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Effect of incorporation of some wastes on a wheat-guar rotation system on soil physical and chemical properties

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Abstract

Background: Improving levels of organic matter in desert soils is necessary for their cultivation. A two-year study (2008 to 2010) was conducted on a sandy clay loam soil at the experimental research farm of the Omdurman Islamic University, Sudan to determine the effect of application of crop residue, sewage sludge, and humentos on selected soil properties in wheat-guar crop rotation system. Treatments were recommended inorganic fertilizer (125 kg N ha^{-1} and 92 kg P ha^{-1}), recommended inorganic fertilizer with crop residues, crop residue, sewage sludge (10 t ha^{-1}), humentos soil conditioner (200 L ha^{-1}), and control.

Results: Results showed that soil physical properties were not significantly changed except soil water holding capacity. Application of crop residues with recommended fertilizer and sewage sludge for three seasons significantly increased cation exchange capacity and organic carbon by 57.15 % to 60.95 % and 61.0 % to 65.2 %, respectively. Moreover, combined application of crop residues with recommended inorganic fertilizer and sewage sludge had significantly decreased topsoil pH.

Conclusions: The results showed that judicious combined application of organic wastes with inorganic fertilizers could be a useful practice in sustaining fertility of poor sandy soils.

Keywords: Crop residues, Sewage sludge, Wheat, Guar, Soil properties

Background

Soil fertility decline is occurring over large parts of the world, particularly the developing countries. It occurs mainly through intensive and continuous cropping without replenishing the nutrient component of soils and through deforestation and clearance of vegetation on sandy soils (Ayoub 1999). Most of the soils in the arid zone (e.g., Sudan) are characterized by low organic matter, low N content, and slow accumulation of organic matter (Ali and Adam 2003). FAO (FAO 1990) data show that chemical fertilizers use have steadily increased over the last decades, and this trend is likely to continue in the coming years. It is estimated that, by the year 2020, at a global level, 70 % of plant nutrients will have to come from fertilizers (Ayoub 1999). For example, the annual global use of fertilizers has increased from about 46 million tons in the 1960s to about 130 million tons in the 1990s (Brown et al. 1997) and will need to double by the year 2030 if the current per capita cereal production of 300 kg year^{-1} (Brown 1996) is to be maintained (Gilland 1993). Fertilizer consumption increased from 14 % (in 1965 to 1966) to 53 % (in 1966), and to sustain food security, in Sub-Saharan Africa, mean fertilizer consumption was roughly 16 % higher in the 1996 to 2000 period than during the 1980 to 1989 period (Crawford et al. 2003).

Considerable efforts have been made to estimate the contribution of N from crop residue decomposition to the subsequent crops. The direct effect of N from organic residue on the cropping system varies from yield decrease due to immobilization of N during decomposition (Hubbard and Jordan 1996) or no effect due to insufficient quantities of crop residues (Kouyate et al. 2000) to an increase in yield due to rapid release of N (Konboon et al. 2000). Application of crop residues can substantially reduce the amount of inorganic fertilizers used as such is a valuable management practice in both environmental and economic terms.

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The use of organic inputs such as crop residues and manures has great potential for improving soil productivity and crop yield through improvement of the soil physical, chemical, microbiological properties and nutrient supply (Abbasi et al. 2009).

Inputs from organic sources (e.g., compost and sewage sludge) play a central role in the productivity of many tropical farming systems by providing nutrients through decomposition and substrate for the synthesis of soil organic matter. The benefits from the application of organic materials to the soil surface or incorporation in the topsoil have widely been appreciated in tropical agriculture and agroforestry (Ogunwole et al. 2010; Abbasi et al. 2009; Ogbodo 2009; Sarwar et al. 2008; Nunes et al. 2008; Moyin-Jesu 2007; Ferreras et al. 2006; Mubarak et al. 1999, 2001a, 2001b, 2003a, 2003b). However, its efficiency varies with the sources of these organic materials. Environmental problems associated with application of raw organic manures might be mitigated by chemical or biological immobilization during composting (Cooperband et al. 2002). Humentos is a liquid soil nutrient that is based on brown coal (lignite). It has a capacity to encourage the formation of clay-humus complexes. We hypothesized that humentos will be effective in improving the water retention capacity and nutrient status of light sandy soils. Thus, it provides better opportunities for cultivation of fragile soils prone to wind erosion. In Sudan, loss of soil fertility and rainfall variability are among the factors that contributed to low yields. Studies on the predominantly sandy soils have shown the complexity of soil fertility problems (Giller 2001). There are slim chances of building soil organic matter in the dry tropics and, hence, nutrient stocks (Giller et al. 1997), rendering farmers to rely heavily on external nutrient inputs on a seasonal basis. However, most of the smallholder farmers use sub-optimal amounts of fertilizers due to cash limitations and poor access to fertilizer markets. Therefore, it is important to recycle both endogenous and exogenous nutrient pools. Moreover, continuous use of fertilizer alone cannot sustain crop yield and maintain soil fertility in the long term (Shoko et al. 2007; Tisdale et al. 1999).

In the tropics, there is an increasing interest in using crop residues for improving soil productivity that can reduce the use of inorganic fertilizer (Fening et al. 2005; Tetteh 2004). The residues left in the field represent a significant resource in terms of organic matter and plant nutrients. The use of crop residues as a soil fertility amendment will enhance the farmers' crop yields and reduce the need for large imports of mineral fertilizers. This, implicitly, will contribute to the savings in Sudan's scarce financial resources that can be directed to other developmental programmers. These crop residues are in sufficient abundance in the farmers' fields at the end of a growing season and play an important role in soil fertility management through their short-term effects on nutrient supply and longer-term contribution to soil organic matter (Karanja et al. 2006). However, they are often disposed by removal (baling) or burning which is often criticized for accelerating losses of soil organic matter and nutrients, increasing carbon emissions, and reducing soil microbial activity (Kumar and Goh 2000). Soil nutrient availability has been suggested as one of the controlling factors affecting the rate of litter decomposition (Swift et al. 1979). The results of the studies on the effects of nitrogen (N) and phosphorus (P) additions on crop residue decomposition are controversial (Liu et al. 2006). In some studies (e.g., Hobbie 2005; Carreiro et al. 2000), N fertilization enhances litter decomposition, while other studies (e.g., Hobbie 2008; Knorr et al. 2005) have shown either a neutral or negative effect on litter decomposition.

Removal of crop residue from the field must be balanced against influencing the environment (soil erosion), maintaining soil organic matter levels, and preserving or enhancing productivity (Wilhelm et al. 2004). Farmers in Sudan have not adopted the incorporation of crop residues partly because they have no adequate information about the nutrient values of these residues or crop residues are used by animals. Understanding the contribution of recycling of crop residues and other organic materials on soil quality is important.

The main aim of this study was to examine the effects of the application of organic residues (crop residues, sewage sludge, and humentos) on some soil chemical and physical properties. Specific objectives include determination of changes in pH, TN, OC, TP, soluble cations (K, Ca, and Mg), bulk density, water retention capacity, aggregate stability, soil resistance, and soil organic matter fractions.

Methods

Site, soil, and climate

This research was part of a four-year project studying the role of recycling of organic residues on crop-soil system belonging to the semiarid tropics of Sudan. In this study, three seasons rotation (wheat-guar-wheat) experiment was conducted from 2008 to 2010 on a sandy clay loam, hyperthermic, mixed, gypsic cambiorthid, nonsaline, with organic matter of less than 1 % (Table 1). The experiment was located in the experimental farm of Omdurman Islamic University, Sudan (15°19.9 N, 32°39′E, 381 m above mean sea level). The area is characterized by low relative humidity; temperature ranges between 40°C (maximum) in summer and 21°C (minimum) in winter (Oliver 1965).

Table 1 Some chemical physical and properties of the experimental site

Variable	Soil depth (cm)	
	0 to 20	**20 to 40**
pH_{paste}	8.1	7.8
ECe (dS m^{-1})	1.05	1.0
OC (%)	0.49	0.47
TN (g kg^{-1})	0.28	0.18
Available P (mg kg^{-1})	8.7	8.5
Soluble Ca (meq L^{-1})	4.6	4.0
Soluble Mg (meq L^{-1})	3.8	3.0
Soluble Na (meq L^{-1})	9.8	9.3
Soluble K (meq L^{-1})	6.2	5.7
Soluble HCO_3^- (meq L^{-1})	3.6	3.3
CEC ($cmol_c$ kg^{-1})	20.8	19.2
Bulk density (g cm^{-3})	1.44	nd
Water-holding capacity (%)	21.92	nd
Sand (%)	52.5	nd
Silt (%)	32.5	nd
Clay (%)	15	nd
Texture	SCL	nd
NH_4 (mg kg^{-1})	67.4	nd
NO_3 (mg kg^{-1})	36.8	nd

CEC, cation exchange; nd, not determined; OC, organic carbon; SCL, sandy clay loam; TN, total nitrogen.

Annual rainfall was 67.5 mm, which varies in intensity and distribution with its peak in August.

Treatments and design

A randomized complete block design with four replications (24 plots of 4.0 m × 4.0 m dimensions) was used to test the following treatments:

1. Control (no crop residues; no fertilizer) (C)
2. Recommended inorganic fertilizer without crop residues (RF + CR)
3. Recommended inorganic fertilizer with crop residues (RF)
4. Crop residues (CR)
5. Sewage sludge (10 t ha^{-1}) (SS)
6. Humentos (soil conditioner) applied at a rate of 200 kg ha^{-1} (H)

For wheat, recommended inorganic N (in the form of urea) and P (in the form of triple super phosphate) were applied at rates of 125 kg N ha^{-1} (two equal doses at sowing and tillering) and 92 kg P_2O_5 ha^{-1} (at sowing), respectively. For guar, a starter dose of N and P was applied (at sowing) at rates of 40 kg N ha^{-1} and 100 kg P_2O_5 ha^{-1}, respectively.

Establishment of wheat-guar rotation and application of organic residues

The site of the experiment was prepared by disk plowing, disk harrowing, and leveling, then after plots, irrigation canals were constructed. Seven days before sowing of the first crop (wheat var condor), sewage sludge and humentos were manually incorporated (1 week before each crop in the rotation) in the top 30-cm soil depth. Wheat seeds were broadcasted (143 kg ha^{-1}) on flat plots, whereas guar (genotype HFG 75) seeds were treated with inoculant (ENRI 16) and sown (3 kg ha^{-1}, 4 to 5 seeds per hole) at a spacing of 0.3 m between holes × 0.75 m between rows, thinned to two stands 3 weeks later. All crops were regularly irrigated every week with the amount of water that was equivalent to the national recommendation (420 m^3 $feddan^{-1}$, i.e., 10-cm head). Experimental plots were kept free from weeds by hand hoeing whenever necessary. Dates of sowing and harvesting of each crop in the rotation and nutrients (N, P, K, Ca, and Mg) content in organic wastes returned before sowing which are presented in Tables 2 and 3, respectively. The concentration of some heavy metals in sewage sludge (Table 4) was determined by dry ashing (Issac and Kerber, 1971).

Harvest and crop residue application

Grains of the first crop were completely lost due to heavy infestation with local birds. About eight plants from each plot were randomly selected from the inner 2 m × 2 m, placed in a labeled envelope, freshly weighed, weighed after oven drying (70°C to 75°C), crushed (0.5 mm), and kept for analysis. Then, straw from the whole plot was harvested, weighed in the field, and either manually incorporated (into the topsoil) or removed according to treatments. Subsequent wheat crop was similarly sampled and harvested (divided into straw and grains). Guar was completely harvested after 3 months and used as green manure. Similarly, crop residue from guar was also either removed or incorporated according to treatments.

Soil sampling and analysis

After the harvest of each crop, soil samples (0 to 20 cm and 20 to 40 cm) were collected from the inner 4 m^2 of the experimental plot using 5-cm Ø auger. Samples were

Table 2 Date of sowing and harvesting of wheat and guar in the rotation

Crop	Sowing	Harvesting
Wheat	18/11/2008	18/2/2009
Guar	9/7/2009	30/9/2009
Wheat	13/11/2009	10/2/2010

Fallow period range between 3 and 5 months.

Table 3 Nutrient content of organic wastes incorporated into the soil kg ha^{-1}

		N	P	K	Ca	Mg	OC	C/N
Acronym	**Description**	**kg ha^{-1}**					**%**	
WR	Wheat residue	4.62	0.65	6.47	2.24	0.66	41.3	59.0
RF + WR	Fertilizer with wheat residue	11.82	1.81	14.45	4.51	1.39	41.3	52.08
GR	Guar residue	83.22	31.45	111.69	62.19	48.62	29.7	15.63
RF + CR	Fertilizer with guar residue	109.64	51.29	135.24	71.24	56.89	29.8	12.96
SS	Sewage sludge applied throughout the experiment	280.0	28.0	340.0	0.96	0.78	24.0	8.57
H	Humentos applied throughout the experiment	300.0	0.35	5.50	0.70	0.7	-	-

air dried, crushed, sieved (2 mm), and kept for chemical (pH_{paste} (Mclean 1982), TN (Bremner and Mulvaney 1982), OC, available P, CEC (Thomas 1982), soluble K, Ca, and Mg (Chapman and Pratt 1961)) and physical (water-holding capacity (Klue 1986), bulk density (Blake and Hartge 1986), and penetration resistance (Davidson 1965)) analysis. Also, about 50 g of fresh soil were taken for each plot and kept in the freezer (−4°C) for the determination of mineral N (NH_4^+-N + NO_3^--N (Bremner 1965)).

Statistical analysis

Statistical analysis software (SAS 1985) was used to test variations between treatments, and the least significant difference (LSD) was used to determine differences between treatment means.

Results and discussion

Soil chemical properties

Soil pH

Initial soil pH was 8.1 and 7.8 in the 0- to 20-cm and 20- to 40-cm depths, respectively (Table 1). Generally, in the 0- to 20-cm depth, application of humentos, sewage sludge, and crop residues with or without inorganic fertilizer resulted in a decrease in soil pH (Table 5). After the harvest of the first crop, SS had significantly ($P \leq 0.0001$) decreased soil pH in the 0- to 20-cm depth by 1.12 to 1.17 units and from 1.05 to 1.22 units in the 20- to 40-cm depth relative to all treatments. After the harvest of the second crop, application of SS had resulted in significantly the lowest (7.3 in the 0- to 20-cm and 7.1 in the 20- to 40-cm depths) pH values, whereas incorporation of wheat residues (with inorganic fertilizer) had significantly decreased the pH, in the 0- to 20-cm depth, by 0.75 units and by 0.55 units (in the 20- to 40-cm depth) as compared to the control. After the harvest of the third crop, plots treated with sewage sludge had consistently maintained the significantly lowest topsoil (0- to 20-cm depth) pH values as compared to other treatments. The reduction in pH due to application of sewage, relevant to all treatments, ranged from 2.63 % to 12.43 % after the third crop. Also, continuous incorporation of crop residues has significantly decreased the topsoil pH as compared to the control treatment. Maximum reduction in pH values after the third crop was 7.14 %. Moreover, in the lower soil depth (20 to 40 cm), reduction in pH due to application of sewage sludge had been significantly observed after the three crops in the cycle. This reduction compared to the control treatment was 10.00 % after the third crop. In this depth, incorporation of crop residues had also resulted in significant reductions in pH but less reduction than the top soil (4.13 % after the third crop). Soil pH directly affects the growth and life of plants because of its effects on nutrient availability.

Table 4 Concentration of heavy metal in sewage sludge and acceptable limit mg kg^{-1}

	Ni	Pb	Zn	Cr	Cu	Cd
Sewage sludge used	18.6	81.4	355.8	2,404.6	48.4	0.7
Acceptable limit[a]	100	500	2500	500	800	10

[a]Sources (Moreno et al. 1999; Chefetz et al. 1996).

The results of this study had clearly showed that the application of organic wastes have an acidifying effect on the top and lower soil depths of the study site. The decrease in soil pH after application of sewage sludge is in agreement with the results reported by Speir et al. (2003) and Usman et al. (2004). The decrease in pH after cumulative sludge may probably be attributed to nitrification of N-NH_4^+ or release of H^+ ions during mineralization from the sludge (Stamatiadis et al. 1999; Antolin et al. 2005). Bulluck et al. (2002) reported a decrease in soil pH following the addition of organic amendments, whereas Melero et al. (2007) reported that organic amendments have only a little effect on soil pH values which reflects the importance of the variations in quality or initial chemical composition of the decomposing material. Paul et al. (2001) conducted a laboratory experiment to study the effects of plant residues of wheat and subterranean clover return on soil pH gradient and reported that the addition of plant

Table 5 Soil pH as influenced by organic waste application (average ± standard deviation)

Treatments	First crop (wheat)	Second crop (guar)	Third crop (wheat)
		0 to 20 cm	
C	8.17a ± 0.15	8.20ab ± 0.08	8.37a ± 0.05
CR	8.17a ± 0.13	7.90c ± 0.08	7.80b ± 0.08
H	8.17a ± 0.10	8.25a ± 0.06	8.45a ± 0.06
SS	7.05b ± 0.06	7.30e ± 0.08	7.40d ± 0.08
RF	8.17a ± 0.10	8.10b ± 0.08	8.40a ± 0.08
RF + CR	8.22a ± 0.05	7.45d ± 0.06	7.60c ± 0.08
LSD	0.1522	0.1167	0.1121
$P\leq$	0.0001	0.0001	0.0001
Treatments	**First crop (wheat)**	**Second crop (guar)**	**Third crop (wheat)**
		20 to 40 cm	
C	8.27a ± 0.17	7.95a ± 0.13	8.00a ± 0.08
CR	8.22a ± 0.17	7.87a ± 0.10	7.67b ± 0.10
H	8.22a ± 0.15	8.00a ± 0.08	8.05a ± 0.06
SS	7.17b ± 0.10	7.10c ± 0.08	7.20d ± 0.08
RF	8.20a ± 0.24	7.97a ± 0.10	8.07a ± 0.13
RF + CR	8.10a ± 0.14	7.40b ± 0.08	7.47c ± 0.10
LSD	0.229	0.138	0.128
$P\leq$	0.0001	0.0001	0.0001

Means in columns, within each depth, followed by different letters are significantly different at $P \leq 0.05$ using LSD.

residue resulted in a rapid (0 to 7 days) increase of soil pH due to the association, and particularly oxidation, of added organic anions. This was followed by a gradual (7 to 119 days) pH decline attributed to the mineralization and subsequent nitrification of added organic N. Organic wastes can influence soil pH through accumulation of CO_2 and organic acid during their decomposition in the soils (Huang et al. 2004; Millar and Baggs 2004; Yunsheng et al. 2007). Gangaiah et al. (1999) and Kushwaha et al. (2000) also reported a decrease in soil pH with application of wheat or rice straw.

Organic carbon

Initial soil organic carbon was 0.49 % and 0.47 % in the 0- to 20-cm and 20- to 40-cm depths, respectively (Table 1). Generally, in the two soil depths (0 to 20 cm and 20 to 40 cm), application of humentos, sewage sludge, and crop residues with or without inorganic fertilizer resulted in an increased in soil OC (Table 6). After the harvest of the first crop, SS compared to all treatments had significantly ($P \leq 0.0001$) increased soil OC in the 0- to 20-cm depth by 0.69 % to 1.43 % and 0.25 % to 0.42 % in the 20- to 40-cm depth. After the harvest of the second crop, application of SS had resulted in significantly highest (1.92 %) OC value in the top soil depth (0 to 20 cm) as relative to all treatments, whereas in the lower soil depth (20 to 40 cm), incorporation of wheat residues (with inorganic fertilizer) had significantly highest (1.04 %) OC value. After the harvest of the third crop, plots with sewage sludge had consistently maintained the significantly highest topsoil OC values as compared to other treatments. The increased in OC due to application of sewage, relevant to all treatments, ranged from 7.56 % to 704.35 % after the third crop. Also, continuous incorporation of crop residues alone (CR) or with inorganic fertilizer (RF + CR) had significantly increased topsoil (0- to 20-cm depth) OC as compared to the control treatments. Maximum increased values were 443.49 % and 647.83 % after the third crop. Similarly, in the lower soil depth, significant increase in OC after incorporation of crop residue with inorganic fertilizer had been observed after all crops in the cycle. The percentage increment in comparison with the control treatment was 610.53 % after the third crop. In this depth, application of sewage sludge had also resulted in significant increase in OC (647.37 % for the third crops).

Decreased in soil OC in the control treatment may be due to continuous cultivation without recycling of crop residue (FAO 1990; Kushwaha et al. 2000; Andrews 2006; Ogbodo 2009). Removal of crop residue from the fields is known to hasten soil organic carbon (SOC) decline especially when coupled with conventional tillage (Yang and Wander 1999; Mann et al. 2002). Increase in soil OC was principally due to the continuous addition of C through the roots and crop residues (Blanco-Canqui and Lal 2007; Bhattacharyya et al. 2008). Increase in soil OC with application of crop residue was reported by

Table 6 Soil organic carbon (%) as influenced by organic waste application (average ± standard deviation)

Treatments	First crop (wheat)	Second crop (guar)	Third crop (wheat)
		0 to 20 cm	
C	0.45e ± 0.01	0.43e ± 0.01	0.23f ± 0.01
CR	0.45e ± 0. 01	0.79d ± 0.01	1.25c ± 0.06
H	1.19b ± 0.01	1.24b ± 0.01	0.92d ± 0.10
SS	1.88a ± 0.01	1.92a ± 0.01	1.85a ± 0.06
RF	0.50c ± 0.02	0.41f ± 0.01	0.39e ± 0.01
RF + CR	0.50c ± 0.01	1.23c ± 0.01	1.72b ± 0.10
LSD	0.017	0.015	0.093
$P\leq$	0.0001	0.0001	0.0001
Treatments	**First crop (wheat)**	**Second crop (guar)**	**Third crop (wheat)**
		20 to 40 cm	
C	0.46c ± 0.01	0.36e ± 0.01	0.19e ± 0.01
CR	0.46c ± 0.01	0.62d ± 0.01	1.10b ± 0.08
H	0.63b ± 0.01	0.80c ± 0.01	0.65c ± 0.06
SS	0.88a ± 0.01	0.98b ± 0.01	1.42a ± 0.10
RF	0.47c ± 0.01	0.39e ± 0.01	0.30d ± 0.01
RF + CR	0.47c ± 0.01	1.04a ± 0.05	1.35a ± 0.06
LSD	0.012	0.042	0.093
$P\leq$	0.0001	0.0001	0.0001

Means in columns, within each depth, followed by different letters are significantly different at $P \leq 0.05$ using LSD.

Dhiman et al. (2000) and Karanja et al. (2006). Ogbodo (2009) found that soil organic matter was significantly higher on the soils treated with rice straw and legume residue than untreated soils. Yadvinder-Singh et al. (2004) found that incorporation of rice residue for 7 years increased soil organic carbon content of the sandy loam soil significantly in comparison with straw burning or removal. In another long-term study, Yadvinder-Singh et al. (2004) reported that wheat straw incorporation increased organic C content from 0.40 % in the control treatment to 0.53 % in the straw incorporation treatment. On the contrary, Naklang et al. (1999) reported no significant effect of rice straw incorporation for 3 years on total and labile C content of a sandy soil. In a rice-barley rotation under dry land conditions in northern India, Kushwaha et al. (2000) reported that incorporation of crop residues increased soil organic carbon significantly by 28 % in comparison with crop residue removal after one annual cycle.

Available P

The effect of application of organic wastes on soil available P was shown in Table 7. After the harvest of the first crop, RF compared to all treatments had significantly ($P \leq 0.0001$) increased soil P in the 0- to 20-cm depth by 0.28 to 0.65 mg kg^{-1} and 0.08 to 0.78 mg kg^{-1} in the 20- to 40-cm depth. After the harvest of the second crop, incorporation of wheat residues (with inorganic fertilizer) had resulted in significantly highest (11.32 mg kg^{-1} in the 0 to 20 cm and 10.72 mg kg^{-1} in the 20- to 40-cm depth) P values, whereas applications of inorganic fertilizer alone had significantly increased P by 0.73 mg kg^{-1} (in the top 0- to 20-cm depth) and by 0.02 mg kg^{-1} (in the 20- to 40-cm depth) as compared to the SS treatment. After the harvest of the third crops, plots with RF + CR had consistently maintained the significantly highest topsoil P values as compared to the other treatments. The increased in P due to incorporations of RF + CR, relevant to all treatments, ranged from 21.99 % to 72.29 % after the third crop. In the lower soil depth (20 to 40 cm), incorporation of crop residue with inorganic fertilizer had significantly increased available P after all crops in the cycle. The percentage increase compared to the control treatment was 59.86 % after the third crops. Similarly, application of inorganic fertilizer alone (RF) had also resulted in significant increase (41.83 % for the third crops in available P. Also, continuous application of inorganic fertilizer alone (RF) had significantly increased topsoil (0- to 20-cm depth) P as compared to the SS treatments; the percentage increase was 8.76 % after the third crops.

The incorporation of crop residues may increase crop-available P either directly by the process of decomposition and release of P from the biomass or indirectly by increase in the amount of soluble organic matter which are mainly organic acids that increase the rate of desorption of phosphate and, thus, improve the available P content in the soil (Nziguheba et al. 1998). Sharma et al. (2001) and Singh and Sharma (2000) found slight or no increase in available

Table 7 Soil available phosphorus (mg kg^{-1}) as influenced by organic waste application (average ± standard deviation)

Treatments	First crop (wheat)	Second crop (guar)	Third crop (wheat)
		0 to 20 cm	
C	8.50c ± 0.11	8.47e ± 0.13	7.47f ± 0.11
CR	8.52c ± 0. 13	8.67d ± 0.13	8.87d ± 0. 07
H	8.40c ± 0.13	8.50de ± 0.11	8.67e ± 0.13
SS	8.77b ± 0.11	9.17c ± 0.11	9.70c ± 0.11
RF	9.02a ± 0.11	9.90b ± 0.13	10.55b ± 0.20
RF + CR	9.02a ± 0.11	11.32a ± 0.13	12.87a ± 0.07
LSD	0.187	0.176	0.186
P≤	0.0001	0.0001	0.0001
Treatments	**First crop (wheat)**	**Second crop (guar)**	**Third crop (wheat)**
		20 to 40 cm	
C	8.07c ± 0.07	8.22 cd ± 0.11	7.10f ± 0.13
CR	8.15c ± 0. 08	8.15d ± 0. 23	8.37d ± 0. 11
H	8.20c ± 0.13	8.37c ± 0.11	8.02e ± 0.13
SS	8.55b ± 0.08	8.80b ± 0.13	9.37c ± 0.17
RF	8.85a ± 0.08	8.82b ± 0.17	10.07b ± 0.11
RF + CR	8.77a ± 0.11	10.72a ± 0.13	11.35a ± 0.16
LSD	0.136	0.214	0.220
P≤	0.0001	0.0001	0.0001

Means in columns, within each depth, followed by different letters are significantly different at $P \leq 0.05$ using LSD.

P in the soils treated with rice or wheat straw. The long-term application of corn residues may increase the levels of P and K in the soil (Dam et al. 2005). On decomposition study, organic P in crop residues could provide a relatively labile form of P to succeeding crops, thus, providing a larger pool of mineralizable soil organic P to supplement soluble inorganic P pools (Cavigelli and Thien 2003; Fuentes et al. 2006). The increase in available P concentration in organic waste treatments with recommended fertilizer could be due to high microbial activity induced by the addition of organic residues, and soluble inorganic P, which speed up P cycling (Melero et al. 2007). Another study by Abbasi et al. (2008) showed that white clover residues tested for chemical composition showed 2.9 to 4.4 g kg^{-1} P as compared to 1.8 g kg^{-1} P in the grass samples. Therefore, increase in soil P might be due to the high concentration of P in guar residues, its mineralization and accumulation in soil, or possibly by increasing the retention of P in soil.

Water-soluble K

Generally, water-soluble K decreased in all treatments with repeated cultivation in comparison with the data from the first crop (Table 8). Continuous cultivation for three seasons without fertilization decreased water-soluble K in the 0- to 20-cm soil depth from 5.07 in the first season to 2.60 meq l^{-1} (95 % reduction) in the third season. Similar trend was observed in the lower depth. Application of SS had significantly ($P \leq 0.0001$) resulted higher K values in the two soil depths in all seasons. The increase in water-soluble K due to continuous sewage sludge application relative to the control was 2.35, 1.18, and 1.35 units after the first, second, and third crops, respectively, in the top soil depth. Similar trend was observed in the lower depth. Continuous incorporation of crop residues with inorganic fertilizer (RF + CR) had significantly increased topsoil K as compared to the control treatment. The highest increased value was 40.38 % after the harvest of the third crop. However, in the lower soil depth, increased in soil K (43.48 %) due to incorporation of crop residues with inorganic fertilizer had been significantly observed after the third crop in the cycle.

The decreased in water-soluble K in the control treatment may be attributed to higher removals in harvested crops. Bijay-Singh et al. (2003) have reported the role of crop residue in soil K in wheat-rice cropping system. Yadvinder-Singh et al. (2004) reported that the release of K from rice straw occurred at a fast rate, and within 10 days after incorporation, available soil K contents increased from 50 mg K kg^{-1} in the untreated control to 66 mg K kg^{-1} in the straw-amended treatment. Potassium was not bound in any organic compound in the plant material, and thus, its release does not involve microorganisms. Mishra et al. (2001) reported that during the decomposition of rice straw, K contents decreased from 1.30 to 0.28, and about

Table 8 Soil water-soluble K (meq L^{-1}) as influenced by organic waste application (average ± standard deviation)

Treatments	First crop (wheat)	Second crop (guar)	Third crop (wheat)
	0 to 20 cm		
C	5.07e ± 0.10	2.42 d ± 0.12	2.60e ± 0.08
CR	5.20d ± 0.08	2.70c ± 0.08	3.00d ± 0.08
H	6.32b ± 0.08	2.92b ± 0.10	3.45c ± 0.06
SS	7.42a ± 0.13	3.60a ± 0.08	3.90a ± 0.08
RF	5.85c ± 0.06	2.45d ± 0.13	2.55e ± 0.06
RF + CR	5.92c ± 0.10	3.07b ± 0.13	3.65b ± 0.06
LSD	0.0979	0.1513	0.1112
P≤	0.0001	0.0001	0.0001
Treatments	**First crop (wheat)**	**Second crop (guar)**	**Third crop (wheat)**
	20 to 40 cm		
C	5.32e ± 0.05	2.18f ± 0.10	2.30e ± 0.08
CR	5.42de ± 0.05	2.57d ± 0.10	2.72d ± 0.10
H	6.20b ± 0.08	2.80c ± 0.08	2.97c ± 0.10
SS	7.02a ± 0.10	3.45a ± 0.06	3.50a ± 0.08
RF	5.57c ± 0.10	2.35e ± 0.06	2.17e ± 0.10
RF + CR	5.47 cd ± 0.15	3.00b ± 0.08	3.30b ± 0.08
LSD	0.1248	0.121	0.1392
P≤	0.0001	0.0001	0.0001

Means in columns, within each depth, followed by different letters are significantly different at $P \leq 0.05$ using LSD.

79 % of the total K present in rice straw was released within 5 weeks after its incorporation into the soil; 95.3 % of K from straw was mineralized by the end of 23 weeks. On incubation study, Kaur and Benipal (2006) found that incorporation of rice residue and farmyard manure increased available K status and water-soluble and fixed K.

Soil mineral nitrogen

Generally, soil mineral nitrogen in the control treatment decreased significantly after all crops in the cycle in comparison with the data after harvest of the first crop (Table 9). Application of sewage sludge, inorganic fertilizer with or without crop residues, and humentos resulted in significant ($P \leq 0.0001$) increase in soil mineral nitrogen (NH_4^+ and NO_3^-). After the harvest of the first crop, RF + CR had significantly ($P \leq 0.0001$) increased soil mineral nitrogen in comparison to all treatments by 0.33 % to 30.82 % and 0.24 % to 51.63 % for NH_4^+ and NO_3^-, respectively. After the harvest of the second crop, incorporation of wheat residues with inorganic fertilizer had resulted in significantly highest soil mineral N (60.15 NH_4^+ and 24.27 NO_3^-) values, whereas applications of SS had significantly increased SMN by 8.65 and 4.8 units for NH_4^+ and NO_3^-, respectively, as compared to the control. However, incorporation of wheat residue for the first time in the rotation decreased soil mineral nitrogen by 11.6 and 13.2 for NH_4^+ and NO_3^-, respectively, in comparison with the previous season (first season). After the harvest of the third crop, plots with RF + CR had consistently maintained the significantly highest SMN values as compared to other treatments. The maximum increased in SMN due to the application of RF + CR, relevant to all treatments, was 105.73 % and 207.88 % (after the third crop) for NH_4^+ and NO_3^-, respectively. Also, continuous incorporation of crop residues has significantly increased SMN as compared to the control treatments. Maximum increased values after the third crop were 56.65 % and 87.27 % NH_4^+ and NO_3^-, respectively. The decreased in mineral nitrogen after wheat residue incorporation (second crop) can be explained by N immobilization and ammonia volatilization processes occurring as a consequence of having high levels of residue on the soil surface with a high C/N ratio (Reiter et al. 2002). The study showed that, proportionately, more N is available to the subsequent crop from legume than from cereal. This result was agreed with the result found by (Mubarak et al. 2003b). Tsuji et al. (2006) reported that the levels of inorganic N and N mineralization after summer cropping in no-till conditions were lower when the aboveground residue was removed, which explained why yields of winter crop were lower under residue removal conditions.

Total soil nitrogen

Initial soil TN was 0.28 and 0.18 gkg^{-1} in the 0- to 20-cm and 20- to 40-cm depths, respectively (Table 1). Generally, in the two soil depths, application of sewage sludge and

Table 9 Soil mineral nitrogen (mg kg^{-1}) as influenced by organic waste application (average ± standard deviation)

Treatments	First crop (wheat)	Second crop (guar)	Third crop (wheat)
		NH4^{+}-N	
C	66.67e ± 0.10	49.15f ± 0.57	48.07f ± 0.12
CR	66.67e ± 0. 10	55.05d ± 0. 13	75.30c ± 0. 08
H	68.17d ± 0.17	50.00e ± 0.16	56.75e ± 0.06
SS	76.90c ± 0.08	57.80b ± 0.28	70.52d ± 0.10
RF	87.02b ± 0.13)	56.95c ± 0.17	79.30b ± 0.08
RF + CR	87.22a ± 0.10	60.15a ± 0.24	98.72a ± 0.10
LSD	0.176	0.463	0.136
P≤	0.0001	0.0001	0.0001
Treatments	**First crop (wheat)**	**Second crop (guar)**	**Third crop (wheat)**
		NO_3^--N	
C	33.12d ±0.17	17.85e ± 0.13	16.50f ± 0.08
CR	33.12d ± 0. 26	19.95c ± 0. 19	30.90d ± 0. 08
H	35.15c ± 0.28	18.82d ± 0.10	22.30e ± 0.08
SS	42.20b ± 0.16	22.65b ± 0.51	36.85c ± 0.06
RF	50.10a ± 0.36	19.92c ± 0.15	40.25b ± 0.06
RF + CR	50.22a ± 0.66	24.27a ± 0.21	50.80a ± 0.08
LSD	0.526	0.356	0.121
P≤	0.0001	0.0001	0.0001

Means in columns, within each depth, followed by different letter(s) are significantly different at $P \leq 0.05$ using LSD.

crop residues with or without inorganic fertilizer resulted in an increased in soil TN (Table 10). After the harvest of the first crop, SS compared to all treatments had significantly ($P \leq 0.0001$) increased TN in the 0- to 20-cm depth by 0.04 to 0.07 units and from 0.04 to 0.06 units in the 20- to 40-cm depth. After the harvest of the second crop, incorporation of wheat residues (with inorganic fertilizer) had significantly increased TN, in the 0- to 20-cm depth, by 16.67 % and by 24.00 % (in the 20- to 40-cm depth) as compared to the inorganic fertilizer alone (RF). After the harvest of the third crop, plots with RF + CR had consistently maintained the significantly highest topsoil (0- to 20-cm depth) TN values as compared to other treatments. The increase in TN due to the application of RF + CR, relevant to SS treatment, was 8.33 units, which is 10.53 % after the third crop. Also, continuous incorporation of crop residues has significantly increased the top soil TN as compared to the control treatments. Maximum increased value after the third crops was 78.95 %. However, in the lower soil depth (20 to 40 cm), increased in TN due to the application of RF + CR had been significantly observed after all crops in the cycle. These increase compared to the control treatment was 94.12 % after the third crop. In this depth, incorporation of crop residues had also resulted in significantly increased TN, but less increase (52.94 %) is recorded for the third crop.

After the harvest of the first crop, SS treatments increased soil TN by 14.29 % relative to the RF treatment. After the harvest of the third crop, the extent of the increase in soil total N over the RF was 30.0 %, 20.0 %, and 13.3 % in FR + CR, SS, and CR, respectively. The increase in soil total N with organic waste applications is likely attributed to the positive balance of total SOC and might have been partially due to a slow mineralization or N release capacity of organic wastes that might resulted in higher total N in soil. Continuous application of inorganic N sources in soil improved the activities of microorganisms, which enhanced the transformation process in soil including the decomposition of plant residues and accumulation of N in soil (Anwar et al. 2005; Bhattacharyya et al. 2008). Guar residue may stimulate biological N_2 fixation in the soil, which may also have been responsible for the increase in total soil N. In addition, the organic residue treatments produced more crop dry matter (biomass) and, therefore, possibly had more extensive root systems that may have contributed to increased N levels. The N concentration of guar residue (28 $g\,kg^{-1}$) contributed to the increase in N concentration of soil. The results clearly showed that addition of organic wastes with mineral fertilizer could increase total N content of soil due to N addition of organic residues. Kushwaha et al. (2000) observed a significant increase of 33 % in total N with the

Table 10 Soil total nitrogen (g kg^{-1}) as influenced by organic waste application (average ± standard deviation)

Treatments	First crop (wheat)	Second crop (guar)	Third crop (wheat)
		0 to 20 cm	
C	0.26c ± 0.01	0.21e ± 0.01	0.19f ± 0.01
CR	0.25c ± 0. 01	0.29c ± 0. 01	0.34c ± 0. 01
H	0.25c ± 0.01	0.23d ± 0.01	0.21e ± 0.01
SS	0.32a ± 0.01	0.34b ± 0.01	0.36b ± 0.01
RF	0.28b ± 0.01	0.30c ± 0.01	0.30d ± 0.01
RF + CR	0.28b ± 0.01	0.35a ± 0.01	0.39a ± 0.01
LSD	0.017	0.012	0.012
P≤	0.0001	0.0001	0.0001
Treatments	**First crop (wheat)**	**Second crop (guar)**	**Third crop (wheat)**
		20 to 40 cm	
C	0.22c ± 0.01	0.18d ± 0.01	0.17c ± 0.01
CR	0.22c ± 0. 01	0.23c ± 0. 01	0.26b ± 0. 01
H	0.22c ± 0.01	0.19d ± 0.01	0.18c ± 0.01
SS	0.28a ± 0.01	0.31a ± 0.01	0.32a ± 0.01
RF	0.24b ± 0.01	0.25b ± 0.01	0.26b ± 0.01
RF + CR	0.23bc ± 0.01	0.31a ± 0.01	0.33a ± 0.01
LSD	0.017	0.011	0.014
P ≤	0.0001	0.0001	0.0001

Means in columns, within each depth, followed by different letters are significantly different at $P \leq 0.05$ using LSD.

incorporation of crop residues compared to their removal after one annual cycle.

Water-soluble calcium and magnesium

The effect of the application of organic wastes on water-soluble Ca and Mg was presented in Tables 11 and 12, respectively. After the harvest of the first crop, SS treatments increased Ca and Mg by 36.84 % and 32.20 %, respectively, compared to the RF treatment. After the harvest of the third crop, the increase in Ca and Mg in comparison with the RF was 27.36 %, 21.89 %, and 13.18 % and 38.21 %, 34.64 %, and 14.29 % in SS, FR + CR, and CR, respectively. The increase of Ca and Mg by organic waste application may be due to release of the organic forms of these elements in the organic residue (Ogbodo 2009). Moyin-Jesu (2007) reported that the application of 6 t ha^{-1} of plant residues increased significantly the soil Ca and Mg.

Cation-exchange capacity

Initial CEC was 20.8 and 19.2 cmol$_c$ kg^{-1} in the 0- to 20-cm and 20- to 40-cm depths, respectively (Table 1). Generally, in the two soil depths, application of humentos, sewage sludge, and crop residues with or without inorganic fertilizer resulted in an increased in CEC (Table 13). After the harvest of the first crop, SS in comparison to all treatments had significantly ($P \leq 0.0001$) increased CEC in the 0- to 20-cm depth by 4.1 % to 5.58 % and from 1.83 % to 4 % in the 20- to 40-cm depth, whereas in H treatment, CEC increased in the 0- to 20-cm depth by 0.5 % to 1.42 % and from 2.02 % to 2.13 % in the 20- to 40-cm depth. After the harvest of the second crop, incorporation of wheat residues (with inorganic fertilizer) had significantly increased CEC, in the top 0- to 20-cm depth, by 1.39 % and by 3.24 % (in the 20- to 40-cm depth) as compared to the SS. After the harvest of the third crop, plots with RF + CR had consistently maintained the significantly highest topsoil CEC values as compared to other treatments. The percentage increase in CEC due to the application of RF + CR, relevant to SS treatment, was 3.45 % after the third crop. Also, continuous incorporation of crop residues has significantly increased topsoil CEC as compared to the control treatments. Maximum increased value after the third crops was 9.39 %. However, in the lower soil depth (20 to 40 cm), the increase in CEC due to the application of RF + CR had been significantly observed after all crops in the cycle. This increase compared to the control treatments was 86.28 % after the third crop. In this depth, incorporation of crop residues had also resulted in significantly increased CEC, but less increase (20.43 %) is recorded for the third crop.

This increase in CEC may be the result in an increase in available K in organic residue. Increase in CEC released more non-exchangeable K from the soils, which might

Table 11 Soil water-soluble Ca (meq L^{-1}) as influenced by organic waste application (average ± standard deviation)

Treatments	First crop (wheat)	Second crop (guar)	Third crop (wheat)
		0 to 20 cm	
C	2.85b ± 0.19	3.37c ± 0.10	4.20d ± 0.08
CR	2.85b ± 0.13	3.37c ± 0.13	4.55c ± 0.06
H	2.90b ± 0.12	3.67b ± 0.10	4.67c ± 0.13
SS	3.90a ± 0.10	3.95a ± 0.19	5.12a ± 0.10
RF	2.85b ± 0.19	3.32c ± 0.19	4.02e ± 0.10
RF + CR	2.97b ± 0.15	3.80ab ± 0.15	4.90b ± 0.10
LSD	0.195	0.235	0.138
P≤	0.0001	0.0001	0.0001
Treatments	**First crop (wheat)**	**Second crop (guar)**	**Third crop (wheat)**
		20 to 40 cm	
C	2.05c ± 0.24	3.72b ± 0.10	3.90d ± 0.08
CR	3.00b ± 0.18	3.75b ± 0.10	4.07c ± 0.10
H	3.05b ± 0.35	3.67b ± 0.15	4.40b ± 0.08
SS	3.75a ± 0.33	4.20a ± 0.14	4.70a ± 0.08
RF	3.12b ± 0.17	3.80b ± 0.08	3.80d ± 0.10
RF + CR	3.30b ± 0.16	4.20a ± 0.08	4.65a ± 0.06
LSD	0.409	0.176	0.121
P≤	0.0001	0.0001	0.0001

Means in columns, within each depth, followed by different letters are significantly different at $P \leq 0.05$ using LSD.

Table 12 Soil water-soluble Mg (meq L^{-1}) as influenced by organic waste application (average ± standard deviation)

Treatments	First crop (wheat)	Second crop (guar)	Third crop (wheat)
		0 to 20 cm	
C	3.52b ± 0.10	2.62d ± 0.10	2.87d ± 0.10
CR	3.55b ± 0.06	2.82c ± 0.10	3.20c ± 0.08
H	2.92c ± 0.10	2.87c ± 0.10	3.45b ± 0.06
SS	3.90a ± 0.08	3.50a ± 0.08	3.87a ± 0.10
RF	2.95c ± 0.13	2.92c ± 0.10	2.80d ± 0.08
RF + CR	2.92c ± 0.10	3.35b ± 0.13	3.77a ± 0.10
LSD	0.151	0.144	0.124
P≤	0.0001	0.0001	0.0001
Treatments	**First crop (wheat)**	**Second crop (guar)**	**Third crop (wheat)**
		20 to 40 cm	
C	2.85c ± 0.13	2.95b ± 0.15	2.40d ± 0.08
CR	2.55d ± 0.21	2.80b ± 0.12	3.02c ± 0.10
H	3.02ab ± 0.17	2.95b ± 0.13	3.25b ± 0.06
SS	2.82bc ± 0.10	3.32a ± 0.13	3.70a ± 0.08
RF	2.80c ± 0.14	2.90b ± 0.14	2.50d ± 0.14
RF + CR	3.07a ± 0.13	3.27a ± 0.10	3.60a ± 0.08
LSD	0.209	0.192	0.138
P≤	0.0001	0.0001	0.0001

Means in columns, within each depth, followed by different letters are significantly different at $P \leq 0.05$ using LSD.

Table 13 Cation-exchange capacity (cmol$_c$ kg^{-1}) as influenced by organic waste application (average ± standard deviation)

Treatments	First crop (wheat)	Second crop (guar)	Third crop (wheat)
		0 to 20 cm	
C	19.82 cd ± 0.13	19.35f ± 0.06	19.15f ± 0.06
CR	19.90bc ± 0. 08	20.02d ± 0. 50	20.95c ± 0. 06
H	20.00b ± 0.08	20.25c ± 0.06	20.30d ± 0.08
SS	20.82a ± 0.05	30.05b ± 0.06	30.45b ± 0.06
RF	19.72d ± 0.10	19.65e ± 0.06	19.67e ± 0.10
RF + CR	19.75 cd ± 0.17	30.47a ± 0.10	31.50a ± 0.08
LSD	0.155	0.124	0.121
P≤	0.001	0.0001	0.0001
Treatments	**First crop (wheat)**	**Second crop (guar)**	**Third crop (wheat)**
		20 to 40 cm	
C	18.75c ± 0.06	17.55e ± 0.10	16.40e ± 0.08
CR	18.77bc ± 0. 13	19.22c ± 0. 05	19.75c ± 0. 06
H	19.15ab ± 0.57	19.30c ± 0.08	19.72c ± 0.10
SS	19.50a ± 0.08	29.30b ± 0.08	29.45b ± 0.06
RF	18.77bc ± 0.10	18.50d ± 0.08	18.40d ± 0.08
RF + CR	18.77bc ± 0.13	30.25 a ± 0.06	30.55 a ± 0.06
LSD	0.383	0.112	0.119
P≤	0.0001	0.0001	0.0001

Means in columns, within each depth, followed by different letters are significantly different at $P \leq 0.05$ using LSD.

have resulted in increased available K and K utilization by crops in addition to the residues that own K supply. The corresponding increase in K uptake by plants indicated that solution K is removed by plants; more K is released from non-exchangeable to exchangeable and soluble pools. The increase in CEC is determined by the proportional increase in SOM content, and any change in SOM directly affected the CEC of soil (Mubarak et al. 2003b; Abbasi et al. 2009).

Effect on soil physical properties

Bulk density, water-holding capacity, and soil resistance

The effect of different treatments on soil physical properties is presented in Table 14. The significantly ($P < 0.0001$) higher soil water-holding capacity after the third crop was detected only on sewage sludge-treated plots. Sewage sludge significantly reduced soil bulk density after the third crop. The physical properties of the soils such as saturated and unsaturated hydraulic conductivity, water retention capacity, bulk density, total porosity, pore size distribution, soil resistance to penetration, aggregation, and aggregate stability were improved in plots amended with sewage (Aggelides and Londra 2000). Angin and Yaganoglu (2011) attributed the increase in water-holding capacity values in plot treated with sewage sludge to its high organic matter content. Although, crop residue application with or without fertilizer caused a little increase in water-holding capacity, these increases were not statistically

Table 14 Effect of organic and inorganic fertilizers on soil physical properties (average ± standard deviation)

Treatments	Water-holding capacity (%)	Soil bulk density (gcm^{-3})	Penetration resistance (mm)
C	21.90b ± 0.08	1.44a ± 0.04	17.00a ± 1.15
CR	21.93b ± 0.48	1.44a ± 0.04	17.50a ± 1.00
H	21.88b ± 0.10	1.38ab ± 0.05	17.00a ±1.15
SS	23.23a ± 0.10	1.37b ± 0.03	17.00a ± 1.15
RF	21.88b ± 0.10	1.40ab ± 0.02	17.50a ± 1.00
RF + CR	21.95b ± 0.06	1.38ab ± 0.05	17.50a ± 1.00
LSD	0.140	0.060	1.68
P≤	0.0001	0.11	0.951

Means in columns, followed by different letters, are significantly different at $P \leq 0.05$ using LSD.

significant compared to the control plots. The absence of significant change on soil bulk density and soil water-holding capacity indicates that changes in these properties are expected to develop slowly after initiation of organic waste application. Three to four years are required for soil under conservation tillage to develop a more favorable porosity in 0- to 15-cm soil (Mubarak et al. 2003b). Incorporation of the crop residue with or without inorganic fertilizer for four seasons significantly increased water-holding capacity over the control and recommended fertilizer treatments. Application of NPK + FYM reduced soil bulk density from 1.3 Mg m^{-3} in the control plots to 1.18 Mg m^{-3} (Hati et al. 2006). Continuous cereal monoculture cropping and removal of crop residues result in the deterioration of the physical, chemical, and biological properties of the soil (Giller et al. 1997). Ogbodo (2010) reported that soil moisture, total porosity, and water infiltration were significantly ($P < 0.05$) higher on residue-treated plots, whereas soil bulk density and temperature were significantly ($P < 0.05$) reduced by the residue treatments compared to the soil with no residue treatments. The products of residue decompositions (polysaccharides and humus) acted as binding materials on the soil particles, hence, improving the soil pore volume, aggregation and structure, and reducing the density per unit volume of soil (Ogbodo 2010). The organic residues improved bulk density, total porosity, macro and micro pores, soil water retention, and soil hydraulic conductivity compared with untreated soil (Shaaban 2006).

Conclusions

Two seasons of continuous incorporation of organic wastes in the desert soil significantly increased CEC, total N, OC, and available P and decreased soil pH. The soil physical properties had no significant effect by organic waste application except bulk density was decreased and water-holding capacity was increased by sewage sludge application. Therefore, for effective positive changes in soil properties, a long-term (more than three seasons) application of organic wastes is recommended.

Competing interests

The authors declare that they have no competing interests.

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Authors' contributions

Rezig F.A.M she is the main author and did the field and laboratory job and drafted the manscript. Elhadi, E.A particpate in some field work, statstical analysis and participate in correction of the manscript. Mubarak, A. R He is the main supervisor and draft the proposal and participate in the correction of the manscript. All authors read and approved the final manuscript.

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