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Effect of Incorporation of some Wastes on a Wheat- Guar Rotation System of a Desert Soil: 11. Yield and Nutrients Uptake

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ABSTRACT

A two-year study (2008-2010) was conducted on a sandy clay loam soil at the experimental farm of the Omdurman Islamic University (Sudan) to determine the effect of application of organic waste in sustaining yields of wheat and guar in a crop rotation system. Treatments were control, recommended inorganic fertilizer, recommended inorganic fertilizer with crop residues, crop residues, sewage sludge and soil conditioner (humentos). During the three crops, cycle of continuous application of crop residues with inorganic fertilizers, inorganic fertilizers and sewage sludge produced high and sustainable wheat yield by 300,133.9 and119.8percentage respectively in comparison to plots where crop residue was removed. Nitrogen and potassium uptake by the subsequent crops were significantly higher in plots treated with crop residues with inorganic fertilizers, inorganic fertilizers and sewage sludge, by 9.7 4 and 4% respectively in comparison to the control, whereas phosphorus uptake by the subsequent crops was significantly higher in humentos treatment, by 53.7%.
Key words: crop residues, yield, nutrients, wheat, guar, poor sandy soil

INTRODUCTION

Continuous soil fertility degradation is the most critical problem affecting Sudan's agricultural development. According to Syers *et al*. (1997) soil fertility is a key factor in soil degradation and is probably the major cause of the reduction in crop yield. Annual rates of nutrient depletion from cultivated land have been estimated as 4.4, 0.5 and 3.0 million tonnes of N, P and K, respectively (Sanchez *et al.*, 1997). Cropping intensification without fertilizers or with sub optimal fertilizer rates has resulted in low crop yield, increased soil erosion and soil nutrient mining. As noted by Henao and Baanante (1999), if nutrient depletion and land degradation continue at the current rates, farmers in Africa will not manage to grow enough food for the increasing populations in the next decade. Restoring of soil fertility depletion is required to increase per capita agricultural production (Sanchez and Leakey, 1997). In the past, farmers maintain soil fertility through long fallow periods and opening of new lands. The demands for land increase because the increase in population has led to a break down in soil fertility maintenance strategies (Kayuki and Wortmann, 2001). Soil fertility restoration could be achieved by inorganic and organic inputs. Use of inorganic fertilizers by resource – poor farmers is constrained by inadequate supply, unstable prices of agricultural produce, scarce financial resources, and lack of access to credit. Sustainable agriculture became a major global issue of during this decade

(Farshad *et al*.,1993) Agronomic practices aimed at reducing the dependence on chemical fertilizers, e.g., incorporation of crop residues (Prasad *et al*.,1999) can contribute to sustainability mainly through improvement of soil fertility as judged by organic carbon, available P and K content. Moreover, In the sub-tropics and tropics it is difficult to increase soil organic matter (OM) content substantially, however, it is highly desirable to add crop residues and other OM to the soil, whenever possible to maintain soil fertility (Kanwar,1997). In Khartoum State there is tremendous amount of sewage sludge produced in the vicinity of the State that could be used in amelioration of these soils and counteract land degradation and the consequences of nutrient depletion, remediation strategies are often implemented Information regarding the effect of crop residues, in a crop rotation system on yield and nutrient uptake is still needed, particularly in Sudan where residue removal through open burning is widely used. The aim of this project was to assess the effects of application of organic residues (crop residues and sewage sludge) on wheat and guar dry matter yield and nutrient content.

MATERIALS and METHODS

Site, soil and climate

The experiment was located at the agricultural experimental farm of Omdurman Islamic University. Sudan (Latitude 15°19.9N.,Longitude, 32°39´E and 381 m above the sea level).) the study was conducted for a three rotation (wheat-guar-wheat) and extended from the year 2008-2010. The climate of the area is semi-arid with low relative humidity. The temperature ranges between 40°C maximum in summer and 21°C minimum in winter (Oliver, 1965). Annual rainfall was 67.5 mm, which varies in intensity and distribution with its peak in August (Meteorology Department, 1993). Some physical-and chemical properties of the soil were shown in Table 1.

Experimental treatments and design

A randomized complete block design (RCBD) with four replications (24 plots of 4 .0× 4.0 m dimensions) was used to test the following treatments.

1. Control (NFC) no crop residues-no fertilizer (C)
2. Recommended fertilizer NP without crop residues (RF)
3. Recommended fertilizer NP with crop residues (RF+CR)
4. Crop residues (CR)
5. Sewage sludge (10t ha^{-1}) (SS)
6. Exotic soil conditioner (Humentos) imported from Germany, 200 L ha^{-1}(H)

For wheat, recommended rates of N application at sowing in form of urea and P in from of triple super phosphate were 125 and 92 kg/ha respectively. For guar N and P were applied (at sowing) at rates of 96 and 100 kg/ha respectively.

Sowing and harvesting

To maximize N fixation, guar seeds, were treated with an inoculant (EN 16 I) and planted at a spacing of 0.3 × 0.75 m.Wheat was sown broad cast at rate of 143 kg seeds ha^{-1}. All crops were regularly irrigated every week with amount of tap water that was equivalent to the field capacity of the soil, weeds was managed manually whenever necessary. The duration of each crop in the ration is presented in Table1.The wheat was harvested at physiological maturity (90 days), guar was used as green manure and harvested after 70 days.

Table 1. Some physical and chemical properties of the experimental site.

Soil depth (cm) Variable	0-20	20-40
pH	8.1	7.8
ECe (dS m^{-1})	1.05	1
O.C (%)	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
Soluble Mg (Meq L^{-1})	3.8	3
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 (cmolc kg^{-1})	20.8	19.2
Bulk density (g cm^{-3})	1.44	nd
Water holding capacity %	21.92	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

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

Table 2. Time of sowing and harvesting wheat and guar crops 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

Note: fallow period range between 3 and 5 months.

Table 3. Nutrient content of organic wastes incorporated to the soil.

Crop Residues	N g kg^{-1}	P mg kg^{-1}	K g kg^{-1}	Ca g kg^{-1}	Mg g kg^{-1}	OC %	C/N
Wheat	7	11	9.8	3.4	1	41.3	59
Guar	19	71.8	25.5	14.2	11.1	29.7	15.63
Sewage sludge	28	28	34	4.8	3.9	24	8.57
Humentos	30	17.5	27.5	3.5	3.5	-	-

Plant analysis

Moisture content was determined by drying the samples (wheat and guar residue) to constant weight in 70° C oven, weight, ground and sieved (1 mm sieve) for analysis. Two gm of the sample was placed in to a muffle furnace at 550° C until a constant weight was obtained. The weight of the plant ashing was defined as ash content, then elements (Ca, Mg, K and P), and organic carbon were determined according to the method described by Chapman and Pratt (1961) 10 ml of 5N HCL were added to the ash and placed in a hot sand bath for about 5 min. The contents were filtered using (whattman NO.42) with distilled water into a50 ml volumetric flask. Total N, was determined using micro-kjelahI (Van Schoumenberg and Walinge, 1973) nitrogen digestion and distillation method, 0.2 gm of oven-dried sample was weight in to a 100 ml kjelahI flask.0.4 gm of catalyst mixture and 3.5 ml of concentrated sulphuric acid were added. The sample was heated in an electric heater for 2 hrs. The sample was cooled, diluted and was placed in the distillation apparatus; 20 ml of 40% NaOH were added, and distilled for 7 min.The ammonia evolved in 20 ml of 2% boric acid solution, contained in conical flask attached to the receiving end. The trapped ammonia was titrated against 0.01 N HCL using universal indicator (methyl red + bromocresol green). Ca and Mg, were determined together according to Chapman and Pratt (1961) by taking 2 ml of the ash extraction in a 50 ml conical flask 20 ml of distilled water, 10 drop of buffer ammonium chloride were added and 3-4 drops of eriochrome black T. (E.B.T) were added to the extract giving purple colour.The mixture was titrated against (0.1N EDTA) until a blue colour indicating the end point was reached. The Mg content was estimated by sub-extracting the Ca from Ca+Mg contents. The Ca was determined by taking 2 ml of ash extract in a 50 ml conical flask and completed to 25 ml by distilled water, 0.2 g of meroxide indicator added with sodium hydroxide and titrated against EDTA. K was determined by flame photometer. Phosphorus, analysis was carried out in line with the method of Chapman and Pratt (1961). 5 ml of the ash extracted was pipetted in to a 25 ml volumetric flask.10 ml of ammonium molybdate-ammonium vandate reagent was added. The content of the flask were mixed and diluted to volume. The density of the color was read after 30 minutes at 470-nnm using acoloimeter.astandar curve of different KH_2 PO_4 concentration was plotted to calculate the phosphorus concentration. Organic C, was measured by using modified Walky Black methods (Walkey and Black, 1934) 10 ml of $K_2Cr_2O_7$ (1N) was added to 0.5 gm of the oven dry plant sample followed by carefully addition of 20ml of concH_2SO_4, and placed on water bath for 30 min, cooled the clear solution was separated and completed to 100 ml with distilled water. After one hr 10 ml of conc. Orthophosphoric acid was added 2-3 drops of orthophenatroline were added to 10 ml of the pure solution. Then titrated against ferrous ammonium sulphate (0.5N). Ash alkalinity, The procedure developed by Jungk (1968) was used to determine ash alkalinity. Briefly0, five ml of 0 .1N HCL was added to 0.25gm of 1mm sieved plant materials and heated (100-150 °C) in a hot plate until drying. The acidified material was ashed (500 °C) for three hours, cooled and 20 ml of 0.1 NHCL was added. The mixture was then boiled, cooled and filtered. The alkalinity of the ash was determined by back titration the remained acid with 0.1N NaOH used 2-3 drops of phenophsaliene indicator at end point colour change to pink.

Crop residue application

After harvest, crop residues were ploughed in to the top 20 cm soil depth before sowing the subsequent crops. Dry matter yield data and nutrient content of each crop were analyzed using SAS statistical analysis software (SAS, 1985). The least significant difference (LSD) method was used to determine differences between treatment means.

RESULTS AND DISCUSSION

Total dry matter production TDM at harvest

Generally, TDM was production significantly affected by organic wastes application (Table 4). After harvest of the first season, TDM in the RF+CR and RF treatments was three fold greater than the control, while 0.63 unit increase in TDM compared to the control was recorded in SS treatments. In the third season, the increase in TDM ranged from 4.13, 1.38 and 1.14 unit in RF+CR, RF, and SS treatments respectively over the CR treatment. This result was in agreement with the result reported in the previous studies (Deguchi et al., 2005; Deguchi et al., 2007) in which, white clover mulch and P fertilizer increased the yield of corn compared to no and low P application treatments. The observed increase in TDM yield could be attributed to better soil physical conditions, enhanced root growth and increased nutrient capture (Baijukya et al., 2005) in addition to better soil environment for the biological activity and nutrient cycling (Arya et al., 2007). Gilbert (2000) reported that only legumes that produce above 2 Mg $ha^{-1}$of biomass (50 kg N ha^{-1}) would be expected to provide better yield response for maize in the following season. However, Baijukya et al. (2005) reported that the impact of plant residues on the following crops is not necessarily from N provision as this depends on many factors including the quality of the legume biomass in terms of N release and the management of residues. Therefore, it is imperative to estimate the N mineralization potential and N releasing capacity of plant residues before applying in soil as N source.

The demand of wheat for N is high; yield of the subsequent wheat after incorporation of leguminous crop like guar was expected to be higher than the yield of the first wheat crop due to the additional N added from the crop residue. Similar result was also found by (Mubarak *et al*., 2002). Glab and Kulig (2008) reported that wheat yields from reduced tillage system without mulch residues were significantly lower than the yield when fodder radish mulch residue was applied. Safwat *et al.* (2002) reported that peanut leaves supplied with 60 kg N ha^{-1} resulted in high wheat yield compared with the treatment without added crop residues. They attributed the increase in wheat yield to the release of nutrients from the residue, which had an effect on soil properties and plant growth. Ruffo and Bollero (2003) however, stated that excessive biomass cover could possibly decrease yield and that reduces crop stands due to poor soil-seed contact and poor germination.. They added that on the other hand, little residue may not be adequate for soil and water conservation goals. Das et al. (2002) conducted a field experiment to study the recycling effect of crop residues with chemical fertilizers on physicochemical properties of soil at crop harvest and yield of rain-fed wheat. Application of rice straw at 5 t ha-1 or wheat straw at 5 t ha-1 with chemical fertilizers wheat field improved the physicochemical properties of soil (pH, bulk density, hydraulic conductivity, organic matter, cation exchange capacity and maximum water holding capacity) than initial values after two years of study and also increased the grain and straw yield of wheat.

Table 4. Total dry matter yield of wheat and guar (t ha^{-1}) as influenced by organic wastes application.

Treatments	1st Crop (wheat)	2nd Crop(guar)	3rd Crop (wheat)
C	0.54 d (0.04)	3.31 bc (1.09)	1.66 c (0.24)
CR	0.66 d (0.03)	4.38 ab (0.88)	2.50 c (0.00)
H	0.56 c (0.06)	2.89 c (0.41)	2.17 c (0.94)
SS	1.17 b (0.09)	4.69 a (0.29)	3.64 b (0.65)
RF	1.47 a (0.04)	4.05 abc (0.88)	3.88 b (1.03)
RF+CR	1.49 a (0.04)	4.83 a (0.38)	6.63 a (0.63)
LSD	0.07	1.16	0.88
$P \leq$	0.0001	0.016	0.0001
C.V	4.58	19.15	17.27

Note: Means in the columns, within each crop, followed by different letter (s) are significantly different by LSD. (Values in parenthesis are standard errors.)

Nitrogen content:

Generally, N content was significantly affected by organic wastes application. The effect of application of organic wastes on N content was given in (Table 5). In the first season, N content was 7.98, 7.93 and 7.73 g kg^{-1}) for FR, RF+CR, and SS treatments respectively, Significantly ($P \leq 0.0001$) higher than the N content of the anther treatments .In the second season, N content in guar was 22.70, 21.95 and 20.95 g gk^{-1} for RF+CR, SS and FR treatments respectively, Significantly ($P \leq 0.016$) higher than the N content in the other treatments. Nitrogen content in the third season was 10.98, 9.93, 9.55 and 8.70 g gk^{-1} for RF+CR, FR, SS and CR treatments respectively, significantly ($P \leq 0.0001$) higher than the N content of wheat crop in humentos and control plots. The increased in N content could be attributed to N content from incorporation crop residues (Kaleem *et al*., 2009). Anther study by Aggarwal and Sarma (2002) found that N uptake by wheat grain and straw increased when crop residues incorporated. Rato *et a*l. (2008) found that sludge application significantly increased N concentration in wheat**.**

Table5. Nitrogen content of wheat and guar (g kg^{-1}) as influenced by organic wastes application

Treatments	1st Crop (wheat)	2nd Crop(guar)	3rd Crop (wheat)
C	6.40 d (0.08)	19.03 e (0.13)	7.05 e (0.17)
CR	6.43 d (0.10)	19.73 d (0.10)	8.70 d (0.08)
H	6.75 c (0.06)	19.90 d (0.12)	7.20 e (0.22)
SS	7.73 b (0.10)	21.95 b (0.13)	9.55 c (0.06)
RF	7.98 a (0.10)	20.95 c (0.13)	9.93 b (0.10)
RF+CR	7.93 a (0.10)	22.70 a (0.08)	10.98 a (0.17)
LSD	0.137	0.183	0.17
$P \leq$	0.0001	0.0001	0.0001
C.V	1.26	0.585	1.28

Note: Means in the columns, within each crop, followed by the different letter (s) are significantly different using LSD. (Values in parenthesis are standard errors.)

Phosphorous content:

Hutmentos treatment was significantly ($P \leq 0.0001$) higher in P content than the other treatments. In the first and the second, crop (Table 6). Application of humentos increased P content 150 % and 50% for wheat and guar respectively in comparison with control. After harvested the third season, the increase in P content ranged from 18.16, 12.83 and 12 units in RF+CR, FR, and H treatments compared the CR treatment. Addition of residues with inorganic fertilize P increase available P and P uptake compared to residue alone due to increase in microbial P (Deguchi et al., 2007 ; Bah *et al*.,2006 and Reddy *et al*.,2005).

Table 6. Phosphorous content of wheat and guar (g kg^{-1}) as influenced by organic wastes application

treatments	1st Crop (wheat)	2nd Crop(guar)	3rd Crop (wheat)
C	10.17 d (0.64)	71.80 d (0.53)	11.00 f (0.38)
CR	9.83 d (0.84)	71.80 d (0.96)	12.17 e (0.33)
H	25.50 a (0.64)	108.36 a (0.57)	24.17 c (0.64)
SS	18.33 b (0.38)	98.39 c (0.52)	18.17 d (0.33)
RF	12.33 c (0.38)	99.06 c (0.56)	25.00 b (0.38)
RF+CR	12.17 c (1.00)	106.20 b(0.65)	30.33 a (0.38)
LSD	1.12	1.05	0.647
$P \leq$	0.0001	0.0001	0.0001
C.V	5.07	0.76	2.13

Note: Means in the columns, within each crop, followed by the different letter (s) are significantly different using LSD. (Values in parenthesis are standard errors.)

Potassium content

Generally, K content was significantly affected by organic wastes application. The effect of application of organic wastes on K uptake was given in Table 7. In the first season, application of RF had not significant effect on K content. Wheat crop in the humentos and sewage sludge plot has significantly higher K content. After harvested the second season, K content was (28.00 and 26.63 g gk^{-1}) for RF+CR and SS treatments respectively, Significantly ($P \leq 0.001$) higher than the K content of other treatments. After harvested the third season, K content was (12.60, 11.20, 10.85 and 10.15 g gk^{-1}) for RF+CR, FR, SS and CR treatments respectively, Significantly ($P \leq 0.0001$) higher than the K content of other treatments. The increases in K content in the second and third seasons of RF+CR and SS treatments, may indicate that application of RF+CR and SS increase K uptake by the subsequent crops. The increase in K uptake by wheat in RF+CR and SS treatments compared to the control (C) could be attributed to K content in the guar residue and SS. In other study, it was reported that application of 4 t ha^{-1} of millet straw over a 4-year period had increased total K content of pearl millet by 65% compared to fertilizer only (Bationo *et al*, 1993). In addition, an increase of 50% in the K concentration of the shoot DM of groundnut due to application of 4 t ha^{-1} (60 kg K ha^{-1}) of millet straw was observed (Rebafka et al, 1993). In the humid tropics, incorporation of maize increased K uptake of the following maize crop by 30% over the control (Bationo *et al*, 1993). The increase in K uptake by maize due to white clover residues and P fertilizer was 2-fold over control was also reported by (Kaleem et *al*., 2009)

Table7. Potassium content of wheat and guar (g kg^{-1}) as influenced by organic wastes application

Treatments	1st Crop (wheat)	2nd Crop(guar)	3rd Crop (wheat)
C	9.75 c (0.06)	25.53 d (0.13)	9.85 e (0.06)
CR	9.70 c (0.08)	25.85 c (0.13)	10.15 d (0.06)
H	9.90 b (0.08)	25.85 c (0.24)	9.95 e (0.06)
SS	10.40 a (0.08)	26.63 b (0.10)	10.85 c (0.06)
RF	9.70 c (0.08)	25.93 c (0.22)	11.20 b(0.08)
RF+CR	9.70 c (0.08)	28.00 a (0.08)	12.60 a (0.08)
LSD	0.12	0.025	0.11
P $\leq$	0.0001	0.0001	0.0001
C.V	0.84	0.631	0.69

Note: Means in the columns, within each crop, followed by the different letter (s) are significantly different using LSD. (Values in parenthesis are standard errors.)

Calcium and magnesium content

Generally, Ca and Mg have similar trend of K. Calcium content was significantly affected by organic wastes application. The effect of application of organic wastes on Ca content was given in Table 8. After harvested the first season, Ca content was 3.63 and 3.25 g kg^{-1} for SS and H treatments respectively, Significantly ($P\leq$0.0001) higher than the Ca content 3.52 g gk^{-1} of H treatments. After harvested the third season, Ca content was 6.70, 5.00, 4.85 and 3.85 g gk^{-1}) for RF+CR, FR, SS and CR treatments respectively, Significantly ($P \leq$0.0001) higher than the Ca content 3.38 g gk^{-1} of control treatments. The effect of application of organic wastes on Mg content was given in (Table 9). After harvested the first season, Mg content was 1.40 and 1.03 g kg^{-1} for SS and H treatments respectively, Significantly ($P\leq$0.0001) higher than the Mg content 0.90 g kg^{-1} of RF treatment. After harvested the third season, Mg content was 4.88, 3.38, 3.25 and 2.40 g gk^{-1} for RF+CR, FR, SS and CR treatments respectively, Significantly ($P \leq$0.0001) higher than the Mg content 1.03 g gk^{-1} of the control treatments.

Table 8. Calcium content of wheat and guar (g kg^{-1}) as influenced by organic wastes application

Treatments	1st Crop (wheat)	2nd Crop(guar)	3rd Crop (wheat)
C	3.00 c (0.08)	14.18 d (0.13)	3.38 d (0.10)
CR	3.05 c (0.06)	14.30 d (0.14)	3.85 c (0.13)
H	3.25 b (0.06)	14.43 c (0.10)	3.38 d (0.10)
SS	3.63 a (0.13)	14.98 a (0.10)	4.85 b (0.06)
RF	3.00 c (0.08)	14.60 b (0.10)	5.00 b (0.08)
RF+CR	3.03 c (0.10)	14.75 a(0.06)	6.70 a (0.08)
LSD	1.3	0.143	0.29
P $\leq$	0.0001	0.0001	0.0001
C.V	2.7	0.651	4.31

Note: Means in the columns, within each crop, followed by the different letter (s) are significantly different using LSD. (Values in parenthesis are standard errors.)

Table 9. Magnesium content of wheat and guar (g kg^{-1}) as influenced by organic wastes application

Treatments	1st Crop (wheat)	2nd Crop(guar)	3rd Crop (wheat)
C	0.85 d (0.06)	11.08 d (0.10)	1.03 e (0.15)
CR	0.80 d (0.08)	11.13 d (0.22)	2.40 c (0.08)
H	1.03 b (0.05)	11.48 c (0.10)	2.10 d (0.14)
SS	1.40 a (0.08)	12.03 a (0.17)	3.25 b (0.06)
RF	0.90 cd (0.08)	11.70 b (0.08)	3.38 b (0.10)
RF+CR	0.93 c (0.10)	11.78 b(0.17)	4.88 a (0.10)
LSD	0.12	0.208	0.16
$P \leq$	0.0001	0.0001	0.0001
C.V	7.8	1.198	3.77

Note: Means in the columns, within each crop, followed by the different letter (s) are significantly different using LSD. (Values in parenthesis are standard errors.)

CONCLUSIONS

Incorporating sewage sludge into the soil supplied an average of 280000 kg N ha^{-1} to subsequent crop while 4.62–83.22 kg N ha^{-1} was supplied by incorporating the wheat and guar residues respectively. For a three crop rotation, the maximum yield (6.63t ha^{-1}) of wheat was observed by returning crop residues to the field with inorganic fertilizer whereas, complete removal of crop residues (control) tended to decrease yield (1.66 t ha^{-1}). Increase of 23.40 % total N content, compared to the control, was found in wheat plants where crop residues were incorporated. Combining crop residue with inorganic fertilizer further improved wheat N content by 55.74 %. Humentos improved P content in the first wheat crops by 106.81% as compared to control and 39.12 % as compared to sewage sludge. Whereas combining crop residues with CM had increased K content by 115–139%.

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