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ORIGINAL RESEARCH

Germination of several wheat cultivars in desert soil after amendment with raw and digested poultry manure with and without combination with mineral fertilizer

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Abstract

Purpose This study aimed to investigate the effect of time interval between sowing and amendment with non-digested and digested poultry manure and their combinations with urea on the germination of three wheat cultivars (*Slambo*, *Acsad*, and *Karim*) in the desert soil.

Methods The cultivars were sown on four different dates, i.e. directly, 10, 20 and 30 days after amendment. Fertilizers were applied at a rate of 350 kg Tot N ha^{-1}. The germinated seeds were recorded daily starting at day 4 after sowing until day 14 after which the following germination attributes were calculated: time to reach 50% germination ($T_{50\%}$), final germination percentage (FGP) and germination index (GI). Additionally, radicle length, plumule length and seedling dry weight were also determined.

Results Sowing near to the application delayed and reduced seeds germination particularly in the treatments amended with non-digested and digested manure in combination urea. This was confirmed by all germination attributes, i.e. high values of $T_{50\%}$ and low values of FGP and GI. Moreover, sowing near to the application reduced the length of plumule and radicle as well as decreased seedling dry weight of all wheat cultivars.

Conclusion Results suggested that prolonging the period between amendments and sowing to 20 or 30 days would give better germination attributes and increase plumule and radicle length plus increasing seedling dry weight.

Keywords Seed germination · Digestate · Poultry manure · Urea · Wheat cultivars

Introduction

Desert soil is by far the predominant soil in the southern part of Libya, where grain crops such as barley and wheat are cultivated under sprinkler irrigation. Wheat (*Triticum aestivum* L.) occupies the first rank in Libya in terms of cultivated area, i.e. about 165,000 ha with an annual yield of 200,000 tons (Alabasi et al. 2017). In this region, wheat yield is far below the optimal due to the fertility of desert soils is low to provide the crop with the essential plant nutrients. Therefore, the application of fertilizers to this soil is necessary to improve its productivity. Urea is the most widely used chemical nitrogenous fertilizer in Libya, although several studies have shown that it is not good for improving soil properties (Angus et al. 2014; Lungu and Dynoodt 2008). Therefore, replacing chemical fertilizers with organic fertilizers or combine it with organic fertilizers is required to improve soil fertility. Numerous studies have reported that the application of organic fertilizers to soils of arid and semiarid regions enhances significantly soil fertility through improving soil properties compare to application of mineral fertilizers (Diacono and Montemurro 2010; Elhadi et al. 2016; Elnesairy et al. 2016; Hati et al. 2006). Organic fertilizers such as animal manures have a considerable amount of nutrients in organic form and hence is not immediately

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available to the plant until decomposition by heterotrophic soil microorganisms occurs (Ladd and Jackson 1982). In fact, due to the dryness and the absence of soil organic matter, desert soils have a low microbial activity to breakdown organic components and release plant nutrients (Angel et al. 2013; Makhalanyane et al. 2015). It has been reported that microbial communities of the desert soil have higher relative abundances of genes associated with dormancy and lower abundances associated with the nutrient release (Fierer et al. 2012). Therefore, anaerobic digestion of animal manure before application to the soil might be an effective way to increase nutrient availability to the plant. Several studies have shown that fertilizing soils with digested manure results in higher yields compare to compost and mineral fertilizers (Abubaker et al. 2012, 2017; Abubaker 2012). Anaerobic digestion is used worldwide to sustain waste management and produce bioenergy (Angelidaki and Ahring 2000). Moreover, anaerobic digestion leads to the generation of residues called digestate that rich in mineralized plant nutrients (Makádi et al. 2012; Möller and Müller 2012; Odlare et al. 2011). Although, digested and non-digested organic waste has a positive effect on crop yield, however, some other studies have reported an adverse effect of these materials on wheat seeds germination. Abubaker et al. (2017) reported that the application of digestate and non-digested to desert soil, especially in the combination with urea delayed and reduced the germination of wheat seeds. In another study by Bacilio et al. (2003) showed that the composts generated from dairy cow manure have inhibitory effects on wheat seed germination. This negative effect has been attributed to the contaminants that generated during decomposition of organic waste such as ethylene oxide (Wong et al. 1983) and organic acid (Bacilio et al. 2003; Makádi et al. 2012). Moreover, the concentration of ammonia in digestate is high (García-González et al. 2016) and this can reduce and delay wheat seeds germination (Bremner and Krogmeier 1989; Wan et al. 2016). In fact, it is unclear if this adverse effect will last for a short or long period and thus can be avoided by adjusting the cultivation strategy, e.g. prolonging the period between application and sowing. The objective of present study was to investigate the influence of time interval between sowing and application of non-digested and anaerobically digested poultry manure with and without combination with urea on the germination of three wheat cultivars in desert soil.

Materials and methods

Soil sampling and description

Sandy topsoil (0–20 cm) was collected from desert area that has not been cultivated or fertilized before, located at Sabha city, a southern part of Libya (22°30′N, 10°E). After sampling, the soil transported to the laboratory where it was cleaned, sieved (4-mm screen) and stored at lab temperature (20 ± 3 °C). Physical and chemical characteristics of the soil are shown in Table 1. Percentage of sand, silt, and clay was determined according to Bouyoucos (1962). The water-holding capacity of the soil was measured according to Forster (1995). Soil pH was measured in the suspension at a soil-to-deionized water ratio of 1:2 using a pH meter 3030 (Jenway, Ltd., UK). Electrical conductivity (ECe) was determined in a 1:1 (v/v) water-to-soil suspension using the conductivity meter (model 4070, ELE, England). Soil organic matter content (OM) was measured according to Ball (1964). Total soil nitrogen (Tot N) was determined using Kjeldahl technique modified by Bradstreet (1954). Total soil carbon (Tot C) was analysed by a loss-on-ignition method described by Dean (1974). Soil phosphorus (P) was extracted according to the method described by Chapman and Pratt (1961) and determined using Cecil CE 202 spectrophotometer at 420 nm (Super Aquarius, Cecil Instruments, Cambridge, England). Potassium (K) and sodium (Na) were measured using a flame photometer (Jenway, PFP7, UK) according to Protocol: P05-001A and Protocol: P05-002A, respectively. Soil magnesium (Mg) and calcium (Ca) were determined by atomic absorption spectrometer (AAS, Analytik Jena AG 400) according to the methods of Ramakrishna et al. (1966).

Non-digested, digested manure and urea

Approximately 30 kg of poultry manure was collected from broiler farm located in Sabha city, a southern part of Libya. In this farm, wood shavings were used as bedding and grinded grain (i.e. wheat, barley, corn, and soybeans)

Table 1 Physical and chemical properties of the soil used in the germination experiment

Parameters	Values
Physical properties	
Sand (%)	97
Clay (%)	1.3
Silt (%)	1.7
Water-holding capacity (%)	21.5
Chemical properties	
pH_{paste}	8.2
ECe (ds m^{-1})	2.8
OM (%)	0.4
Tot N (%)	0.09
Tot C (%)	0.89
P (g kg^{-1} dw)	0.07
K (g kg^{-1} dw)	0.08
Na (g kg^{-1} dw)	0.25
Mg (g kg^{-1} dw)	0.05
Ca (g kg^{-1} dw)	0.2

as nutriment. The collected manure transported to the laboratory where it was cleaned, portioned and stored at room temperature (20 ± 3 °C) until use. The manure was solid and almost dry contains only 2% of moisture. The digestion of manure was performed anaerobically in a sealable plastic container (30 L volume) provided with a regulator in the lid letting the flow of air from the container and prevents back-flow into it. The digestion started by adding a manure to deionized water at a ratio of 6:10 after which the container sealed. The anaerobic digestion was operated at the mesophilic temperature (42–48 °C) for 30 days retention time, after which the container opened and digested manure portioned into small plastic bags, and stored at − 18 ± 3 °C until use. The physical and chemical characteristics of fertilizers are shown in Table 2. Dry matter (DM) was determined using oven drying at 100 °C for 24 h as described by Windham et al. (1987). The pH was determined at a manure-to-deionized water ratio of 1:6 using a pH meter 3030 (Jenway, Ltd., UK). Tot N was measured by the Kjeldahl method according to Bradstreet (1954). Tot C was measured by a loss-on-ignition method according to Dean (1974). Tot P was extracted by HNO_3 according to Pungor and Horval (1994) and determined using Cecil CE 202 spectrophotometer at 420 nm (Super Aquarius, Cecil Instruments, Cambridge, England). Tot K was extracted by HCl (Protocol: P05-004A) and analysed by the flame photometer (Jenway, PFP7, UK). The mineral fertilizer used in the experiment was urea ($CO(NH_2)_2$) composed of 20% C, 26.6% O, 46.6% N, 6.7% H.

Treatments

The germination experiment was performed in a plastic dishes (7.5 cm diam. × 5 cm height) at the research farm of the faculty of agriculture, Sabha University, Libya. The experiment consisted of five fertilizers, three wheat cultivars (*Slambo*, *Acsad*, and *Karim*) and four sowing dates. Six treatments were used in the experiment showing in Table 3. The experiment was set up in a random block design with four replicates of each treatment, resulting in a total of 252 dishes. The fertilizers were applied at a rate corresponding to 350 kg Tot N ha^{-1}. At the start, 200 g of soil were weighted into each dish and amended with target fertilizer, after that sprayed with 15 ml of distilled water. The combination with mineral fertilizers was applied so that a 50% of the applied N came from the manure and 50% came from the urea. The dishes were irrigated every other day.

Sowing and germination attributes

Four sets of dishes were prepared, each set contains 60 dishes in total 240 dishes (fertilized) + 12 unfertilized dishes were used as control (control was run only at the first sowing). The first set was sowed directly after amendment, the second set sowed 10 days after amendment, the third set sowed 20 days after amendment and the fourth set sowed 30 days after amendment. Each dish was sowed with 15 seeds at the depth of 1 cm (broken and small seeds were avoided), i.e. corresponding to a sown rate of 170 kg seeds ha^{-1}. Before the start of the experiment, all wheat cultivars were tested for their vitalities according to Ellis et al. (1985), which were 99 ± 4, 89 ± 6 and 95 ± 3 for *Slambo*, *Karim* and *Acsad*, respectively. After sowing, all dishes were placed on trolleys under controlled condition (13 h day, 11 h night, temperature 20 ± 2 °C and air humidity 34%). The sowed dishes were checked daily and germinated seeds were counted at day 4, 6, 8, 9, 12 and 14 from sowing. From the germination counts, several germination attributes were calculated including time to reach 50% germination ($T_{50\%}$), final germination percentage (FGP) and germination index (GI). $T_{50\%}$ was calculated according to the formula of Coolbear et al. (1984) modified by Farooq et al. (2005). FGP and GI were calculated according to the formulas described by Dastanpoor et al. (2013). At the end of the experiment (day 14), seedlings were carefully removed from the soil by placing them in flat pans of water where radicles could be freed from soil particles with little injury. After that, the length of plumule and radicle of each seedling was measured. In the

Table 2 Physical and chemical characteristics of non-digested and digested poultry manure used in germination experiment

Parameters	Non-digested manure	Digested manure
DM (%)	98	15.2
pH	9.3	9.7
Tot N (g kg^{-1} dw)	42.6	46.2
Tot C (g kg^{-1} dw)	470	395
C/N	11	9
Tot P (g kg^{-1} dw)	14.2	13.9
Tot K (g kg^{-1} dw)	3.9	18

Table 3 Treatments used in the germination experiment

No.	Abbreviations	Treatments
1	C	No fertilization
2	U	Urea
3	PM	Non-digested poultry manure
4	PM + U	Non-digested poultry manure (50% N) + urea (50% N)
5	DPM	Digested poultry manure
6	DPM + U	Digested poultry manure (50% N) + urea (50% N)

end, seedling dry weight in each treatment was determined after drying in the oven at 75 °C for 24 h.

Statistical analyses

The obtained data were analysed using the SPSS (WIN. Version 17) procedure GLM multiple variables, where two-way ANOVA followed by Tukey (HSD) multiple comparison tests were used for repeated testing of paired differences between treatments regarding $T_{50\%}$, FGP, GI, plumule length, radicle length and seedling dry weight, where time of sowing, fertilizer type, wheat cultivars and their interactions were considered as fixed factors. The dataset was unbalanced as it contained only one set of control running at first sowing. Differences considered significant at $p<0.05$ unless otherwise not stated.

Results

Germination attributes

Application of non-digested and digested poultry manure especially in combination with U had delayed and reduced the germination of the three wheat cultivars considerably in the first and second sowing. However, in the third and fourth sowing, the germination enhanced markedly. This adverse effect was confirmed by all germination attributes i.e. high values of $T_{50\%}$ and low values of FGP and GI. The analysis of variance showed that the germination of wheat seeds was mostly affected by fertilizer type and sowing date rather than wheat cultivars. Statistical analysis showed significant ($p<0.05$) effect of sowing date and fertilizer type on $T_{50\%}$, FGP and GI. Whereas the effect of wheat cultivars was only significant ($p<0.05$) on FGP but not on the other germination attributes. Moreover, the analysis of variance showed significant ($p<0.05$) interaction effect of sowing date × fertilizer type and fertilizer type × wheat cultivars on all germination attributes. Whereas, the interaction effect of sowing date × fertilizer type × wheat cultivars was only significant ($p<0.05$) on FGP but not on the other germination attributes.

Time to reach 50% germination

$T_{50\%}$ represent estimated time for cumulative germination to reach 50% of its maximum (Table 4). In treatments amended with U, $T_{50\%}$ was significantly ($p<0.05$) shorter in the fourth sowing ranged from 3.8 ± 1.2 to 4.7 ± 1.4 for all wheat cultivars compared to other sowing dates where it ranged from 4.4 ± 0.8 to 7.6 ± 2.0 (Table 4). Treatments amended with PM + U, DPM and DPM + U significantly ($p<0.05$) reduced $T_{50\%}$ (ranged from 2.5 ± 0.9 to 3.6 ± 1.0) on the fourth sowing for all wheat cultivars compared to first, second and third sowing (ranged from 3.3 ± 0.6 to 10.3 ± 3.8). Moreover, at the first sowing PM treatments gave lower $T_{50\%}$ by all wheat cultivars ranged from 3 ± 0.0 to 3.7 ± 1.2 compared to treatments amended with U, PM + U, DPM and DPM + U (ranged from 3.8 ± 0.6 to 10.3 ± 3.8).

Final germination percentage

FGP reached its maximum in U treatments at the first and fourth sowing (ranging from 70 ± 10 to 93 ± 6%) while in the second and third sowing was lower (ranging from 60 ± 0 to 77 ± 6%) (Table 5). Treatments amended with PM and DPM showed higher FGP in the first sowing compared to treatments amended with PM + U and DPM + U with exception of that *Karim* cultivar had lower FGP in PM treatment (Table 5).

Moreover, FGP for *Slambo* cultivar was significantly ($p<0.05$) low in the treatment amended with DPM + U compared to treatment amended with PM + U in the first sowing. At the second, third and fourth sowing FGP increased significantly ($p<0.05$) in both PM + U and DPM + U treatments without any significant differences between them. Moreover, in the treatments sowed with *Acsad* and *Karim* cultivars, it seems PM + U had lowered their FGP significantly ($p<0.05$) compared to the application of DPM + U in the first sowing. Overall, FGP had increased significantly ($p<0.05$) in the fourth sowing compared to the other sowing dates, where they have reached their maximum (100%) especially for *Slambo* and *Acsad* cultivars.

Germination index

GI represent germination speed, low values mean slower germination and higher values mean faster germination. GI has increased significantly ($p<0.05$) in U treatments in the fourth sowing date compared to the other sowing dates by all wheat cultivars with exception of *Karim* cultivar where no significant difference was detected between the first and fourth sowing (Table 6). In the third and fourth sowing, GI increased significantly ($p<0.05$) (ranged from 7.5 ± 1.4 to 19.4 ± 1.9) in most treatments amended with PM, PM + U, DPM and DPM + U (Table 6). Furthermore, in the first and second sowing GI had decreased in the treatments amended with PM + U and DPM + U compared with treatments amended with PM and DPM by all wheat cultivars. Moreover, the results demonstrated that *Slambo* cultivar had higher GI compared to other wheat cultivars in most treatments and at most sowing dates.

Table 4 The time to reach 50% germination ($T_{50\%}$) of three wheat cultivars (*Slambo*, *Acsad* and *Karim*) after 14 days growing period sown in desert soil on four sowing dates after amendment with non-digested and anaerobically digested poultry manure with and without combination with urea

Fertilizer type	Wheat cultivars	$T_{50\%}$ (days)			
		First sowing	Second sowing	Third sowing	Fourth sowing
C	*Slambo*	5.7 ± 1.3	–	–	–
C	*Acsad*	5.6 ± 0.6	–	–	–
C	*Karim*	3.4 ± 0.6	–	–	–
Urea	*Slambo*	7.6 ± 2.0	5.0 ± 1.1	4.4 ± 0.8	3.8 ± 1.2
Urea	*Acsad*	5.9 ± 1.4	5.5 ± 1.9	5.0 ± 1.4	3.8 ± 1.4
Urea	*Karim*	6.4 ± 1.1	5.6 ± 3.6	5.4 ± 1.2	4.7 ± 1.4
PM	*Slambo*	3.0 ± 0.0	4.3 ± 2.2	6.6 ± 1.6	3.8 ± 1.4
PM	*Acsad*	3.4 ± 0.8	5.3 ± 2.0	4.6 ± 2.7	4.4 ± 1.3
PM	*Karim*	3.7 ± 1.2	4.5 ± 0.9	4.0 ± 0.0	4.8 ± 1.6
PM + U	*Slambo*	9.1 ± 0.9	3.3 ± 0.6	4.3 ± 0.7	3.0 ± 0.0
PM + U	*Acsad*	10.3 ± 3.8	4.3 ± 2.2	4.4 ± 1.2	3.6 ± 1.0
PM + U	*Karim*	9.2 ± 3.3	6.5 ± 0.5	4.2 ± 1.0	3.0 ± 0.0
DPM	*Slambo*	4.0 ± 0.0	4.1 ± 1.0	4.0 ± 0.9	2.5 ± 0.9
DPM	*Acsad*	3.8 ± 0.6	4.0 ± 0.9	4.3 ± 1.3	3.0 ± 0.0
DPM	*Karim*	5.0 ± 0.9	3.8 ± 1.4	3.6 ± 0.8	3.4 ± 0.8
DPM + U	*Slambo*	7.3 ± 1.2	7.0 ± 0.0	4.7 ± 0.4	3.0 ± 1.4
DPM + U	*Acsad*	7.9 ± 2.6	6.6 ± 2.2	4.2 ± 1.0	3.0 ± 0.0
DPM + U	*Karim*	5.1 ± 2.7	7.0 ± 1.0	4.2 ± 1.0	3.4 ± 1.4

Values represent the average ± standard deviation ($n = 4$)

– no control used in the second, third and fourth sowing

Table 5 Final germination percentage (FGP) of three wheat cultivars (*Slambo*, *Acsad* and *Karim*) after 14 days growing period sown in desert soil on four sowing dates after amendment with non-digested and anaerobically digested poultry manure with and without combination with urea

Fertilizer type	Wheat cultivars	FGP (%)			
		First sowing	Second sowing	Third sowing	Fourth sowing
C	*Slambo*	88 ± 1.4	–	–	–
C	*Acsad*	93 ± 2.5	–	–	–
C	*Karim*	88 ± 6.3	–	–	–
Urea	*Slambo*	93 ± 6	63 ± 15	67 ± 6	93 ± 12
Urea	*Acsad*	70 ± 10	73 ± 6	60 ± 0	83 ± 6
Urea	*Karim*	90 ± 17	70 ± 17	77 ± 6	90 ± 10
PM	*Slambo*	93 ± 12	100 ± 0	93 ± 12	100 ± 0
PM	*Acsad*	100 ± 0	93 ± 12	100 ± 0	100 ± 0
PM	*Karim*	60 ± 0	87 ± 12	80 ± 0	87 ± 12
PM + U	*Slambo*	80 ± 20	93 ± 12	100 ± 0	100 ± 0
PM + U	*Acsad*	60 ± 0	73 ± 23	100 ± 0	100 ± 0
PM + U	*Karim*	47 ± 12	73 ± 12	100 ± 0	87 ± 12
DPM	*Slambo*	93 ± 12	93 ± 12	100 ± 0	100 ± 0
DPM	*Acsad*	100 ± 0	93 ± 12	100 ± 0	100 ± 0
DPM	*Karim*	93 ± 12	87 ± 12	100 ± 0	93 ± 12
DPM + U	*Slambo*	53 ± 23	93 ± 12	100 ± 0	100 ± 0
DPM + U	*Acsad*	73 ± 12	67 ± 31	100 ± 0	93 ± 12
DPM + U	*Karim*	80 ± 0	80 ± 0	87 ± 23	87 ± 23

Values represent the average ± standard deviation ($n = 4$)

– no control used in the second, third and fourth sowing

Table 6 Germination index (GI) of three wheat cultivars (*Slambo*, *Acsad* and *Karim*) after 14 days growing period sown in desert soil on four sowing dates after amendment with non-digested and anaerobically digested poultry manure with and without combination with urea

Fertilizer type	Wheat cultivars	GI (% day^{-1})			
		First sowing	Second sowing	Third sowing	Fourth sowing
C	*Slambo*	11 ± 0.3	–	–	–
C	*Acsad*	14 ± 0.5	–	–	–
C	*Karim*	15 ± 1.5	–	–	–
Urea	*Slambo*	13.9 ± 0.8	11.7 ± 2.7	8.4 ± 2.0	15.3 ± 3.1
Urea	*Acsad*	11.8 ± 1.2	12.5 ± 0.8	7.5 ± 1.4	13.0 ± 2.0
Urea	*Karim*	13.0 ± 4.3	10.8 ± 3.0	10.6 ± 2.1	14.7 ± 2.9
PM	*Slambo*	13.4 ± 2.8	16.7 ± 0.0	15.0 ± 1.7	15.8 ± 0.8
PM	*Acsad*	14.6 ± 3.6	12.9 ± 1.6	14.8 ± 2.5	16.7 ± 1.7
PM	*Karim*	11.7 ± 0.5	13.3 ± 1.4	12.5 ± 0.0	13.2 ± 1.0
PM + U	*Slambo*	7.9 ± 2.4	14.7 ± 1.9	19.4 ± 1.9	16.7 ± 0.0
PM + U	*Acsad*	4.7 ± 0.3	11.3 ± 4.0	17.8 ± 1.0	16.9 ± 1.3
PM + U	*Karim*	3.8 ± 0.6	10.1 ± 1.7	17.8 ± 1.0	14.2 ± 1.4
DPM	*Slambo*	15.0 ± 1.4	16.4 ± 1.7	18.3 ± 1.7	16.0 ± 0.6
DPM	*Acsad*	16.7 ± 0.0	17.2 ± 3.5	17.8 ± 1.9	16.4 ± 0.5
DPM	*Karim*	13.3 ± 1.4	13.5 ± 1.4	16.3 ± 1.8	16.7 ± 3.3
DPM + U	*Slambo*	5.7 ± 1.0	11.0 ± 0.9	16.7 ± 0.0	16.4 ± 1.3
DPM + U	*Acsad*	6.7 ± 0.0	7.6 ± 3.6	17.8 ± 1.0	15.6 ± 1.9
DPM + U	*Karim*	10.3 ± 1.0	10.6 ± 1.0	15.6 ± 4.8	17.5 ± 4.6

Values represent the average ± standard deviation (n = 4)

– no control used in the second, third and fourth sowing

Plumule and radicle length

Analysis of variance showed significant ($p < 0.05$) effect of sowing date and fertilizer type on plumule and radicle lengths. Whereas wheat cultivars have significant ($p < 0.05$) effect only on radicle length. Moreover, there was significant ($p < 0.05$) interaction effect of sowing date × fertilizer type and fertilizer type × wheat cultivars on the plumule and radicle length. Whereas, radicle length was affected significantly ($p < 0.05$) by the interaction of sowing date × wheat cultivars and sowing date × fertilizer type × wheat varieties, but not the plumule length. The results displayed remarkable differences in the plumule and radicle length of seedlings obtained from the control compared to the results found in the other treatments (Fig. 1). In U treatments, plumule and radicle length were reduced significantly ($p < 0.05$) at all sowing dates in comparison with control, with the exception of plumule length of *Slambo* cultivar on the fourth sowing where showed no significant differences between U treatment and the control (Fig. 1). Amendment with PM + U and DPM + U significantly ($p < 0.05$) reduced plumule and radicle length at the first sowing for all wheat cultivars in comparison with treatments of PM, DPM, U and control (Fig. 1). However, in the second, third and fourth sowing plumule and radicle length increased significantly ($p < 0.05$) in the treatments of PM + U and DPM + U in comparison with the first sowing, U treatments and control.

Seedlings dry weight

Analysis of variance displayed significant ($p < 0.05$) effect of sowing date, fertilizer type and wheat cultivars as well as their interaction on seedling dry weight. In the U treatments seedling dry weight was not improved significantly at the first, second and third sowing compared to the control with exception of *Karim*'s which was significantly ($p < 0.05$) higher (Fig. 2). Furthermore, amendment with PM, PM + U, DPM and DPM + U did not improve seedling dry weight significantly on the first and second sowing in comparison with the control and U treatments. However, in the third and fourth sowing seedling dry weight has increased significantly ($p < 0.05$) for most wheat cultivars (Fig. 2).

Discussion

Several studies have shown that application of non-digested and digested manures enhanced wheat growth and yield particularly at combination with U (Abubaker et al. 2017; Kiani et al. 2005). However, in the present study, the germination of wheat cultivars was delayed and reduced when sowing was made directly or after 10 days from amendments with non-digested and digested manures. The adverse effect was more pronounced in the treatments amended with non-digested and digested manures in combination with urea as well as sole urea. This observation

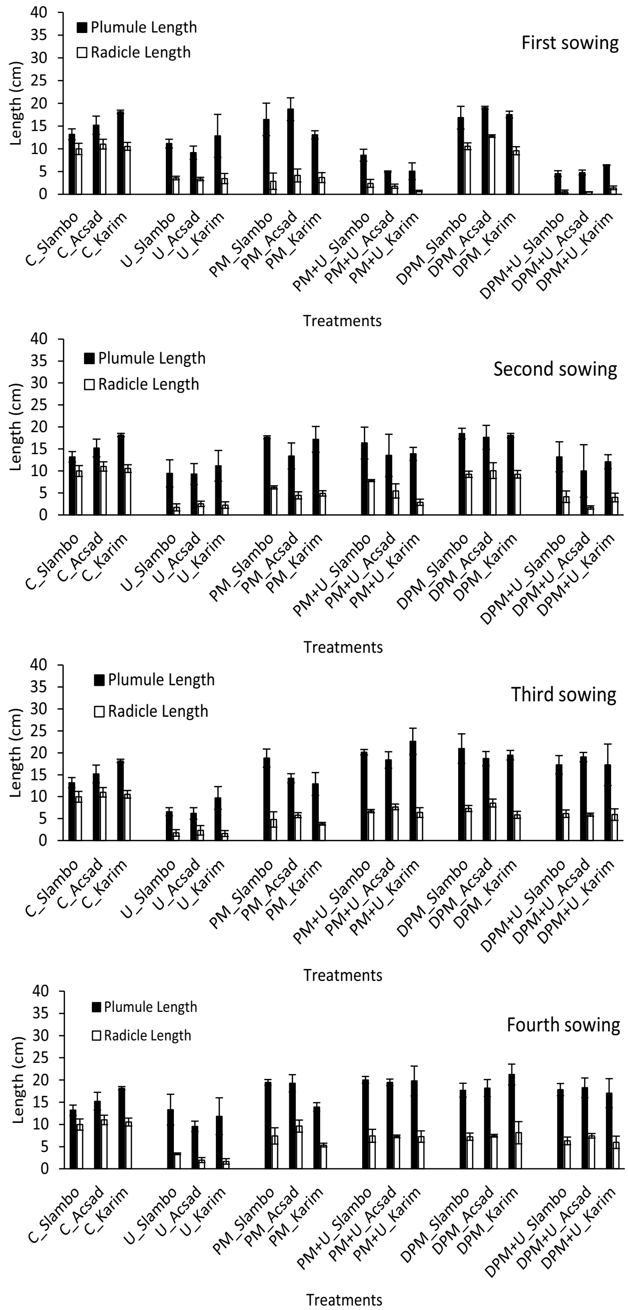

Fig. 1 Plumule and radicle length of three wheat cultivars (*Slambo*, *Acsad* and *Karim*) after 14 days growing period sown in desert soil on four sowing dates after amendment with non-digested and anaerobically digested poultry manure with and without combination with urea. Bars represent mean ± standard deviation ($n = 4$)

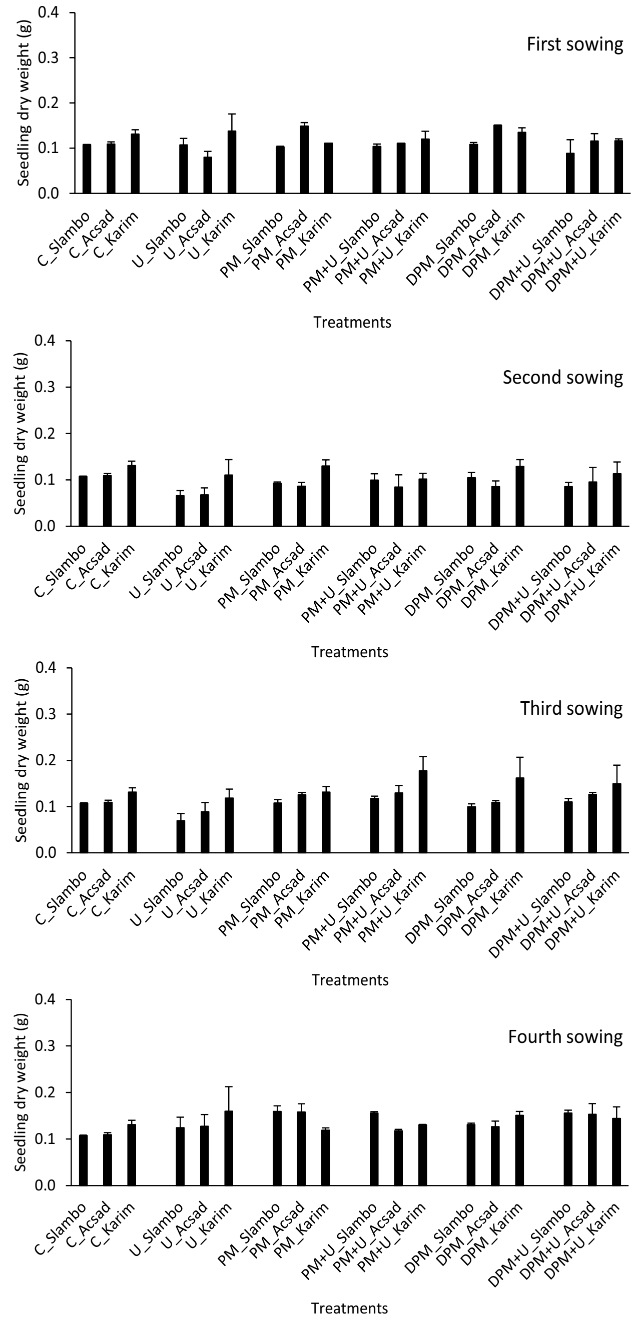

Fig. 2 Seedling dry weight of three wheat cultivars (*Slambo*, *Acsad* and *Karim*) after 14 days growing period sown in desert soil on four sowing dates after amendment with non-digested and anaerobically digested poultry manure with and without combination with urea. Bars represent mean ± standard deviation ($n = 4$)

was in agreement with results reported by Abubaker et al. (2017) who found that sowing wheat seeds two days after amendment with non-digested and digested poultry manure with and without combination with urea reduced germination percentage considerably. Moreover, Gupta and Gupta (2011) reported a similar effect on okra seeds germination when sowing was performed 6 to 18 h after treatment with anaerobically digested poultry manure. This negative effect has been explained by the existence of humic acids in digested manure that formed during anaerobic digestion (Bacilio et al. 2003; Šerá and Novák 2011). In another study, Kaparaju et al. (2012) reported that anaerobically digested orange waste have a toxic effect on seeds germination of

Chinese cabbage and they referred this toxicity to ammonia and organic acids in the digestate. Tunes et al. (2012) have reported that the presence of organic acids which originating from the anaerobic decomposition of organic material can significantly reduce the germination of wheat cultivars, radicle length and dry weight. It is well known that concentration of ammonia in digested manure is higher compared to raw manure (García-González et al. 2016), which was found to reduces wheat seed germination and suppresses root hair formation (Bremner and Krogmeier 1989; Wan et al. 2016). The adverse effect of combining manure with urea on seeds germination and radicle length have been reported in another study where they referred this adverse effect to the presence of ammonia, which formed through hydrolysis of urea by soil urease (Bremner and Krogmeier 1989). Moreover, Wan et al. (2016) have reported an inhibition effect of urea on seed germination and radicle growth in six wheat cultivars, they explained this effect by the formation of ammonia in the soil after application. Soil microorganisms can contribute to ammonia production in the soil by releasing ureases enzyme, which will convert urea to carbon dioxide and ammonia (Maier 2009). However, sowing seeds either 20 or 30 days after amendment enhanced seed germination, radicle length, plumule length and seedling dry weight. This probably was due to the degradation of fertilizers components and the transformation of mineral N by soil microorganisms (Powlson et al. 2001). Kuwatsuka and Shindo (1973) have reported that the concentration of phenolic substances in waste-treated soil decreased rapidly and reached that of the control on the day 30 after waste disposal. In addition, degradation of organic materials will also lead to the release of plant nutrients, which will enhance the growth of radicle and plumule resulted in increasing seedling dry weight. The present study showed that *Acsad* and *Slambo* cultivars had better germination percentages than those of *Karim*. This was probably due to their vitalities, which were higher for *Slambo* (99 ± 4%) and *Acsad* (95 ± 3%) compared to *Karim* (89 ± 6%).

Conclusion

It can be concluded that all tested fertilizers displayed short-term effects on wheat seeds germination, which can be avoided by applying fertilizer at least 20 days prior to the sowing. It seems to fertilize soil 20–30 days before sowing, can reduce the adverse effect of the substances that responsible for delayed germination in non-digested, digested poultry manure and urea. However, the early application of fertilizers, especially digestate, may cause the loss of nutrients such as N in the form of ammonia. Therefore, further work remains to evaluate the effect of prolonging the period between applications and sowing on wheat growth and yield.

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