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ORIGINAL RESEARCH

The effect of municipal sewage sludge on the quality of soil and crops

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Abstract
Purpose To examine the effects of the application of composted sewage sludge fertilizer (commercially sold as Kala compost) and inorganic (NPK) fertilizers on soil quality and on two crops (radish and beans) irrigated using groundwater and sewage treated wastewater (TWW) for irrigation by measuring heavy metals in the soil and plants and other parameters such as crops yield, TOC in soil, chlorophyll index and total nitrogen.
Methods The field experiments were conducted in an open area in Agricultural Experimental Study at Sultan Qaboos University campus, Oman. In this research, "green beans and white radish" were examined under the application of Kala and NPK fertilizers. The experimental design was a randomized complete block with four replicates.
Results The results showed that the yield, TOC and chlorophyll contents of green beans and white radish increased when soil was amended with Kala compost compared to NPK. Chemical analysis of soil and the two crops did not show any risk of heavy metal accumulation.
Conclusions Considering that the experiment was a short duration one, there is a need for more continuous long-term experiments (at least 5 years) that will improve the understanding on the effects of composted sewage sludge on soil fertility and crop yield to contribute to the development of sustainable agricultural practices in an arid environment of Oman.

Keywords Sewage sludge · Soil quality · Kala compost · Green beans · White radish · Oman

Abbreviations

AES	Agricultural Experimental Station
Analysis of variance (ANOVA)	Statistical analysis of data
CCI	Chlorophyll content index (chlorophyll measurement unit)
EC	Electrical conductivity
FAO	Food and Agricultural Organization
GW	Groundwater
Kala compost	Organic fertilizer is produced from the municipal sewage treated wastewater (Kala is the commercial name of the product sold in the market)
NPK fertilizers	Inorganic fertilizer with three elements: nitrogen, phosphorus, and potassium
TN	Total nitrogen
TOC	Total organic carbon, which is found in soil when organic matters are decomposed
TWW	Treated wastewater
USEPA	United States Environmental Protection Agency
WHO	World Health Organization

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Introduction

Water deficit causes significant problems in arid and semi-arid countries especially with the acceleration of population and economy growth (Al-Busaidi and Ahmed 2014; Padmavathiamma et al. 2014; Ahmed et al. 2008; Prathapar et al. 2005). Therefore, the usage of treated municipal wastewater is a very useful resource for irrigation and industrial purposes (Saffari and Saffari 2013; Ahmed et al. 2005). Because of the rapid growth in Oman's water demand, studies were conducted to improve the suitability of using treated wastewater for irrigating crops without having any adverse impact of heavy metals. On the other hand, municipal sewage sludge (the end products of treated domestic wastewater) comprises heavy metals and organic chemicals which can cause risk to the food chain and subsequently to human health (Harrison et al. 2006; Zhao et al. 2012; Baawain et al. 2014a, 2014b; Jaffar Abdul Khaliq et al. 2017). Therefore, studies are needed for land application of sewage sludge to avoid any serious risk to the environment.

Municipal sewage sludge fertilizers can improve the physiochemical properties of soil and affect crop yields and its growth (Antonkiewicz and Pelka 2014; Onwudiwe et al. 2014; Baawain et al. 2014a, b; Jaffar Abdul Khaliq et al. 2017). These fertilizers are very rich in macro and micronutrients, which can supply nutrients to plants and increase their fertility (Al-Busaidi 2014b; Zhao et al. 2012).

The aim of this study was to determine the effect of Kala compost (organic fertilizer) and NPK (inorganic fertilizer) on the quality of soil and crops (green beans *Phaseolus vulgaris* and white radish *Raphanus sativus*) by measuring heavy metals in soil and in the crops. In addition, the aim was to measure other parameters such as crop yields, TN in soil and crops, TOC in soil and crops, chlorophyll index when both plants were irrigated with groundwater (GW) and treated wastewater (TWW).

Materials and methods

This study was performed in the field of an open area in Agricultural Experimental Station (AES) at Sultan Qaboos University (SQU). There were 6 plots in 3 sites, each plot of 3 m width and 3.5 m length, these plots were divided into two rows by 1 m buffer zone and amended with either 22 kg Kala compost or 0.5 kg of NPK (Al-Busaidi and Ahmed 2016). 5 seedlings (15 days after sowing seeds) of each plant were transplanted in each of half plot as per the treatments detailed in Table 1.

The composition of NPK fertilizer was 20% total nitrogen (N): 4.6% nitrate nitrogen, 2.5% ammoniacal nitrogen, 12.9% uric nitrogen, 20% phosphorus pentoxide (P_2O_8) = 8.7% P and 20% K_2O (16.6% K).The composition of Kala compost is given as follows:

pH 7.6, EC 31 mS/cm, total organic carbon (TOC) 28.04%, total nitrogen (TN%) 2.6–2.8, moisture content 24%.

Cd 1.03 mg/kg, Pb 63.8 mg/kg, Cu 225.4 mg/kg, Zn 519.2 mg/kg, Cr 119.5 mg/kg, Ni 87.07 mg/kg, Hg 1.524 mg/kg, Mo 6.789 mg/kg and Se 0.5096 mg/kg (Haya 2016).

Before growing, all plots were mulched to prevent direct effects of heat on the plants. Each plot was irrigated with 20 L by drip irrigation method with GW and TWW for 15 min daily. TWW was obtained from the sewage treatment plant at SQU, whereas GW was obtained from a well at the AES; the chemical analyses of GW and TWW are given in Table 2. Both plants were planted on 3 October 2015. Radish was grown before beans in a period of

Table 1 Experimental details of municipal sewage sludge on the quality of soil and crops

Sites	Details	Irrigation method
1D1	Radish and beans +NPK (first site and at right side)	TWW
1D2	Radish and beans +Kala (first site and at left side)	TWW
1B1	Radish and beans +NPK (first site and at right side)	GW
1B2	Radish and beans +Kala (first site and at left side)	GW
2B1	Radish and beans +Kala (second site and at right side)	GW
2B2	Radish and beans +NPK (second site and at left side)	GW
2D1	Radish and beans +Kala (second site and at right side)	TWW
2D2	Radish and beans +NPK (second site and at left side)	TWW
3D1	Radish and beans +NPK (third site and at right side)	TWW
3D2	Radish and beans +Kala (third site and at left side)	TWW
3B1	Radish and beans +NPK (third site and at right side)	GW
3B2	Radish and beans +Kala (third site and at left side)	GW

D irrigation method by treated wastewater, *B* irrigation method by groundwater

Table 2 Chemical analysis of GW and TWW (mg/l)

Water	Mn	Fe	Zn	Cu	Cr	Cd	Pb	Ni	B
GW	0.002	0.013	0.013	0.008	<0.002	<0.001	<0.001	<0.001	0.295
TWW	0.002	0.016	0.064	0.024	<0.002	<0.001	0.066	<0.001	0.508
EPA standard	0.200	5.000	5.000	0.500	0.100	0.010	0.100	0.100	0.750
FAO standard	0.200	5.000	2.000	0.200	0.100	0.010	0.500	0.200	0.750
Omani standard	0.500	5.000	5.000	1.000	0.050	0.010	0.200	0.100	0.750

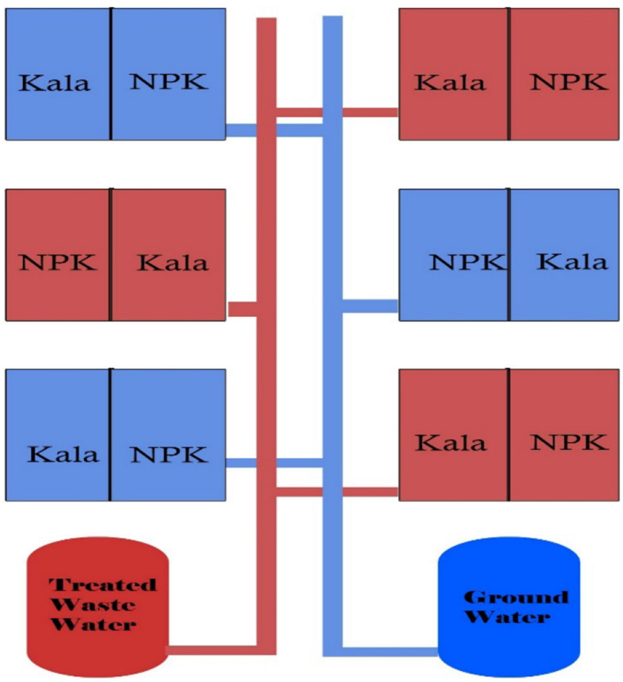


Fig. 1 The design of the study site

18 days, whereas beans were grown within a period of 1 month.

The field experimental plots were set up in a randomized block design as shown in Fig. 1 and each site had 4 treatments for two crops (four replicates for each treatment were analyzed) and the chemical analysis data were recorded for the statistical analysis. The treatment details of the experiment are illustrated in Table 3.

The third location was ignored as the crop growth was very poor due to operational problems.

Initial physical and chemical soil analysis

Soil samples were collected from each site in all plots from a depth of 10 cm. The samples were air dried, sieved through 2-mm sieve and kept in plastic bags. The composition of soil was determined using the hydrometer method (Klute 1986) and its texture was determined using soil triangle (Brady 1984). EC and pH were measured using pH and EC electrodes (Thermo Scientific Orion 4-star) after applying the saturated paste method (Richards 1954). Soil TOC was analyzed by the FORMACSHT TOC/TN ANALYSER model (SKALAR) and the concentrations of heavy metals were measured using ICP instrument after applying the saturated paste method.

Table 3 Treatment details for two crops in each site

Treatments	Details
T1	GW + Kala
T2	GW + NPK
T3	TWW + Kala
T4	TWW + NPK

Soil analysis after harvesting

Soil samples after harvesting were collected from a depth of 10 cm from all plots. These were kept in labeled plastic bags, ground and passed through a 2-mm sieve. EC, pH, TOC and concentrations of heavy metals were determined using the same method as described above. TN% was determined by the Kjeldahl method as mentioned by Alkhamisi (2013) and Bremner and Mulvaney (1982).

Plant analysis after harvesting

Biomass of plants and yield

The two crops were harvested two times weekly and washed to remove sand and dust. For their physical analysis weights were recorded and their growth was measured each time (leaf color, surface area and chlorophyll measurements). A measurement of chlorophyll content index (CCI), which is related to nitrogen content in the leaves, was measured by a chlorophyll meter. At the end of each harvesting day, plant samples were kept in plastic bags to be frozen for further chemical analysis.

Plant analysis

In order to determine heavy metals in the plants samples after harvesting period, leaves and roots of the radish crop were cut as well as the edible part of the beans crop and the same method of heavy metals analysis using Wet Acid Digestion method EPA 3050 (http://www.cropsoil.uga.edu/

oplank/sera368.pdf) was performed, four replicates of each treatment were analyzed and the chemical analysis data were recorded for the statistical analysis, TN% was also determined using the Kjeldhal method.

Statistical analysis

All data for EC, pH, TN% and heavy metals for soil and plant samples were analyzed using the analysis of variance (ANOVA). Data were analyzed using the computer software JMP (SAS Institute Inc 2013) and 5% probability level was used to determine the significance of the test.

Results and discussion

Soil analysis before harvesting

Soil texture was determined as sandy loam of 70.2% sand, 18.8% silt and 11.0% clay. EC and pH before adding fertilizers were at 1.3 mS/cm and 8.0, respectively. The initial analysis results of heavy metals in soil samples are given in Table 4, these results represent values before adding any fertilizers.

Soil analysis after harvesting

EC and pH

Mean EC values in (mS/cm) are shown in Table 5.

Electrical conductivity values for sites which were amended with NPK fertilizer and were irrigated by GW and TWW as shown in the table above were higher than the sites which were amended by Kala compost. This revealed that, although Kala compost has a high initial EC value of 31 mS/cm, it leached much better than NPK fertilizer. The statistical results of ANOVA for both EC and pH were not significant ($p > 0.05$) among all treatments (see Table 12), this is in line with El-Nahhal et al. (2013) who found that both EC and pH values were not significantly different among treatments and were high at the top soil profile of a depth ranging from 0 to 30 cm compared to a depth from 90 to 120 cm. This was because the top profile of soil is more acidic than the deep profile and the highest EC values at the upper layers of soils may have been affected due to the decomposition of organic compounds (Nogueirol et al. 2013).

Table 4 Initial values of heavy metal concentrations in soil samples in mg/kg

Element (mg/kg)	Treatment			
	T1	T2	T3	T4
Fe	0.25	0.39	0.20	0.29
Zn	0.5	0.55	0.52	0.51
Cu	1.08	0.86	0.57	0.53
B	0.023	0.014	0.03	0.03
Cr	<0.3	<0.3	<0.3	<0.3
Ni	0.64	<0.5	<0.5	<0.5
Ag	<0.01	<0.01	<0.01	<0.01
Cd	<0.01	<0.01	<0.01	<0.01

Table 5 Mean values of EC in mS/cm and pH of soil samples

Treatments	EC (mS/cm)	pH
T1 (GW + Kala)	4.5	7.8
T2 (GW + NPK)	6.9	7.5
T3 (TWW + Kala)	4.7	7.7
T4 (TWW + NPK)	5.4	7.7

TOC (total organic carbon) analysis

Figure 2 shows the analysis of total organic carbon (TOC) in soil samples.

Soil samples with Kala compost media in the above figure shows a higher TOC value than in the media of NPK fertilizer. This observation is consistent with Singh and Agrawal (2011) and Mi et al. (2016) that the application of organic fertilizers leads to increasing the values of organic carbon compared with NPK fertilizer. In addition, adding municipal sewage sludge compost results in increasing of TOC values (Pena et al. 2015). The TOC in Kala compost-amended soil is 39% (irrigated with GW) which is higher than TOC in soil samples under the application of NPK. The corresponding increase was 14% when soils were irrigated with TWW. The statistical analysis of variance indicated that TOC levels were strongly significant among all treatments ($p < 0.05$), but both the sites and the interaction of sites with treatments were not significant (see Table 12).

Heavy metal analysis

The results of heavy metals of soils are given in Table 6.

As appears in Table 6, all concentrations of metals were within the standard range of the limits as shown in Tables 7 and 8. However, Fe has the highest limit in our results, which agrees with the findings of Nogueirol et al. (2013) who reported that Fe concentration was the highest in their study especially at a depth ranging from 0 to 10 and from 10 to 20 cm, showing that Fe was mostly stuck to the mineral fraction found in the soil.

In our experiment, most metals in soil samples after harvesting showed higher concentrations compared to their

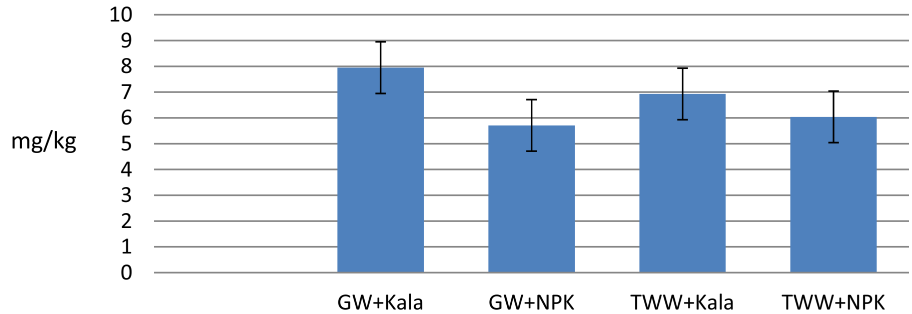


Fig. 2 TOC in soil samples in mg/kg

Table 6 Mean values of heavy metals in soil in mg/kg after harvesting

Element (mg/kg)	Treatments			
	T1 GW + Kala	T2 GW + NPK	T3 TWW + Kala	T4 TWW + NPK
Fe	49.8	64.7	19.6	29.6
Zn	1.2	3.9	2.5	2.2
Mn	0.1	ND	ND	ND
Cu	1.6	1.01	1.3	0.9
B	0.093	0.036	0.11	0.07
Cr	8.6	5.04	7.2	4.2
Ni	1.04	0.5	0.7	0.6
Ag	0.1	0.09	0.09	0.09
Cd	0.1	0.07	0.07	0.06

initial concentration. The increase may be due to the more active chemical processes taking place on the top layer such as the salt accumulation, decomposition of organic compounds and irrigation water quality (Al-Busaidi 2014b), and also for the high retention of heavy metals in the soil with different amendments (Singh and Agrawal 2011). Therefore, the statistical analyses of these elements were not significantly different ($p > 0.05$) within all treatments (see Table 12).

Plant analysis after harvesting

Biomass of crops and yield

No phytotoxicity signs were detected in this experiment for both crops. As shown in Fig. 3, the yield of both plants was the highest under the application of Kala compost compared to NPK fertilizer. This result is in accord with Al-Toubi (2015) who found that the yield of cucumbers grown was more in Kala media compared to Diwan compost and SQU agricultural compost. In addition, the same finding was found by Al-Saadi (2016) that the yield and biomass of tomato were increased by applying Kala compost. Therefore, applying sewage sludge develops soil physicochemical properties, thus increasing the yield of the plants (Antonkiewicz and Pelka 2014). In our experiment, the yield of beans increased under the application of Kala compost compared to NPK fertilizer. The increases were 22% (TWW) and 77% (GW) for beans and 33% (TWW) and 96% (GW) for radish. The statistical analysis as summarized in Table 12 points that the yield of both crops was significant among all treatments ($p < 0.05$); the site in radish was significant but not in beans, also the interaction of sites with treatments in both plants was not significant.

Total nitrogen % in soil and plant samples

Soil samples showed the lowest levels of TN% compared to plant samples as shown in Fig. 4. This can be explained that nitrogen had been taken from soil and accumulated in the plants. Therefore, the statistical analysis of TN% (ANOVA) in soil samples among all treatments was not significant ($p > 0.05$) as summarized in Table 12.

In addition, TN% in plants, which were amended with Kala compost and irrigated with either GW or TWW, showed higher values than plants which were amended by NPK. This observation agrees with Al-Toubi (2015) that TN% was higher with Kala fertilizer than the other two types of compost (Diwan compost and compost which is produced by AES at SQU) because Kala contains high amounts of organic matter.

Table 7 Concentration of heavy metals in soils and plants: Source Alloway (1995)

Element	Normal range in soils[b]	Critical soil total concentration (mg/kg)[b]	Normal range in plants[a]	Critical concentrations in plant (mg/kg)[c]	
				a	b
Ag	0.01–8	2	0.1–0.8		1.0–4
As	0.1–40	20–50	0.2–7	5.0–20	1.0–20
Au	0.001–0.02	–	0.0017		<1
Cd	0.01–2.0	3.0–8.0	0.1–2.4	5.0–30	4–200
Co	0.5–65	25–50	0.02–1	15–50	4.0–40
Cr	5–1500	75–100	0.03–14	5.0–30	2.0–18
Cu	2–250	60–125	5.0–20	20–100	5.0–64
Hg	0.01–0.5	0.3–5	0.005–017	1.0–3	1.0–8
Mn	20–10,000	1500–3000	20–1000	300–500	100–7000
No	0.1–40	2.0–10	0.03–5	10.0–50	
Ni	2–750	100	0.02–5	10–100	8–220
Pb	2–300	100–400	0.2–20	30–300	
Sb	0.2–10	5–10	0.0001–0.2		1.0–2
Se	0.1–5	5.0–10	0.001–2	5.0–30	3.0–40
Sn	1–200	50	0.2–6.8	60	63
Ti	0.1–0.8	1	0.03–3	20	
U	0.7–9		0.005–0.06		
V	3–500	50–100	0.001–1.5	5.0–10	1.0–13
W	0.5–83		0.005–0.015		
Zn	1–900	70–400	1–400	100–400	100–900

[a]Data mainly from Bowen (1979)

[b]The critical soil total concentration is the range of values above which toxicity is considered to be possible. Data from Kabata-Pendias and Pendias (1992)

[c]The critical concentration in plants is the level above which toxicity effects are likely. a Data from Kabata-Pendias and Pendias (1992); b values likely to cause 10% depression in yield; data from Macnichol and Beckett (1985)

Table 8 Standard threshold limit values of heavy metals in soils and fruits: Source CPCB (2002)

Samples	Standards	Fe	Zn	Cu	Pb	Cd	Mn	Cr	Ni	As
Soil (mg/kg)	Indian Standard (Awashthi 2000)	NA	300–600	135–270	250–500	3–6	NA	NA	75–150	–
	WHO/FAO (2007)	–	–	–	–	–	–	–	–	–
	European Union Standards (EU 2002)	NA	300	140	300	3.0	NA	150	75	–
	USEPA (2010)	NA	200	50	300	3.0	80	NA	–	–
	Kabata-Pendias and Pendias (2010)	1000	NA	NA	NA	NA	NA	NA	–	–
Plant (mg/kg)	Indian Standard (Awashthi 2000)	NA	50.0	30.0	2.5	1.5	NA	20	5	1.1
	WHO/FAO (2007)	450	60.0	40.0	5.0	0.2	500	5.0	10	–
	European Union Standards (EU 2002)	NA	60	40	0.30	0.20	NA	NA	–	–
	USEPA (2010)	–	–	–	–	–	–	–	–	–

Therefore, in our experiment, TN showed an increase between 13 and 40% for beans and an increase between 10.25 and 21% in leaves for radish under the application of Kala compost when both plants were irrigated with GW and TWW, respectively. However, TN showed no increase in the roots of radish when the plant was irrigated with GW using either NPK or Kala fertilizers, but showed an increase of 3.86% when it was irrigated with TWW under the application of Kala compost.

The statistical analyses of TN % as summarized in Table 12 for all plant samples were not significant ($p > 0.05$) among all treatments; however, the result was

Fig. 3 Mean yields of two crops per plot in grams

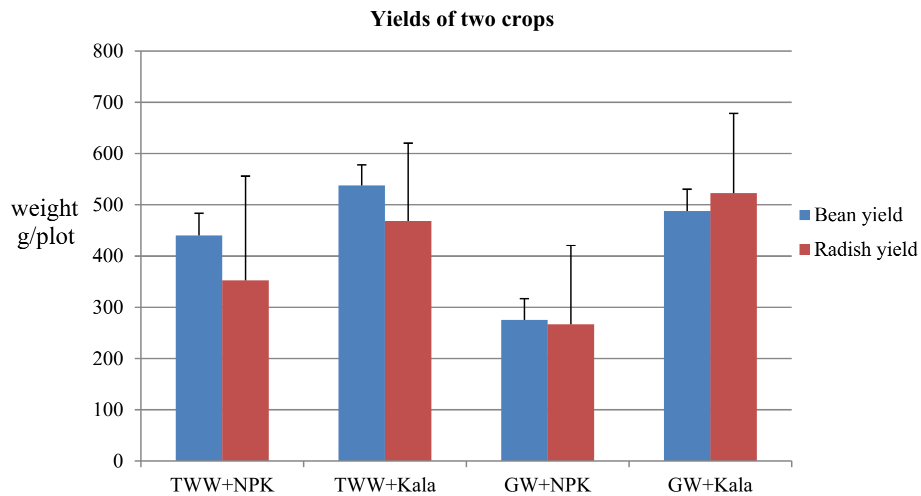
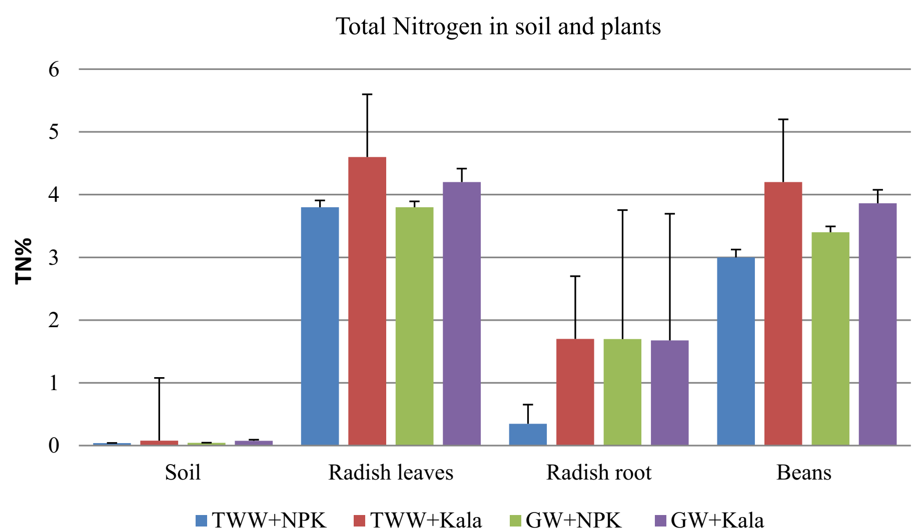


Fig. 4 Total nitrogen in soil and plants



significant ($p < 0.05$) only for the leaves in radish crop, this may be because the nitrogen level which relates to the chlorophyll content is found in the leaf part of plants (Daughtry et al. 2000).

Measurements of chlorophyll

Chlorophyll contents of two crops were collected two times weekly with four replicates; their mean values are shown in Figs. 5 and 6.

As shown from the two figures, the average chlorophyll contents in the treatment using Kala compost was higher than in the treatment using NPK fertilizer. Similar results found by Al-Toubi (2015) that chlorophyll content in Kala media had the highest value over the other two fertilizers of Diwan and SQU agricultural compost. In addition, Singh and Agrawal (2011) reported that, chlorophyll

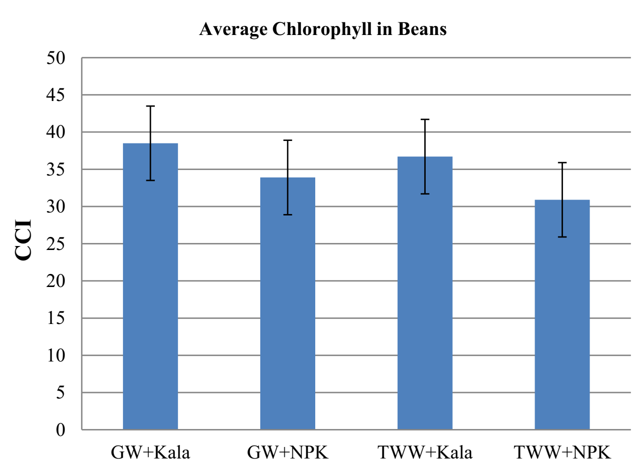


Fig. 5 Average chlorophyll in beans

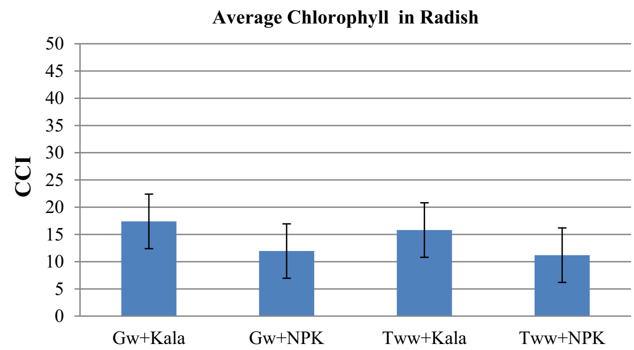


Fig. 6 Average chlorophyll in radish

measurement was the highest in Spinach plant *Spinacia oleracea* with organic fertilizer using farm-yard manure. The chlorophyll contents of beans increased by 19 and 13.6% and increased for radish by 41 and 45.6% when both plants were irrigated with TWW and GW, respectively, using Kala compost instead of NPK. The statistical analysis of variance for the chlorophyll contents in both plants showed that the there was a highly significant difference among all treatments ($p < 0.05$) but not the sites and their interactions were significant (see Table 12).

Heavy metal analysis in plant samples after harvesting

The results of heavy metals in plant samples are given in Table 9.

As appears in Tables 9, 10 and 11, Fe has the highest concentrations in plant samples; this agreed with the findings of Nogueirol et al. (2013) who reported that Fe concentration was the highest when using the method of EPA 3052 among the other methods. Therefore, maybe the EPA 3050 method which was used to extract Fe in our study had a similar affect. In addition, Zn concentration also showed high values in all results, which is in line with Ji et al. (2012) and Saffari and Saffari (2013) who found that the high limit of Zn in plants might relate to the addition of organic manure fertilizers.

The statistical analyses of most heavy metals in root and leaves of radish plant as summarized in Table 12 were significantly different ($p < 0.05$) among all treatments. This is in agreement with Al-Busaidi (2014a, b) who found that the high concentrations of some metals such as Fe, Zn, and Ni in date plant leaves, which were irrigated either by TWW or GW were significant in all locations due to the

Table 9 Mean values of heavy metals of beans in mg/kg

Elements (mg/kg)	Treatments			
	T1 GW + Kala	T2 GW + NPK	T3 TWW + Kala	T4 TWW + NPK
Fe	40.5	43.9	47.2	50.1
Zn	60.6	48.4	36.6	38.3
Cu	6.6	5.9	5.7	4.8
B	27.07	25	29.6	22.3
Cr	5.3	4.5	2.4	2.7
Ni	6.9	3.7	5.7	6.4
Ag	0.3	0.2	0.2	0.2
Cd	1.3	0.1	0.2	0.1

Table 10 Mean values of heavy metals in roots of radish plant in mg/kg

Elements (mg/kg)	Treatments			
	T1 GW + Kala	T2 GW + NPK	T3 TWW + Kala	T4 TWW + NPK
Fe	125.2	299.5	175.07	145
Zn	32.1	23.1	29.6	23.5
Mn	0.4	7.3	7.3	ND
Cu	7.9	5.3	3.08	4.07
B	21.5	23	26	22
Cr	1.3	2.1	1.2	7.2
Ni	2.4	5.4	1.6	7.9
Ag	0.1	0.1	0.2	0.2
Cd	0.1	0.1	0.2	0.2

Table 11 Mean values of heavy metals in leaves of radish plant in mg/kg

Elements (mg/kg)	Treatments			
	T1 GW + Kala	T2 GW + NPK	T3 TWW + Kala	T4 TWW + NPK
Fe	349.8	426.7	264.2	226.1
Zn	56.7	44.3	17.2	46.2
Mn	0.4	ND	1.7	ND
Cu	5.3	7.2	3.08	7.09
B	7	14	9.5	11.5
Cr	ND	1.2	3.4	2.6
Ni	2.05	4.1	3.9	4.8
Ag	0.2	0.2	0.2	0.2
Cd	0.7	0.2	0.1	0.6

Table 12 Summary of statistical analyses during the experimental study

Description	Conclusions based on *F* test (5%)
Analysis in soil samples after harvesting	
1. Analysis of pH	Treatments, sites and the interaction (site with treatment) were not significant
2. Analysis of EC	Treatments, sites and the interaction (site with treatment) were not significant
3. Analysis of TOC	Highly significant among the treatments, but sites and the interaction (site with treatment) were not significant
4. Analysis of heavy metals	Treatments, sites and the interaction (site with treatment) were not significant
5. Analysis of TN%	Treatments, sites and the interaction (site with treatment) were not significant
Analysis in plant samples after harvesting	
1. Analysis of yield in both crops	Treatments in both plants were significant
	Radish: site was significant; interaction (site with treatment) was not significant
	Beans: both site and the interaction (site with treatment) were not significant.
2. Analysis of chlorophyll in both crops	Treatments in both plants were highly significant
	Site and the interaction (site with treatment) were not significant in both plants
3. Analysis of TN% in beans	Treatments, sites and the interaction (site with treatment) were not significant
4. Analysis of TN% in leaves of radish	Treatment was highly significant; sites and the interaction (site with treatment) were not significant
5. Analysis of TN% in roots of radish	Treatments, sites and the interaction (site with treatment) were not significant
6. Analysis of heavy metals in bean plant	Most heavy metals were not significant except Zn, Ni, Ag and Cd
7. Analysis of heavy metals in roots of radish plant	All heavy metals were significant except Cd and B
8. Analysis of heavy metals in leaves of radish plant	All heavy metals were significant except Cu

soil formation and plant growth especially when Kala compost or organic manure was applied. Also, Gupta et al. (2010) found that metal accumulation per gram dry weight of plant tissue is more in the leafy portions than in the roots, and El-Nahhal et al. (2013) found a high concentration of heavy metals in the leaves of Chinese cabbage and corn when irrigated either with treated wastewater or with freshwater in their experiment.

On the other hand, the statistical results in our experiment showed that the differences in most trace elements in bean plants were not significant ($p > 0.05$) among all treatments (see Table 12). However, Zn, Ni Ag and Cd were significant ($p < 0.05$) with all treatments for this plant.

Generally, all metal concentrations in plant samples were within the standard range of the limits as given in

Tables 7 and 8, which indicate no risk of heavy metals accumulation in the plant samples.

Conclusions

The application of sewage sludge to agricultural activities has been a widely accepted for better growth and practice during recent years. The production of agricultural land is promoted with use of sewage sludge, because it is considered that such application will increase productivity in agriculture and solve the problem of disposal as well. Therefore, this experiment showed that Kala compost creates good media for producing higher crop yield as compared to NPK. Further, chemical analysis of soil and the two crops did not show any risk of heavy metal accumulation. Both groundwater and treated wastewater irrigation improve soil characteristics, growth of plants and their yield, especially when Kala compost was used for growing the two crops. Treated wastewater irrigation did not show any toxicity or contamination in the soil and the two plants used. However, there is a need for more continuous long-term experiments (at least 5 years) that will improve the understanding on the effects of composted sewage sludge on soil fertility and crop yield to contribute to the development of sustainable agricultural practices in an arid environment of Oman. Recommendations and guidelines for the farmers can be formulated after 5 years of field experiments.

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