The chemical characteristics of composted and vermicomposted cotton residues case study in Sudan

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Abstract

Purpose – The purpose of this paper is to investigate the influence of two decomposition processes, namely, composting and vermicomposting, on the chemical composition of the finished products of a mixture of: cotton residues; soil and cotton residues; farmyard; soil.

Design/methodology/approach – Composting experiments were done over six months to prepare four different mixtures as follows: cotton residues + soil (C); cotton residues + soil + earthworms (C + E); cotton residues + soil + farmyard manure (C + F); and cotton residues + soil + farmyard manure + earthworms (C + F + E). Electrical conductivity, pH, nitrate-N, ammonium-N, ash, total phosphorus, total nitrogen, total organic carbon, carbon: nitrogen ratio, total potassium and trace elements (Mn, Fe, Cu and Zn) were determined on monthly-based samples.

Findings – Significant differences ($p < 0.05$) in organic carbon, nitrate-N, nitrogen, phosphorus, and potassium content were recorded in vermicompost compared to compost. In general, results indicated that vermicompost had a significant effect compared to compost and a positive effect on the chemical properties of the finished products.

Originality/value – This research work was carried out by four researchers from two institutions concerned with agricultural production and environmental aspects related to soil productivity. The paper emphasizes on production of organic fertilizers with good quality and monitoring of composting process for better management practices of agricultural wastes in Sudan.

Keywords Sudan, Soil mechanics, Cotton, Cotton residues, Farmyard manure, Composting, Vermicomposting

Paper type Case study

Introduction

Sudan is one of the two largest countries in Africa; it covers an area of about 1,881,000 km^2 after separation of South Sudan. The arable land constitutes about one-third of the total area of the country (Higher Council of Environment and Natural Resources, 2003).

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Applicable amounts of tons of cotton, wheat and other crops residues are burnt annually in irrigated schemes of Gezira-Managil (one of the largest state owned farms in the world), Rahad and Souki. These schemes, with heavy clay soils, extend over three million hectares. Cotton residues (CR) are in particular burnt in order to prevent the spread out of residue-borne diseases such as bacterial blight (black arm disease). This practice may lead to many environmental problems such as contamination of water, soil and plants since burning the crop residues together with the residual herbicides and insecticides produce toxic materials and gases. Furthermore, burning of such residues interferes with natural decomposition of organic matter in the soil and causes loss of a valuable source.

Crop residues are vital resource for the maintenance of soil productivity, since not only the residues are the primary substrate for the replenishment of soil organic matter, but also serve as an important source of plant nutrients (Janzen and Kucey, 1988). Retention of crop residues, when converted to organic matter, can improve soil physical, chemical and biological properties. Addition of the organic matter can improve soil chemical properties such as: increase the organic carbon (OC) content, cations exchange capacity (CEC) and consequently availability of plant nutrients (Giusquiani *et al.*, 1995).

Composting is defined as the decomposition or breakdown of organic waste by a mixed population of micro-organisms in a warm, moist, aerated environment (FAO, 1987) while decomposition under controlled conditions involving earthworms is called vermicompost (Viljoen *et al.*, 1992).

Material and methods

Experimental site

Compost and vermicompost were prepared over six months at the demonstration farm of the Faculty of Agriculture, University of Khartoum, Sudan (latitude 15°14′N and longitude 32°32′E and elevation of 380 meters above mean sea level).

Materials

CR were collected from Gazira Scheme, Gazira State, Sudan. The residues were first chopped manually and then mechanically using a heavy truck until an optimum size (less than two-inch length) was obtained. Farmyard manure (F) was collected from cow farm located in the Faculty of Veterinary Medicine, University of Khartoum, Sudan. Cows were normally fed with concentrate plus Abu Sabin (*Sorghum bicolor*). While, earthworms (V) (*Eisenia foetida*) were collected from commercial farms in Jabal Awlia and Toti Island Khartoum State, Sudan.

Methods

Composting and vermicomposting experiment

The decompostid mixture consisted of a mixture of soil, farmyard manure (F) and CR at 1:1:5 ratios on dry weight basis. Other mixtures were prepared without addition of farmyard manure which mixed at the ratio 1:5 (soil:CR). Compost (without earthworm) was made in pits ($2 \times 1 \times 0.7$ m) and vermicompost was prepared in (2.4 m^3) plastic barrels. The rate of the inoculated earthworms was about 2 kg/m^2 including eggs, larvae and adults according to Dominguez and Edwards (1997). Earthworms were added one month after the initiation of the composting process to avoid exposure of earthworm to high temperature during the initial stages of composting. Water was sprinkled every two days using an iron sprayer to maintain the moisture level of 60-80 percent, barrels were kept under shade to avoid direct sunlight and high temperature that adversely affect earthworms. Measurement of temperature was taken every three days with digital thermometer. Composted and vermicomposted piles were turned every two weeks to get homogeneity. Samplings were taken monthly for chemical analysis till the end of the experiments that lasted for six months.

Samples analysis

Compost and vermicompost were analyzed at the Department of Soil and Environment Science, Faculty of Agriculture, University of Khartoum and Environmental and Natural Resources Research Institute (ENRRI), National Center for Research (NCR), Sudan.

The pH was measured in suspension of 1:5 (soil:$CaCl_2$) according to Hendersont *et al.* (2008) while the electrical conductivity $(EC)_{1:5}$ was determined in suspension (soil:water). Available phosphorus (P) was measured calorimetrically by the molybdenum blue method (Jackson, 1958). Nitrogen (N) was estimated by micro-Kjeldahl method (Association of Official Analytical Chemists, 1990) and OC was determined by Walkley and Black (1934) method. Dry ashing was conducted to prepare the samples for the determination of calcium (Ca^{2+}), magnesium (Mg^{2+}), sodium (Na^{+}) and potassium (K^{+}) according to Chapman and Pratt (1961). Sample extraction was performed following the procedure of Perkin (1994) for the determination of manganese (Mn), iron (Fe), copper (Cu) and zinc (Zn). Mineral nitrogen (NO_3^--N and NH_4^+-N) in compost and vermicompost were measured according to Bremner and Keeney (1965).

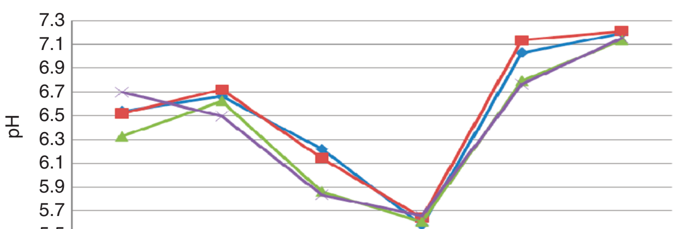
Statistical analyses

Analysis of variance was followed to test the significant differences among variables. Means were separated using Duncan's multiple range test. Unless otherwise stated, null hypothesis was rejected at $p > 0.05$. SAS software was used for all statistical analyses (SAS Institute, 2000).

Results and discussion

Effect of compost and vermin-compost on pH and EC

The pH of both treatments is depicted in Figure 1, the values increased at the beginning of the composting process to an alkaline neutral state. This increase was due



	W8	W12	W16	W200	W24	W26
CR+F	6.54	6.66	6.22	5.5775	7.03	7.1925
CR	6.52	6.7175	6.145	5.64	7.135	7.2125
CR+F+V	6.3275	6.625	5.8625	5.605	6.7925	7.1375
CR+F	6.6975	6.50	5.835	5.6575	6.765	7.155

Notes: CR, cotton residues; F, Farmyard manure; V, earthworms; W, Week

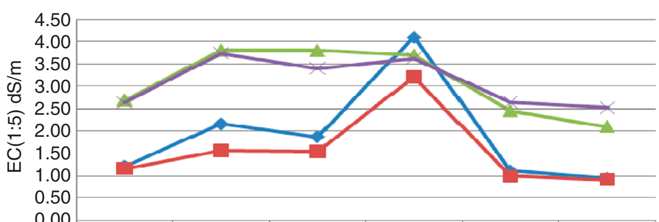
Figure 1.
Effect of treatments and time on pH during the periods of fermentation

to the high-microbial activity and fast decomposition (Sundberg and Jönsson, 2008). The finished products from all piles showed a similar pattern of change in pH that was within optimal range for plant growth (5 and 6.5) (Goh and Haynes, 1977).

Figure 2 shows the change in EC during the decomposition, Results indicated that there were slight initial increases in all piles with time. However, for piles without earthworms a sharp increase was observed after the 12th week. The differences in EC values resulted from the addition of earthworms were significantly higher ($p \leqslant 0.01$) over the whole period of decomposition. Atiyeh *et al.* (2000) reported that addition of earthworms could accelerate the decomposition and mineralization of organic matter. However, the EC value of both treatments was <4 dS/m, which is considered appropriate for plant growth (Abid and Sayadi, 2006).

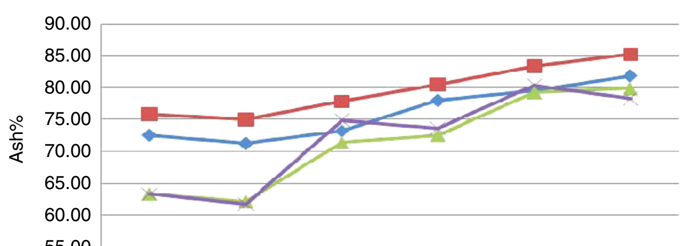
Effect of compost and vermicompost on ash content and C:N ratio

The ash content and C:N of both compost and vermicompost were shown in Figures 3 and 4, respectively. The results revealed that no significant difference (>0.05) in the ash content were observed between the two types of vermicompost (with and without farmyard manure). However, there was higher significant difference ($p \leqslant 0.01$) between compost and vermicompost. The highest values of ash content were those of the compost during the whole period of decomposition. This result could be attributed to the rapid breakdown of C components and mineralization by the



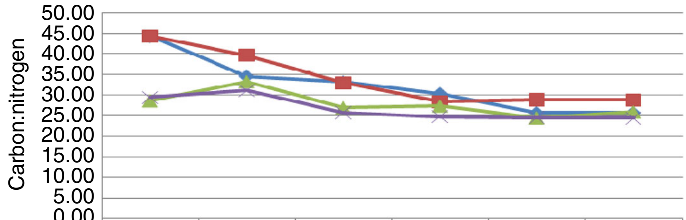
	W8	W12	W16	W20	W24	W26
CR+F	1.21	2.16	1.88	4.10	1.11	0.94
CR	1.16	1.56	1.55	3.20	1.00	0.92
CR+F+V	2.68	3.81	3.80	3.70	2.45	2.10
CR+V	2.63	3.74	3.40	3.63	2.64	2.52

Figure 2.
Effect of treatments and electrical conductivity during the period of fermentation



	W8	W12	W16	W20	W24	W26
CR+F	72.56	71.26	73.20	77.98	79.56	81.86
CR	75.81	75.01	77.82	80.45	83.30	85.19
CR+F+V	63.36	62.17	71.47	72.59	79.26	79.85
CR+V	63.34	61.76	74.91	73.63	80.39	78.25

Figure 3.
Effect of treatments on ash content during the period of fermentation

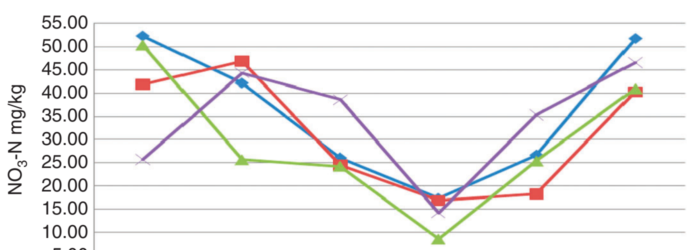


	W8	W12	W16	W20	W24	W26
CR+F	44.29	34.66	33.26	30.46	25.74	25.77
CR	44.30	39.68	33.00	28.40	28.89	28.81
CR+F+V	28.66	33.29	26.98	27.39	24.53	25.95
CR+V	29.45	31.14	25.72	24.79	24.62	24.41

Figure 4.
Effect of treatments and time on carbon:nitrogen during the period of fermentation

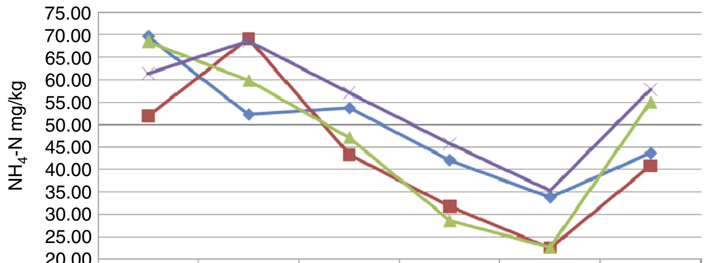
earthworms (Atiyeh *et al.*, 2000). The values of C:N of the four types of compost, were decreasing throughout the experiment period in four types of compost were decreasing throughout the experiment periods. The C:N ratios of vermicompost were lower over the whole period of decomposition. However, the final values of C:N ratio of all piles were between 24:1 and 29:1. On the other hand, it was observed that the C:N ratio in vermicompost initially increased, illustrating that much more rapid decomposition and rates of mineralization have been taken place. This result was in accordance with that reported by Vinceslas-Akpa and Loquet (1994). The gradual decrease in C:N ratio with time may be explained by the loss of OC as CO_2 (Gaur and Singh, 1995).

Effect of compost and vermicompost on nitrate-N (NO_3-N) and ammonium-N (NH_4-N)
The concentration of NO_3-N and NH_4-N of both compost and vermicompost were shown in Figures 5 and 6. The concentration of NO_3-N gradually decreased during the first 16 weeks of the decomposition and then increased to the higher values at the end of the decomposition period. The piles with CR plus farmyard manure (CR + F) showed the highest NO_3-N values while the piles without farmyard manure (CR) showed the lowest concentration. NH_4-N dropped from the initial values in the fourth week to lowest values in 24th week. The reduction was as follows: 69.67-43.62, 51.94-40.83, 68.54-55.02 and 61.45-57.85 mg/kg for CR + FYM, CR, CR + V and CR + FYM + V, respectively. The high concentration of the NH_4-N at the initial



	W8	W12	W16	W20	W24	W26
CR+F	52.26	42.11	26.13	17.42	26.73	51.72
CR	41.80	46.86	24.51	16.89	18.31	40.25
CR+F+V	50.36	25.69	24.28	8.57	25.39	40.90
CR+V	25.73	44.32	38.58	14.29	35.27	46.56

Figure 5.
Effect of treatments and time on the concentration of nitrate-nitrogen during the fermentation period



	W8	W12	W16	W20	W24	W26
CR+F	69.67	52.27	53.71	42.09	33.77	43.62
CR	51.94	69.17	43.27	31.74	22.53	40.83
CR+F+V	68.54	59.89	47.14	28.52	22.57	55.02
CR+V	61.45	68.63	57.16	45.72	35.26	57.85

Figure 6.
Effect of treatments and time on the concentration of ammonium-nitrogen during the fermentations period

stages of the decomposition might be due to the high temperature during thermophilic stage (from week four to week eight). Brady and Weil (2002), reported that when substrates temperatures during the decomposition exceeds 40°C, N generally volatilize as ammonia (NH_3^+). Low concentrations of NH_4-N at the end of the decomposition period may be due to leaching caused by the water added to the compost (Phillips, 1988).

Changes in total organic carbon (TOC), total N and P during composting and vermicomposting

Table I shows the evolution of the TOC, total N and total P content during composting and vermicomposting. The TOC content decreased significantly in most of the composted mixtures throughout composting and vermicomposting time particularly after 24 weeks. Such a decrease TOC during the composting process can be considered as a clear indicator of the mineralization of the labile fractions of organic matter by the microorganisms present, which utilize these compounds as a C and energy source to build their own structure (Garcia-pichel and Castenholz, 1993). After 24 weeks, differences in total TOC were observed between different piles. The reduction in both composted and vermicomposted mixtures with farmyard manure (55 and 56 percent) are greater than that of mixture of no farmyard manure (41 and 53 percent), which can be attributed to the higher proportion of labile organic matter present in the farmyard manure (Hernandez *et al.*, 2006).

Concerning the total N content, results indicated significant ($p \leqslant 0.01$) reduction of N in all mixtures. However, N in vermicompost was significantly ($p \leqslant 0.01$) higher than in compost. This reduction was probably due to NH_3 volatilization and leaching into bedding material. Chaudhuril *et al.* (2000) reported that the relatively high level of N during the period vermicomposting is probably contributed by earthworms through excretion of NH_4^+ and secretion of mucus. The final product had a lower concentration of N in all mixtures than the initial N. While the P had no significant differences ($p > 0.05$) among piles during the fourth and eighth week, but after the eighth week, the P increased significantly in all piles up to 16th week followed by slight drop through 20th and the 24th week. Similar results were obtained by Hamad (2009).

Changes in K^+ and trace elements during composting and vermicomposting

Tables II and III shows the concentration of K^+, Mg^{+2}, iron (Fe), Zn and Cu during the composting and vermicomposting. In all piles K^+ tends to increase gradually from

Table I. Changes in total organic carbon, total nitrogen and phosphorus during composting and vermicomposting

	TOC %						TN %						P (ppm)					
Time (weeks)	4	8	12	16	20	24	4	8	12	16	20	24	w4	w8	w12	w16	w20	w24
C	13.7^{l}	15.6^{kl}	15.6^{efg}	7.3^{k}	9.9^{jk}	8.1^{jk}	0.31^{fg}	0.4^{def}	0.5^{cd}	0.3 g	0.28^{g}	0.28^{g}	12.5^{l}	13.1^{kl}	37.9^{fg}	37.2^{fgh}	27.7^{J}	29.8^{ij}
C + F	18.2^{de}	16.9^{ef}	17.4^{de}	11.2^{hi}	11.1^{hi}	8.2^{jk}	0.41^{def}	0.5^{cd}	0.53^{c}	0.37^{efg}	0.39^{def}	0.32^{fg}	17.7^{kl}	19.7^{k}	40.1^{ef}	45.43^{de}	35.3^{fghi}	31.8^{ghij}
C + V	23.7^{c}	25.8^{ab}	18.3^{de}	10.7^{hij}	11.8^{hi}	11.0^{hi}	0.79^{ab}	0.84^{ab}	0.81^{ab}	0.46^{cde}	0.46^{cde}	0.42^{cdef}	30.4^{hij}	30.2^{ij}	57.5^{abc}	57.00^{abc}	61.7^{a}	54.2^{bc}
C + F + V	23.8^{bc}	27.4^{a}	20.1^{d}	12.9^{ghi}	11.4^{hi}	10.5^{i}	0.87^{a}	0.88^{a}	0.74^{b}	0.47^{b}	0.46^{cde}	0.42^{cdef}	40.0^{ef}	41.3^{ef}	62.2^{a}	60.44^{ab}	52.4^{cd}	53.9^{bc}

Notes: Means in the same column with different letter(s) are significantly different ($p \leqslant 0.05$) according to least significant test (LSD)

Table II.
Changes in potassium, magnesium and iron during composting and vermicomposting

	K^+ (ppm)						Mg (ppm)						Fe (ppm)					
Time (weeks)	4	8	12	16	20	24	4	8	12	16	20	24	w4	w8	w12	w16	w20	w24
C	1.3^{bc}	1.08^{e}	0.96^{bcde}	0.8^{f}	0.9^{f}	0.87^{f}	0.69^{abcd}	0.69^{abcd}	0.68^{abcd}	0.71^{abc}	0.67^{bcd}	0.68^{bcd}	42.2^{fg}	45.8^{fg}	44.9^{gh}	47.8^{de}	42.4^{hi}	36^{j}
C + F	1.07^{c}	1.27^{bc}	1.18^{bcd}	1.01^{e}	1.02^{ef}	1.00^{ef}	0.76^{ab}	0.75^{abc}	0.74^{abc}	0.73^{abc}	0.74^{abc}	0.72^{abc}	44.4^{gh}	45.8^{fg}	46.8^{ef}	48.7^{bcd}	39.0^{j}	38.7^{j}
C + V	2.27^{a}	2.00^{abc}	2.13^{ab}	2.00^{ab}	1.79^{abcd}	1.35^{bc}	0.68^{abcd}	0.66^{cd}	0.68^{abcd}	0.68^{abcd}	0.67^{cd}	0.66^{cd}	44.5^{g}	49.2^{bc}	48^{cd}	50^{b}	46.7^{fg}	46.45^{fg}
C + F + V	2.27^{a}	2.11^{ab}	2.11^{ab}	2.29^{a}	1.87^{abc}	1.45^{bc}	0.74^{abc}	0.74^{abc}	0.67^{bcd}	0.64^{d}	0.63^{de}	0.56^{e}	45.9^{fg}	49.7^{bc}	50.4^{b}	53.5^{a}	47.5^{def}	46.45^{fg}

Notes: Means in the same column with different letter(s) are significantly different ($p \leqslant 0.05$) according to least significant test (LSD)

Table III. Change in zinc and copper during the composting and vermicoposting

Time (weeks)	Zn (ppm) 4	8	12	16	20	24	Cu (ppm) 4	8	12	16	20	24
C	0.087^{ab}	0.087^{ab}	0.77^{abcd}	0.08^{abc}	0.08^{abc}	0.070^{cd}	0.059^{a}	0.055^{a}	0.041^{bc}	0.44^{b}	0.038^{bc}	0.036^{bc}
C + F	0.08^{abc}	0.09^{ab}	0.08^{abc}	0.08^{abc}	0.077^{abcd}	0.070^{d}	0.055^{a}	0.053^{a}	0.04^{bc}	0.042^{b}	0.038^{bc}	0.036^{bc}
C + V	0.08^{abc}	0.086^{ab}	0.071^{cd}	0.064^{d}	0.064^{d}	0.073^{cd}	0.041^{bc}	0.056^{a}	0.041^{bc}	0.035^{c}	0.043^{b}	0.041^{bc}
C + F + V	0.088^{ab}	0.086^{ab}	0.071^{cd}	0.076^{bcd}	0.076^{bcd}	0.073^{cd}	0.038^{bc}	0.038^{bc}	0.038^{bc}	0.40^{bc}	0.40^{bc}	0.40^{bc}

Notes: Means in the same column with different letter(s) are significantly different ($p \leqslant 0.05$) according to least significant test (LSD)

the fourth week up to the 12th week. The highest values were obtained in the vermicompost. On the other hand, a significant decrease was observed during the period of week eighth and week 16th in compost. However, until the 24th week no significant difference was observed among piles. Sharma (2003) reported that, in vermicomposting, the presence of microflora in the gut of earthworm might play an important role in K^{+} content.

The concentration of the trace elements, namely, Mn, Fe, Cu and Zn of the finished products, was reduced in all piles. However, the pattern of change in these elements throughout the decomposition was not consistent. These results partially agree with that of Gratelly *et al.* (1996) who reported a reduction in total Cu concentration, but increase in total K, Ca, Mg, Fe, Mn and Zn concentrations during vermicomposting of dairy sludge.

References

Abid, N. and Sayadi, S. (2006), "Detrimental effects of olive mill wastewater on the composting process of agricultural wastes", *Waste Management*, Vol. 26 No. 10, pp. 1099-107.

Association of Official Analytical Chemists (AOAC) (1990), *Official Methods*, ASSOC of chemists, Washington, DC.

Atiyeh, M.R., Jorge, D., Scott, S. and Clive, A.E. (2000), "Change in biochemical properties of cow manure during processing by earthworms (*Eisenia andrei, Bouche*) and the effects on seedling growth", *Bedo Biologia Journal*, Vol. 44 No. 6, pp. 709-24.

Brady, N.C. and Weil, R.R. (2002), *The Nature and Property of Soils*, 13th ed., Prentice Hall, Upper Saddle River, NJ, 960pp.

Bremner, J.M. and Keeney, D.R. (1965), "Steam distillation methods for determination of ammonium, nitrate, and nitrite", *Anal. Chem. Acta*, Vol. 32, pp. 485-95, available at: www.sas.com/

Chapman, H.D. and Pratt, P.F. (1961), *Methods of Analysis of Soils, Plants and Water*, University of California, Berkeley, CA.

Chaudhuril, P.S., Pal, T.K., Tacharjeei, G. and Dey, S.K. (2000), "Chemical changes during vermicomposting (*Perionyx excavatus*) of kitchen wastes. International Society for Tropical Ecology", *Tropical Ecology*, Vol. 41 No. 1, pp. 107-10.

Dominguez, J. and Edwards, C.A. (1997), "Effects of stocking rate and moisture content on the growth and maturation of *Eisenia andrei* (oligochaeta) in pig manure", *Soil Biology & Biochemistry*, Vol. 29 Nos 3/4, pp. 743-6.

FAO (1987), *Soil Management Compost Production and Use in Tropical and Subtropical Environments*, Food and Agriculture Organization of the United Nations, Rome.

Garcia-pichel, F. and Castenholz, R.W. (1993), "Occurrence of UV-absorbing mycosporine – like components among cyanobacterial isolates and an estimate of their screening capacity", *Applied Environment Microbiology*, Vol. 59 No. 1, pp. 163-9.

Gaur, A.C. and Singh, G. (1995), "Recycling of rural and urban wastes through conventional and vermicomposting", in Tandon, H.L.S. (Ed.), *Recycling of Crop, Animal, Human And Industrial Waste in Agriculture*, Fertilizer Development and Consultation Organisation, New Delhi, pp. 31-49.

Giusquiani, P.L., Pagliai, M.G., Businelli, G.D. and Benetti, A. (1995), "Urban waste compost: effects on physical, chemical, and biochemical soil properties", *Journal Environ. Qual*, Vol. 24 No. 47, pp. 175-82.

Goh, K.M. and Haynes, R.J. (1977), "Evaluation of potting media for commercial nursery production of container grown plants", *New Zealand Journal of Agricultural Research*, Vol. 20 No. 3, pp. 363-70.

Gratelly, P.E., Benitez, C., Elvira, A.P. and Nogales, R. (1996), "Stabilization of sludges from a dairy processing plant using vermicomposting", in Rodriguez-Barrueco, C. (Ed.), *Fertilizers and Environment*, Kluwer Academic Publishers, Amsterdam, pp. 323-6.

Hamad, E.N. (2009), "Evaluation of maturity and nutrient content of farmyard manure composted with chicken manure", M.Sc thesis, Faculty of Agriculture, University of Khartoum, Khartoum.

Hendersont, W.H., Lalande, H. and Duquette, M. (2008), "Soil reaction and exchange acidity", in Carter, M.R. (Ed.), *Soil Sampling and Methods of Analysis*, 2nd ed., CRC Press, Boca Raton, FL, pp. 173-8.

Hernandez, G., Hamdani, S., Rajabi, H., Conover, K., Stewart, J., Arvanitogiannis, A. and Shizgal, P. (2006), "Prolonged rewarding stimulation of the rat medial forebrain bundle: neurochemical and behavioral consequences", *Behavioral Neurosciences*, Vol. 120 No. 4, pp. 888-904.

Higher Council of Environment and Natural Resources (HCENR) (2003), *Sudan's First National Communications Under the United Nation framework. Convention and Climate*, Vol. 1, HCENR, Sudan.

Jackson, M.L. (1958), "Phosphorous determinations for soil", in Department of Soil Science, *Soil Chemical Analysis*, Prentice hall, Englewood cliffs, NJ, pp. 135-41.

Janzen, H.H. and Kucey, R.M.N. (1988), "C: N and sulfur mineralization of crop residues as influenced by crop species and nutrient regime", *Plant and Soil*, Vol. 106 No. 1, pp. 35-41.

Perkin, E.G. (1994), "Analytical methods for atomic absorption spectrometer", Manual part No. 03030152, Perkin Elmer Corporation, Norwoalk, CT.

Phillips, V.R. (1988), "Engineering problems in the breakdown of animal wastes by earthworms", in Edwards, C.A. and Neuhauser, E.F. (Eds), *Earthworms in Waste and Environmental Management*, SPB Academic Publishing, The Hague, pp. 111-18.

SAS Institute (2000), *The SAS System for Windows. Release 8.02*, SAS Institute, Cary, NC.

Sharma, K. (2003), "Municipal solid waste management through vermicomposting employing exotic and local species of earthworms", *Biores. Technol*, Vol. 90 No. 2, pp. 169-73.

Sundberg, C. and Jönsson, H. (2008), "Higher pH and faster decomposition in biowaste by increased aeration", *Waste Management*, Vol. 28 No. 3, pp. 518-26.

Viljoen, S.A., Reinecke, A.J. and Hartman, L. (1992), "The temperature requirements of the epigeic earthworm species *Dendrobaena ueneta*", *Soil Biology & Biochemistry*, Vol. 24 No. 12, pp. 1341-4.

Vinceslas-Akpa, M. and Loquet, M. (1994), "13C CPMAS NMR spectroscopy of organic matter transformation in ligno-cellulosic waste products composted and vermicomposted (*Eisenia fetida andrei*)", *European Journal of Soil Biology*, Vol. 30 No. 1, pp. 17-28.

Walkley, A. and Black, T.A. (1934), "A critical examination of a rapid method for determining organic carbon in soils – effect of variations in digestion conditions and of organic soil constituents", *Soil Sci*, Vol. 63, pp. 251-63.

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