Tot N ha^{-1}

Type of yard manure	Tot N (g pot^{-1})	Tot C (g pot^{-1})	C/N	Tot P (g pot^{-1})	Tot K (g pot^{-1})
Cattle manure	0.79	26	33	0.3	0.2
Sheep manure	0.79	21	27	0.1	1.4
Poultry manure	0.79	9	11	0.3	0.3
Digested cattle manure	0.79	23	30	0.3	0.2
Digested sheep manure	0.79	17	22	0.1	1.1
Digested poultry manure	0.79	7	9	0.2	0.4

Table 5: Seeds germination percentage at day 7 and 18 after sowing, and percentage of plant tillering at day 62 after application of digested and non-digested farmyard manures with and without combination with urea at different fertilization rates (50, 150, and 250 kg Tot N ha^{-1}). Urea and control treatments were used for comparison. Values represent the average±standard deviation (n=3)

Treatments	Germinated seeds 7 DAS (%)	Germinated seeds 18 DAS (%)	Plant tillering (%)
Control	23±8	63±3	0.0±0
U 50	57±8	80±1	18±2
U 150	38±6	77±6	18±2
U 250	13±1	62±3	15±6
Cattle manure treatments (CM)			
CM 50	15±0	85±9	11±9
CM 150	40±9	95±9	33±1
CM 250	35±0	85±1	41±7
CM+U 250	13±3	93±7	89±9
DCM 50	15±13	90±1	26±6
DCM 150	60±5	83±3	96±6
DCM 250	25±5	77±1	29±9
DCM+U 250	1.7±3	55±5	100±0
Sheep manure treatments (SM)			
SM 50	12±3	63±8	85±9
SM 150	25±8	85±0	85±9
SM 250	37±9	68±1	100±0
SM+U 250	6.7±3	78±3	100±0
DSM 50	33±3	88±8	81±8
DSM 150	20±9	82±8	85±6
DSM 250	17±8	77±8	78±9
DSM+U 250	10±5	58±7	89±5
Poultry manure treatments (PM)			
PM 50	24±1	67±9	96±6
PM 150	19±3	75±6	100±0
PM 250	13±5	87±9	92±6
PM+U 250	0±0	58±5	100±0
DPM 50	62±6	62±3	89±9
DPM 150	22±6	70±9	92±5
DPM 250	5±6	68±6	55±6
DPM+U 250	7±3	58±5	100±0

Plant Height

The statistical analysis showed significant effects of fertilizer type ($P < 0.05$), application rate ($P < 0.05$) and their interaction ($P < 0.05$) on plant height at 43 and 63 DAS. While at 23 DAS fertilizer type was not significantly affected plant height. In general, at 43 and 64 DAS application of NDM and DM increased plant height significantly ($P < 0.05$) in comparison with the urea treatments and control (Figure 1). Application of SM, DSM, PM, and DPM significantly ($P < 0.05$) increased plant height compared to CM and DCM treatments. Moreover, application of DCM increased plant height significantly compared to CM at all measuring days with the exception of day 64 and application rate of 250 kg Tot N ha^{-1} where no significant different was found between them. Furthermore, no significant difference was found between SM and DSM treatments. At 43 and 64 DAS, application of PM increased plant height significantly ($P < 0.05$) compared to the application of DPM at all measuring days. Combining NDM and DM with urea increased plant height significantly ($P < 0.05$) compared with application of sole urea or sole manure. Moreover, there was no significant different in plant height between NDM and DM treatments at the combination with urea, except for treatment of SM gave lower plant height than DSM. In addition, there was no significant different in plant height between urea treatments (at all fertilization rates) and the control.

Root, Straw, and Ear Biomass

In week nine, the ears started to appear in all treatments except for the control, which was a few days late. The statistical analysis showed significant effects of fertilizer type ($P < 0.05$), application rate ($P < 0.05$), and their interaction ($P < 0.05$) on the root, straw, and ear biomass. Application of NDM and DM significantly ($P < 0.05$) increased roots, straw, and ears biomass at all application rates compared with urea and the control (Figure 2). Root and straw biomass showed a systematic response to application rate, with fractions of biomass increasing with the increased application rate (Figure 2). The straw biomass yield increased significantly ($P < 0.05$) in SM and PM treatments. Ear biomass yield showed no significant differences between and among NDM and DM at application rates of 50 and 150 kg Tot N ha^{-1}, but at the application rate of 250 kg, Tot N ha^{-1} ear biomass increased significantly ($P < 0.05$) in DSM and DPM treatments. Fertilization with SM, DSM, PM, and DPM resulted in higher root and straw biomass compared with treatments of CM and DCM at all application rates. The combination of NDM and DM with urea increased crop biomass fractions

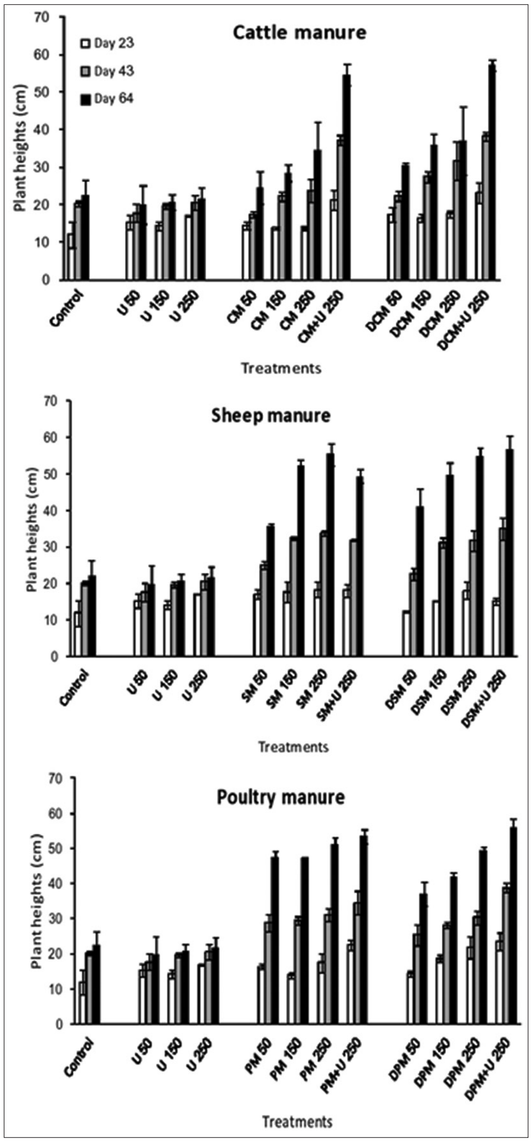

Figure 1: Plant height at 23, 43, and 64 DAS and after application of non-digested and digested farmyard manures with and without combination with urea at different application rates (50, 150, and 250 kg Tot N ha^{-1}). Urea and control treatments were used for comparison. Bars represent means ± standard deviation (*n* = 3)

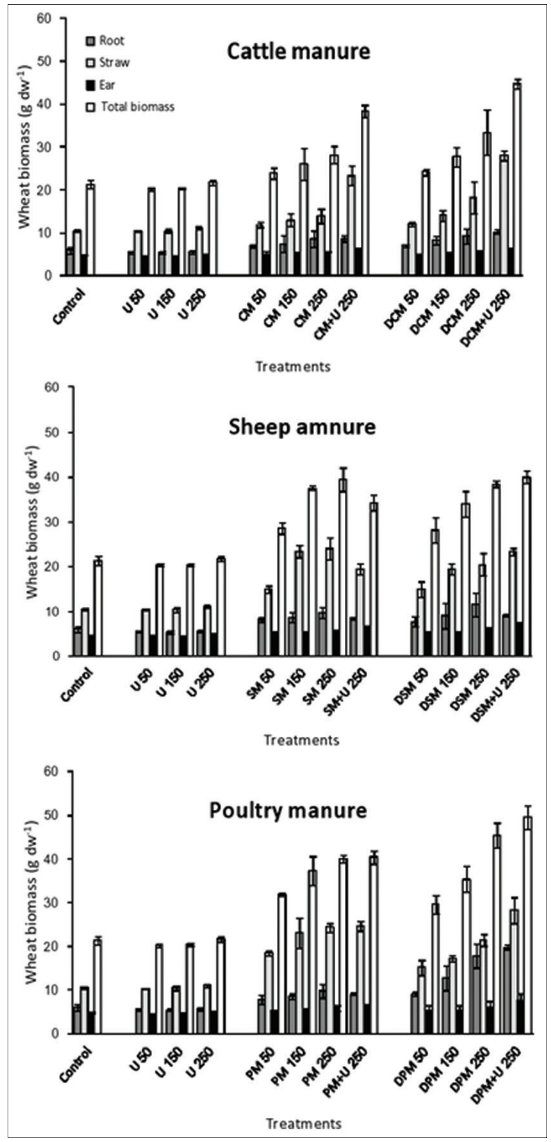

Figure 2: Root, straw, and ear biomass yields after application of non-digested and digested farmyard manures with and without combination with urea at different application rates (50, 150, and 250 kg Tot N ha^{-1}). Urea and control treatments were used for comparison. Bars represent means ± standard deviation (*n* = 3).

significantly ($P < 0.05$), especially in DCM and DPM treatments. There was no significant difference in the root, straw, and ears biomass among urea treatments and the control.

Total Biomass

The statistical analysis showed insignificant effects of fertilizer type on total biomass yield, but application rate significantly ($P < 0.05$) affected total biomass yield. At the application rate of 50 kg Tot N ha^{-1}, CM and DCM treatments showed no differences in total biomass yield compared with the control and all application rates of urea (Figure 2). Whereas at the same application rate SM, DSM, PM, and DPM treatments gave significantly ($P < 0.05$) higher total biomass compared with CM and DCM and all application rates of urea and control (Figure 2). At an application rate of 150 and 250 kg Tot N ha^{-1}, only SM, DSM, PM, and DPM gave significantly ($P < 0.05$) higher total biomass compared with the control and urea treatments (Figure 2). There was no significant different between NDM and DM, except that DPM gave significantly ($P < 0.05$) higher total biomass compare to PM at the application rate of 250 kg Tot N ha^{-1}. Combining NDM and DM with urea only increased total biomass significantly ($p<0.05$) in treatments of CM, DCM, and DPM (Figure 2).

DISCUSSION

Anaerobic Digestion of Farmyard Manure

Digestion of farmyard manure anaerobically created digestate differs from the non-digested in having lower dry matter content, lower Tot C, lower C/N ratios, and higher pH (Table 2). In addition, a small alteration in P and K content of digested manure was also observed. These results are in agreements with other studies where they have reported a similar effect of anaerobic digestion on farmyard manure properties (Bonten *et al*., 2014; Möller and Müller, 2012). Furthermore, anaerobic digestion of farmyard manure will increase proportion of NH_4^+ -N to total N (not measured in this study) (Field *et al*., 1984; Kirchmann and Witter, 1992; Moller and Stinner, 2009), which is a soluble form of N that plant roots can easily absorb (Massé *et al*., 2007). The application of NDM and DM to the soil resulted in different effects on wheat crop, which indicated they are not identical.

Soil Effect

The soil used in this study has not been fertilized or cultivated before. Furthermore, this soil has quite a low nutrient profile compared with other arable soils of various origins (Stenberg *et al*., 1998), which makes it suitable for evaluating new fertilizer. Fertilizing this soil with sole urea gave the lowest crop biomass yield compared with fertilization with manures. Since the extra nitrogen and the other nutrients come from manure during decomposition cannot be expected when fertilizing with sole urea. A similar observation was also reported by Abubaker *et al*. (2012) who found that application of sole urea to poor sandy soil resulted in lower crop biomass yield compared with application of digested slurry and animal manure. In addition, the signs of nutrient deficiency and the smallest plant height, as well as the absence of tillers in unfertilized treatment, are another evidence for the poorness of this soil.

Seed Germination, Plant Tillering, and Plant Height

The high application rate of NDM, DM, and urea reduced SGP significantly in comparison with low application rate treatments and the control. This decrease was more pronounced in the urea treatments than other treatments where an SGP decreased systematically with increasing application rate of urea, which indicates that seed germination was affected by N concentration. Moreover, the high application rate of NDM and DM in combination with urea decreased SGP considerably compared to sole urea and control treatments. A similar effect was reported by Wan *et al*. (2016), who found that SGP reduced by 51-95% at increasing the application rate of urea. The delay in seed germination was also reported by Xiong *et al*. (2013), who found that N treatment delayed germination of wheat seeds of low starch content while speeded seed germination of higher starch content. At a high application rate of DM, SGP reduced significantly compared to the application of NDM. Gupta and Gupta (2011) reported that application of anaerobically digested PM delayed seed germination in comparison with diluted digested (i.e., dilution from 100% to 50% with H_2O). This delayed has been attributed to the humic acids that formed in digested manure during anaerobic digestion (Bacilio *et al*., 2003; Šerá and Novák, 2011).

Fertilization with NDM and DM at different rates showed varying effects on plant tillering. PTP was higher in SM and PM treatments compared to CM treatment at all application rates. Similar results have been reported by Ofosu-Anim and Leitch (2009), who found that application of non-digested sheep and PMs resulted in a significant increase in chlorophyll content of barley leaves and plant tillers compared to CM. This is probably attributed to that nutrients content that bound to the organic molecules in non-digested manure, in the long run, these nutrients will be released slowly results in supporting the crop during the growing period (Sadej and Przekwas, 2008). Combining NDM and DM with urea resulted in the highest PTP compared with application of sole digested manure. Similar results have been reported in several studies (Kassahun *et al*., 2010; Kiani *et al*., 2005). Since nutrients in urea will be available for the plants immediately after application, while the organically bound nutrients in the manure will be released slowly, benefitting the crop during growing period.

In this study, application of NDM and DM increased plant height significantly compared with urea treatment, which is in agreement with the other studies where organic fertilizer showed better plant growth and yield compared to mineral fertilizer (Abubaker *et al*., 2012; Kidinda *et al*., 2015). Furthermore, the results clearly reveal that plant height was affected significantly by nitrogen source, as shown from the height recorded in the treatment of DCM where it produced taller plant than non-digested. Makádi *et al*. (2012) reported that application of digestate resulted in significantly increased aboveground biomass yields in the case of winter and spring wheat than the farmyard manure and non-digested slurry treatment, due to the high availability of nutrients in digestate. Furthermore, the maximum plant height was recorded in the treatments of combining urea with NDM and DM. This result is in line with the findings of Shah *et al*. (2009) and Unagwu

(2014), who reported that nutrient use efficiency increased through the combination of farmyard manure and mineral fertilizer.

Root, Straw, Ears, and Total Biomass

In this study, the pots were dosed with fixed levels of N and in spite of that digested manure treatment produced different biomass yield compared with non-digested indicated that they are unlike in term of supporting wheat growth and yield. Similar results have been reported in several studies where they showed digestate affected wheat growth and yield differently compared with raw manure (Abubaker *et al*., 2012; Adelekan *et al*., 2010; Šimon *et al*., 2015). The application of DCM and DPM with and without combination with urea increased crop biomass yield in comparison with application of sole manure. The positive effects of the digestate on the wheat crop can be explained by high amounts of nutrients available in digested manure compared with non-digested. Makádi *et al*. (2012) and Šimon *et al*. (2015) confirmed that digestate has high available nutrients profile compared with non-digested, which resulted in significantly increased biomass yields of winter and spring wheat. Furthermore, it has been reported in several studies that the crop N uptake is higher with all types of digestate than non-digested manure if N losses by volatilization and leaching are prevented (Cavalli *et al*., 2014; Gunnarsson *et al*., 2010; Loria *et al*., 2007; Odlare *et al*., 2008). Moreover, humic acids in digestate are one of the most important organic fertilizers that increase N uptake and plant growth (Tahir *et al*., 2011).

Urea treatments gave the lowest biomass yield at all application rates in comparison with non-digested and digested treatments. Similar results have been reported by Šimon *et al*. (2015) and Abubaker *et al*. (2012), who stated that application of digestate, gave higher crop biomass yield compared with application of sole urea. However, when combining urea with non-digested or digested manure crop biomass yield has increased significantly compared with application of sole urea or manure. The benefit of combining manures with mineral fertilizer has been reported in several studies where they confirmed this strategy yielded higher wheat biomass (Islam *et al*., 2014; Kearney *et al*., 2012; Kidinda *et al*., 2015). Because nutrient in mineral fertilizer will be available for the crop at application, while the organically bound nutrients in the manure would be released slowly, benefitting the crop during growing period.

This work confirms that application of PM with and without combination with urea is more effective in increasing crop biomass than the application of cattle and SM. This finding is in agreement with other studies, where they showed fertilization with PM gave higher crop yield compared with CM (Detpiratmongkol *et al*., 2014; Ghosh *et al*., 2004; Kidinda *et al*., 2015). The better performance of PM in supporting wheat crop maybe is related to its low C/N ratio (i.e. 11 and 9 for non-digested and digested, respectively). It has been shown that applying organic fertilizer of low C/N ratios below 20 to the soil, stimulate net mineralization, and increased plant N availability (Myrold, 1999). Furthermore, it has been reported that the percentage of mineralized N was higher in PM treatment than that in cattle and SM treatments (Pratt and Castellanos, 1981).

CONCLUSION

Digestion of farmyard manure anaerobically created digestate of high fertilization value, which compared well with that of urea fertilizer, showing positive effects on wheat growth and biomass yield. Application of digested poultry and SM enhanced most growth parameters of the treated plant, as observed; the order of ear biomass yield was DPM>DSM >SM >PM>DCM>urea. The combination of NDM and DM with urea gave the best crop biomass yield than the application of sole either manure or urea. Therefore, when urea is used for fertilizing the desert soils, it should be complemented with organic fertilizer. However, to be able to fully investigate the efficient of digestate in supporting crops growth and yield, further investigation are needed on a field scale. Furthermore, the effect of non-digested and digested manures on seed germination needs further investigation.

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