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Effect of Composted Sludge and K Application on Cotton Yield, Residual Effect on Subsequent Wheat Yield and Soil Characteristics

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Abstract: In calcareous soils, possess high $CaCO_3$ content which concentrate resulting in very hard layers, impermeable to water and plant roots. Therefore, conditioners or organic amendments seem to be tools for sustaining these soils to be employed as additional areas for crop production especially the main crops like cotton. Two field trials were conducted in the summer seasons of 2017 and 2018 to study the interactions between composted sludge and K fertilizers in order to provide more detailed information on the fertilizer value of compost, particularly phosphorus as the availability of this tends to be restricted on such calcareous soils. The experiment included 8 treatments which were the combinations of 4 compost rates i.e.; 0, 5,10 and 15 m^3 fd^{-1} as well as 2 additional K fertilizer rates 0and 24 kg K_2 Ofd^{-1}. Cotton variety Giza 70 seeds were sown in the experimental plots. Another objective for the experiments was to evaluate the residual effect of composted sludge on subsequent crop wheat which was sown on the trial area previously cropped with cotton in both seasons.The results showed that the chemical analysis of the composted sludge parameters comply with the Egyptian Code for Sludge Reuse. Composted sludge supplied cotton with 5.6-16.7, 0.7-2.0 and 10.5-31.5 kg of N,P and K, respectively according to the rate. Micronutrient addition through composted sludge were satisfied and heavy metal metals Ni, Cd, Pb, Cr and Co additions were too small and could not pose any threat to cotton. Compost increased seed cotton yield and the optimum rate of application to soil for cotton production was 5 m^3 fd^{-1}. However, there was no statistically significant effect of K fertilizer on the yield of seed cotton without compost, but K significantly reduced seed cotton production when applied with the optimum dressing of composted sludge. Composted sludge, had a beneficial effect on seed cotton yield and increased production of this important economic yield parameter by up to 200 % compared to the untreated control or soil receiving only K fertilizer. The results of the residual effect of composted sludge on subsequent wheat crop showed that the yield performance data reveal that there were agronomically significant benefits from the previously applied sludge compost. Grain yield was increased by 20 % at the 5 and 10 m^3 fd^{-1} rates and was twice that of normal recommended practice at the highest rate of application of 15 m^3 fd^{-1}. Soil analysis indicated that it is highly calcareous, with an average $CaCO_3$ content of 25.2 % and a mean pH of 8.3, which will reduce the availability of trace elements for crop uptake. There were few obvious trends in the data that could be attributed tocomposted sludge, although there were apparent rate related effects on Zn, Cu and Pb. The annual loading rates of heavy metals were minimal according to the EC Directive 86/278/EEC EC which do not impose threat to the subsequent crops for long decades.

Key words: Composted sludge · Calcareous soil · Cotton · Nutrients · Heavy metals · Wheat · Residual effect

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INTRODUCTION

Calcareous soils are characterized with high pH of which is usually above 7 and may be as high as 8.5. When these soils contain sodium carbonate, the pH may exceed 9. In some soils, $CaCO_3$ can concentrate into very hard layers, termed caliche, that are impermeable to water and plant roots. Therefore, conditioners or organic amendments seem to be tools for sustaining these soils to be as additional areas for crop production especially the main crops like cotton.Cotton area under cultivation is shrinking due to the completion of other crops, long season and the high cost of production. Fertilizer management is costly especially K. The use of organic materials in combination with inorganic fertilizers to optimize nutrient availability to plants is a difficult task as organic materials have variable and complex chemical nature. This requires the understanding and knowledge about the chemical composition, particularly the nutrient content and quality of organic materials and its interaction with inorganic nutrient sources.

Prices of chemical fertilizer are increasing now a days [1] which have made the fertilizer option un attractive and have increasingly turned attention to organic amendments, such as organic manures [2]. There is a huge interest to apply organic matters due to it's high nutrient content [3]. Manures refer to all substances added to the soil in order to increase the supply of plant nutrients [4]. Organic manures supplies most of the nitrogen, sulphur and half phosphorus needed by unfertilized crops [5]. Composted sludge, far from being merely a waste, should be regarded as a natural resource to be conserved and reused rather than discarded. Its use in agriculture is widely regarded as the best practical environmental option and the most sustainable of waste management options [6]. The application of sludge to the soil reduces soil bulk density and improves water holding capacity, aggregation, pore size distribution and aeration characteristics of soil, as well enhancing the workability of treated soil (Hall and Coker, [7]. Moreover, effects of the organic matter applied to the soil in sludge are seen in increased efficiency of mineral fertilizer utilization *by* crops and improved perfonnance Smith) [8]. Integrated use of organic manures and fertilizers has been found to be promising not only in maintaining higher productivity but also for providing stability in crop production.

Under calcareous soil conditions high calcium carbonate and low fertility status which may influence crop growth.To improve the conditions of these soils one factor is very essential, this is potassium (K) fertilizer. Recently, K deficiency in soil due to crop uptake, runoff, leaching and soil erosion [9], 2002. Many studies have shown increased yield and quality in response to potassium fertilization as reported by [10-18]. Moreover, several workers documented favourable responses of cotton growth, productivity to application of potassium as reported by, [21-24]; they indicated that application of potassium treatments significantly improved the no. of bolls/plant, boll weight and seed cotton yield. Yassen, *et al*. [25] suggested that organic manureapplication increased the transfer elements between thesolid phase and soil solution in addition to highermicrobial activity. The activity of soil micro-organismswas higher in the organic farming system, which helpedthe nutrient uptake. The residual effects of organic manures are evident and they have many beneficial effects on the subsequent crops. Gong *et al*. [26] and Enke *et al*. [27] found that long-term addition of organic manure has the most beneficial effect on grain yield of wheat and maize. Also, Tejada and Gonzalez [28] showed that compost application in 2-continuous years increased the number of grains/spike, 1000 grain weight and the number of spikes and grain wheat yield. This positive effect was mainly due to a better N supply with the compost application.

In wheat plant, Nehra and Hooda [29], Tawfik and Gomaa [30], Zeidan *et al*. [31] and Yaduvanshi and Sharma [32] found that organicmanure application significantly enhanced the yield anduptake of N, P and K in wheat.

Therefore the objective of this trials was to study the effect of different rates of composted sludge with K application on cotton yield parameters. Additional target of these trials is to evaluate the residual effect of composted sludge application on subsequent winter crop (wheat) yield and soil characteristics under calcareous soil conditions.

MATERIALS AND METHODS

Two field trials were conducted in the summer seasons of 2017 and 2018 to study the interactions between composted sludge and K fertilizer in order to improve the severe conditions of calcareous soil conditions and provide more detailed information on the fertilizer value of composted sludge applied to cotton, particularly phosphorus as the availability of this tends to be restricted on such calcareous soils. The experiments were conducted in on a private farm Bagdad village Nubaria, Alexandria governorate (28 km Alex-Cairo desert road). The soil under the present investigation was

Table 1: A) Mechanical soil analysis

Clay (%)	Silt (%)	Sand (%)	Texture class
23.3	22.5	54.2	Sandy clay loam

A: Chemical soil analysis

				Total concentration ($mg\ kg^{-1}$)											
pH	EC ($dS\ m^{-1}$)	OM (%)	$CCaCO_3$ (%)	N	P	K	Fe	Mn	Zn	Cu	Cr	Co	Cd	Pb	Ni
8.14	0.39	1.45	33.0	2300	89	3393	11600	106.0	17.8	5.8	6.90	12.5	0.50	4.52	40.0

Table 2: Compost analysis and nutrient addition of composted sludge applied to cotton

									Total concentration ($mg\ kg^{-1}$)							
ds (%)	VS (% ds)	OM (% ds)	pH	EC ($ds\ m^{-1}$)	Total content (% ds) N	Total content ($mg\ kg^{-1}$ ds) P	K	Fe	Mn	Zn	Cu	Ni	Cd	Pb	Cr	Co
87.2	42.8	25.5	7.7	1.82	1.59	0.19	0.30	1.55	132	488	186	46	0.60	43	47	14
Mistrial Decree 222/2005*								-	-	>2800	>1500	>420	>39	>300	>1200	

*Source: The Egyptian Code for Wastewater and Sludge Reuse in Agriculture (222/2005)

characterized by high calcium carbonate and low fertility status that could influence crop growth. The physical and chemical analysis of the soils are presented in Table 1

The experiment included 8 treatments which were the combinations of 4 compost rates i.e.; 0, 5,10 and 15 $m^3\ fd^{-1}$ as well as 2 additional K fertilizer rates 0and 24 kg K_2Ofd^{-1}. The experimental design was Split-Plot Design with 4 replicates. The organic manure occupied the main plots and K in the sub plots. The composted sludge analyses used in the trial are presented in Table 2 (means of two seasons of study).

The experimental area was ploughed twice, ridged and divided to experimental unites each of $21m^2$. Composted sludge rates were applied after manually calibration on a volumetric basis to the assigned plots. In order to secure homogenous incorporation with the soil surface layer, a rotary cultivator was used. Cotton variety was Giza 70 seeds were sown in the experimental plots on 22 April 2017 and 27 April 2018, respectively Sowing was done by hand and seed rate was30 kg fd^{-1}. P and N fertilizers were applied as a common application. Phosphatic fertilizer was applied assuperphosphate at 15.5% P_2O_5 kg fd^{-1} during seed bed preparation while nitrogen fertilizer was applied at 64 kg fd^{-1} in two equal doses at 21 and 35 days from sowing. Potassic fertilizer levels were applied at0 and 24 kg $K_2O\ fd^{-1}$ before the second irrigation. Irrigation was carried out as followed in the district twice a week by drip irrigation. Weeds were controlled by manual cultivation after 20 and 34 days from sowing. Harvest date was29 and 27 October in 2017 and 2018, respectively. The following characters were determined:

- Plant height (cm)
- Branches per plant
- Straw yield (t fd^{-1})
- Seed cotton yield (t fd^{-1})
- Biological yield (t fd^{-1})

Residual Effect of Composted Sludge on Subsequent Crop: Wheat was sown on the trial area previously cropped with cotton in both seasons to examine the residual value of a summer application of composted sludge to the following winter crop. Four replicate plots were harvested from the areas treated with 5, 10 or 15 $m^3\ fd^{-1}$ of composted sludge and the grain, straw and biological yields were determined by quadrate.

Chemical analyses for soil (0-30cm depth) for some selected treatments(control and the heavy applications rates of inorganic and organic fertilizers applied) was carried out after the second season harvest where a composite sample of each treatment was taken from 4 replicates.

The chemical analyses of soil, manure and leaves were carried out according to the methods described by [33] and [34]. The data were statistically processed using software package (MSTAT-C) [35]. LSD 5% test was adopted foe means co.

RESULTS AND DISCUSSION

Fertilizer Inputs of Composted Sludge: The chemical analysis of the composted sludge is given in Table 2. It is clear from the table that composted sludge parameters comply with the Egyptian Code for Sludge Reuse, (2005).

Table 3: Fertilizer inputs of composted sludge application

Application Rate m^3fd^{-1}	N	P	K	Fe	Mn	Zn	Cu	Ni	Cd	Pb	Cr	Co
	$Kgfd^{-1}$				gfd^{-1}							
5	5.6	0.7	10.5	5.425	462	1708	651	161	21	150.5	164.5	49
10	11.1	1.33	21	10.85	924	3416	1302	322	42	301	329	98
15	16.7	2.0	31.5	16.275	1386	5124	1953	483	63	451.5	493.5	147

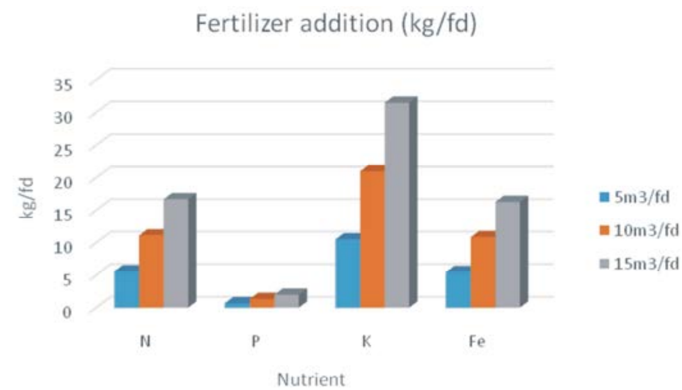

Fig. 1: NPK and Fe additions to cotton according to composted sludge rate

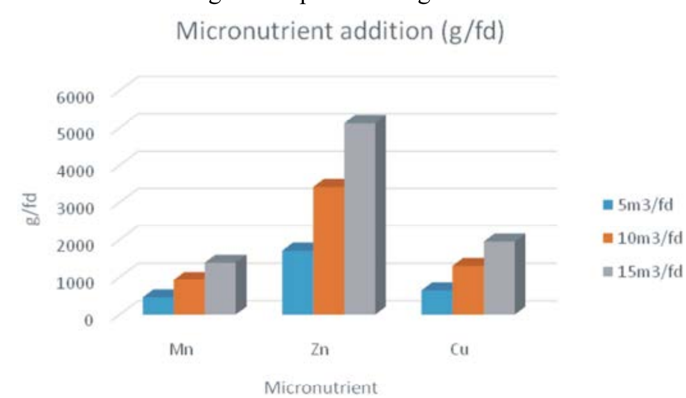

Fig. 2: Micronutrient additions to cotton according to composted sludge rate

Macro and micronutrients applied through composted sludge application are presented in Table 3. Composted sludge supplied cotton with 5.6-16.7, 0.7-2.0and 10.5--31.5 kg of N,P and K, respectively (Fig. 1) according to the rate of application. Micronutrient addition were 5.4--16.3 kg of Fe as well as 462-1386, 1708-5124 and 651-1953g of Mn, Zn and Cu, respectively (Fig. 2). Heavy metals Ni, Cd, Pb, Cr and Co additions were too small (Fig. 3) and could not pose any threat according to the alkaline nature of the soil and high pH values. Organic materials hold great promise due to their local availability as a source of multiple nutrients and ability to improve soil characteristics. According to several authors the improvement of fertility and quality of soil requires the input of organic materials [36-38]. These results are in accordance with the results of [39, 40] who reported that sludge has improved the nutrient content of the crops, including that of the trace elements, which are often deficient in crops and the human diet in Egypt. Increases in the heavy metal content of plants were negligible due to the calcareous soil conditions of Egypt.

Cotton Yield: The statistical analysis of yield data for cotton showed that the effects of K and compost applications on crop performance were complex and interactive and varied markedly depending on the yield parameter under consideration (Tables 2 and 3). Thus, no significant interaction between K supply and rate of compost addition was detected by ANOVA for straw production. This crop component responded positively to K and was increased on average by more than 50 % with fertilizer application compared with plots where K was

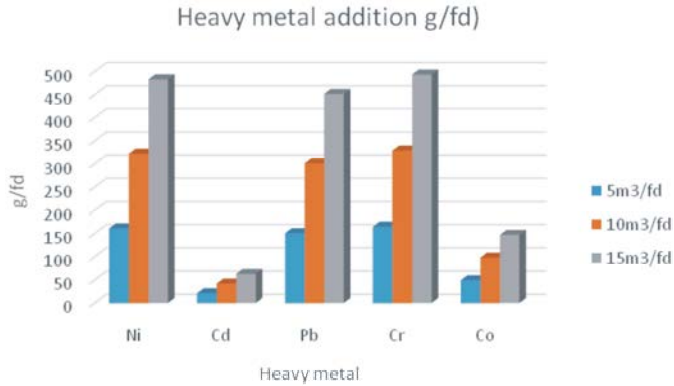

Fig. 3: Heavy metal addition (g/fd) to cotton according to composted sludge rate

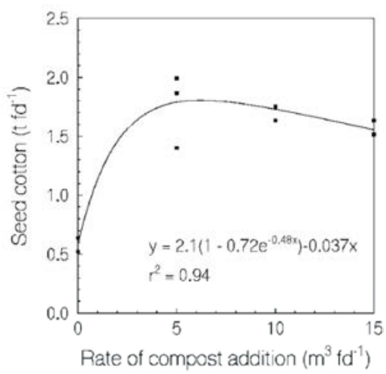

Fig. 4: Seed cotton yield in relation to volumetric rate of sludge compost addition

withheld. There was no evidence of a yield benefit in straw production due to compost application. FAO reports [41] mentioned that at low to moderate yields, cotton can be grown without K application, but it should be applied for higher yields, particularly on low K soils. Recommended rates are similar to those for P at 30-100 kg K2O/ha. In some parts of the world, P and K deficiencies occur where rapidly growing crops are furrow irrigated. This also leads to a loss of bolls in a syndrome known as "premature senescence". Cotton is subject to a number of other nutritional problems.

By contrast, compost increased seed cotton yield and the optimum rate of application to soil for cotton production was 5 m^3 fd^{-1} (Figure 1). However, there was no statistically significant effect of K fertilizer on the yield of seed cotton without compost, but K significantly reduced seed cotton production when applied with the optimum dressing of composted sludge. This effect appeared to be related to the increase in vegetative growth associated with K fertilizer application to the crop. Composted sludge, on the other hand, had a beneficial effect on seed cotton yield and increased production of this important economic yield parameter by up to 200 % compared to the untreated control or soil receiving only K fertilizer. Aneela *et al*. [42] reported a remarkable improvement in cotton yield and quality owning to K fertilization. It has been reported that severe K deficiency in cotton can decrease yield and reduce fiber quality by decreasing the expansion of leaf area and CO2 assimilation capacity [43]. The K nutrition can be improved by using appropriate K source and optimizing correct application method [44, 45]. Emara [46] under Egyptian conditions concluded that the early planting in combination with the high N fertilizer level (60kg N/fad) and foliar application with potassium silicate organic three times at squaring, floret initiation and two weeks after flowering obtaining the high productivity of Egyptian cotton (Giza 86) under clay loam soil. In addition, NPK are very important content nutrient; nitrogen for growth, phosphorus for floret incretion and potassium for distribute water and absorbed nutrients through xylem and also, distribute the photosynthetic substance through phloem to each part of the plant and using K-organic silicate more useful. Potassium influenced cotton lint yield by affecting late season growth. Potassium fertilization increased cotton yield by 9% in 2 yr of a 3-yr [47].

Residual Effect on Subsequent Wheat Crop: The yield performance data presented in Table 6 show that there were agronomically significant benefits from the previously applied sludge compost. Grain yield was increased by 20 % at the 5 and 10 m^3 fd^{-1} rates and was twice that of normal farmer practice at the highest rate of application of 15 m^3 fd^{-1}. The optimum straw yield was obtained at an application of 10 m^3 fd^{-1}, but the maximum grain production occurred at the highest rate of compost

Table 4: Statistical probabilities and significance of treatment effects and interactions for cotton yield components from two-way ANOVA,

Source of variation	Plant height	Branches per plant	Straw yield	Seed cotton yield	Biological yield
Main effects					
Potassium	<0.001***	<0.001***	<0.001***	0.025*	<0.001***
Compost rate	0.256ns	0.131ns	0.009**	<0.001***	0.008**
Interaction					
Potassium x compost rate	0.540ns	0.877ns	0.477ns	<0.001***	0.856ns

Probability values in bold have attained statistical significance

Table 5: Cotton yield components (main effect and interaction mean values

Treatments ---						
Compost	Plant height (cm)	K application	Branches per plant	Straw yield (t fd^{-1})	Seed cotton yield (t fd^{-1})	Biological yield (t fd^{-1})
0 m^3 fd^{-1}	-K	124b	12.4b	3.33bcd	0.58c	3.91c
0 m^3 fd^{-1}	+K	140ab	14.2ab	4.95a	0.68c	5.63ab
5 m^3 fd^{-1}	-K	123b	13.9ab	2.09d	1.78a	3.87c
5 m^3 fd^{-1}	+K	147a	16.2a	4.04abc	1.19b	5.23abc
10 m^3 fd^{-1}	-K	134ab	13.4ab	2.82cd	1.72a	4.54bc
10 m^3 fd^{-1}	+K	146a	15.6ab	4.47ab	1.36ab	5.83ab
15 m^3 fd^{-1}	-K	131ab	13.5ab	3.47bcd	1.54ab	5.01abc
15 m^3 fd^{-1}	+K	147a	16.5a	4.48ab	1.78a	6.26a
Potassium						
Without K		128b	13.3b	2.93b	1.41a	4.34b
With K		145a	15.6a	4.48a	1.25b	5.74a
Compost rate						
0		132a	13.3a	4.14a	0.63b	4.77b
5 m^3 fd^{-1}		135a	15.1a	3.07b	1.49a	4.55b
10 m^3 fd^{-1}		140a	14.5a	3.65ab	1.54a	5.19ab
20 m^3 fd^{-1}		139a	15.0a	3.97a	1.66a	5.64a

Values for each mean category within a column, followed by the same letter, are not significantly different at P=0.05

Table 6: Residual value of summer applied composted sludge to wheat in the following winter season

Treatment to previous crop	Straw yield (t fd^{-1})	Grain yield (t fd^{-1})	Biological yield (t fd^{-1})	Grain yield (% increase above farmer practice)
Recommended practice (control)	7.09c	1.70b	8.79ab	-
Compost 5 m^3 fd^{-1}	4.22d	2.02b	6.24b	19
Compost 10 m^3 fd^{-1}	11.49a	2.05b	13.52a	21
Compost 15 m^3 fd^{-1}	9.13b	3.37a	9.83ab	98
Probability	<0.001***	<0.001***	0.017*	

Table 7: Chemical analysis of soil after cotton (means of sludge treatments), Trial 2.4.1, Baghdad (Units: EC as dS m^{-1}; OM and $CaCO_3$ as %; other elements as mg kg^{-1})

Sludge (m3 fd^{-1})	pH	EC	OM	CaCO3	N	P	K	Fe	Mn	Zn	Cu	Cr	Co	Cd	Pb	Ni
0	8.21	1.29	1.54	25.3	2183	128	3225	10991	91.1	18.4	6.4	8.23	12.74	0.53	4.74	40.0
5	8.21	0.96	0.84	22.8	2825	107	3552	6766	107.3	23.5	9.2	8.68	13.56	0.43	5.96	38.9
10	8.15	1.17	1.82	28.5	1522	199	3013	20094	83.1	23.1	9.0	7.65	11.28	0.38	4.86	33.8
15	8.25	0.85	1.57	24.4	2575	124	3366	10578	97.9	30.3	10.1	8.73	12.90	0.50	5.68	40.5
EC Directive 86/278/EEC										150-300	50-140			1-3	50-300	30-75

addition. Organic manure could help in decreasing wheat mineral fertilizer and was found to be enhancing growth and productivity of wheat [41, 42], they found that long-term addition of organic manure has the most beneficial effect on grain yield of wheat and maize. Also, Tejada and Gonzalez [43] showed that compost application in 2-continuous years increased the number of grains/spike, 1000 grain weight and the number ofspikes and grain wheat yield. This positive effect was mainly due to a better N supply with the compost application.

Soil Characteristics: Soil samples were taken from each plot after cotton harvest and bulked by treatment prior to chemical analysis, the results of which are presented in Table 7. A summary of the main compostedsludge rate effects are summarised in (Table 7). The soil is highly calcareous, with an average $CaCO_3$ content of 25.2 % and a mean pH of 8.3, which will reduce the availability of trace elements for crop uptake (Figs. 5-6). This was the first application of sludge compost to this soil and so the effects on soil quality would be expected to be small. There were few obvious trends in the data that could be

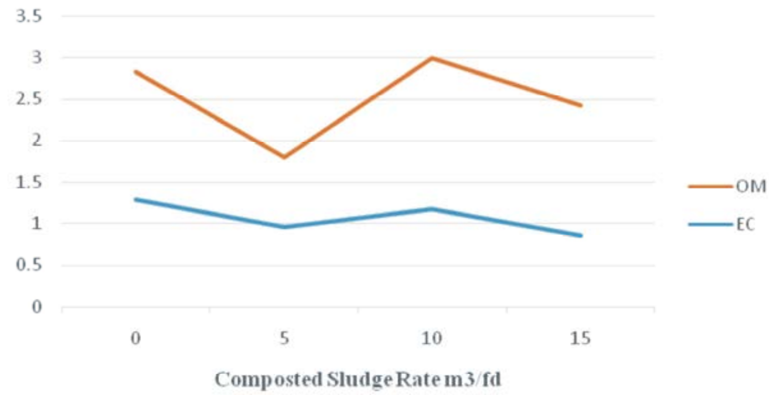

Fig. 5: Effect of Comosted Sludge Application Rate on Ec and OM

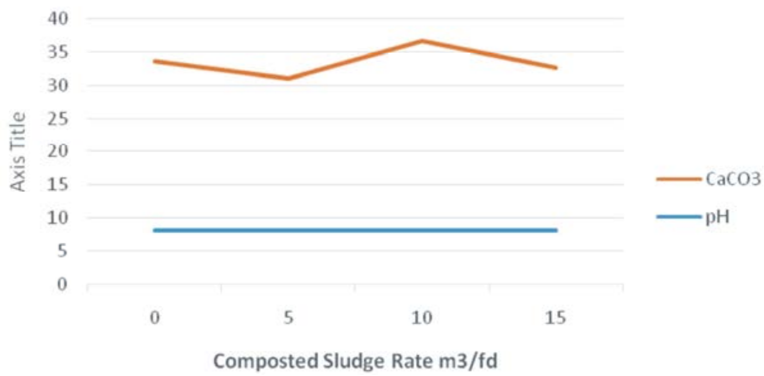

Fig. 6: Effect of Comosted Sludge Application Rate on pH and CaCO[3]

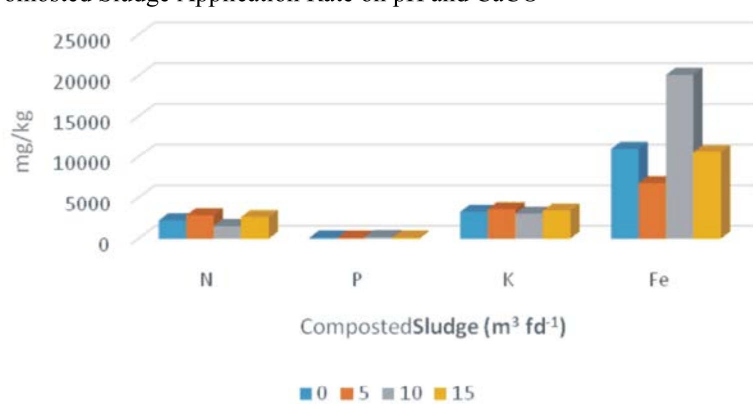

Fig. 7: Effect of composted sludge application on N,P,K and Fe soil concentrations

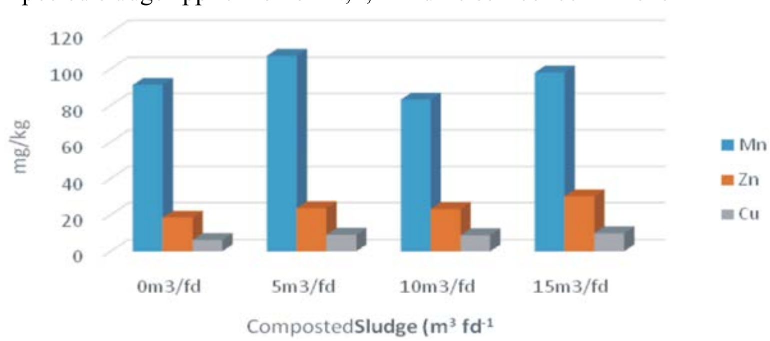

Fig. 8: Effect of composted sludge application on Micronutrient concentrations

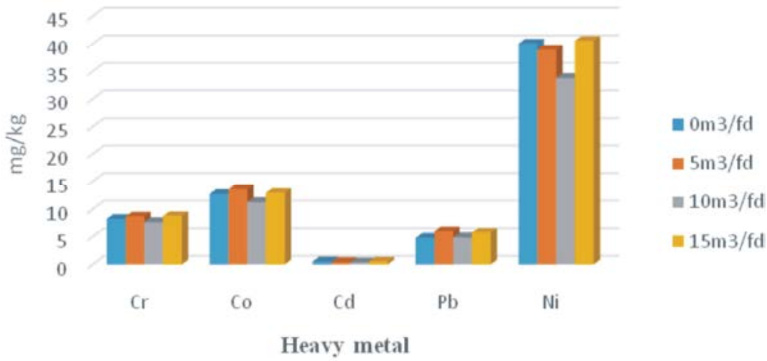

Fig. 9: Effect of composted sludge application on heavy metal concentrations

attributed to sludge, although there were apparent rate related effects on Zn, Cu and Pb (Figs. 7-9). The annual loading rates of heavy metals are minimal according to the EC Directive 86/278/EEC EC which do not impose treat to the subsequent crops for long decades.

CONCLUSION

Calcareous soils have low organic matter status and poor physical condition and the ameliorating effects of organic matter additions on physical properties of desert soils have a major positive benefit on crop productivity which reflected on cotton yield and the subsequent wheat crop. Composted sludge have complex chemical composition and supply plant nutrients and trace elements that are grossly deficient in sandy calcareous desert soils. Such soils are impoverished in most aspects of the nutrient requirements of crops.

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