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Effect of Organic Matters Ameliorating on Growth, Yield and Nutritional Status of Grapevine in Newly Reclaimed Soil

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Abstract: Two field trials were carried out in the winter of seasons on a private farm in the Belbais District, 8 km east of Bilbeis, south of Ismailia canal Sharkia Governorate, in two successive seasons 2017 and 2018. The objective of this trial was to evaluate the effect of sludge on well-established vines grown in a newly reclaimed saline sandy calcareous soil (EC 6.3 ds m^{-1}), $CaCO_3$ 5.6-19% and to determine the potential of sludge as a replacement for the conventional application of FYM. The results showed substantial NPK additions due to the organic manures application per feddan. Heavy metals addition through organic amendments application to grapevine were too small and did not pose any threat to the soil or the plants. Fruit yields from all the trials were increased by the organic amendments relative to inorganic fertilizer and the untreated controls. The quality of fruit, measured in terms of its refractive index, was similar for both the sludge and FYM treatments. Crop yields showed that the differences in the crop response to the different manures were apparent on a cumulative yields basis. Digested sludge performed as well as FYM, although raw sludge was less effective at increasing fruit yields than FYM. Raw sludge applied at a rate of 10 m^3 fed^{-1} gave an equivalent yield to the inorganic fertilizer treatment, but fruit production was significantly smaller than for the equivalent rate of FYM in this trial. Chemical analysis of young grapevine leaves indicated that there were no significant effects on macronutrient concentrations (NPK) or on Cu, although there were effects on Fe, Mn and Zn, but these do not appear to follow any pattern. It could be concluded from this study that there were clear beneficial effect due to organic manures to grapevine which reflected on growth and yield characters. In addition, the sludge application to grapevines and do not impose threat to plant and soil.

Key words: Grapevine · Organic matters · Yield · Newly reclaimed soil

INTRODUCTION

The soils of arid and semiarid regions are considered as problem soils in Egyptwhich havelow organic matter content and need organic amendments to improve their physicochemical and biological properties and thus their productivity and natural fertility [1-3]. Due to the lack of organic manures it is essential to find alternative substances like different sludge products,garbage, food processing wastes and etc. Sewage sludge produced worldwide have made cropland application of this residue an attractive disposal option. Usually, it is rich in organic matter (OM) and plant nutrients such as nitrogen (N), phosphorus (P) and calcium (Ca) [4] and can improve soil physical, chemical and biological properties, such as porosity, aggregate stability, bulk density, soil fertility, water movement and retention [5]. Application of sludge by mixing it with top 30 cm soil layer was found to be more effective in improving soil physical, chemical and fertility conditions of the soil. Moreover, using of sludge as organic manure is considered as a source of nutrients that required for plant which led at the end to increase the

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growth and the yield of cucumber [6]. Sewage sludge application to arable and fruit crops has significantly increased yields in most of the trials, without compromising crop chemical quality and value. Crops treated with sludge have performed at least equal to, or better than normal farmer practice [7]. Digested sludge is usually more effective as a soil amendment in increasing crop yield compared with raw sludge. The optimum rate of application for many crops appears to be about 10 m^3 fed^{-1} although there is evidence from some of the trials that the optimum rate may be lower (5 m^3 fed^{-1}) when sludge is applied regularly in each season [7]. Application of sludge forms are entirely consistent with N equivalency values measured in other experiments within the field trials programme. This implies that sewage sludges are relatively consistent materials for use as fertilizers and soil amendments in agriculture. Moreover,there is increasing evidence from the trials that sludges and FYM may have significant residual value in reclaimed desert soils for increasing the productivity of subsequent crops after application.Noincreases in heavy metal concentrations in soils were detected in the field and fruit trials; this may be anticipated due to relatively low concentrations of heavy metals in Cairo sludges and the small additions made to date. Long-term applications of sewage sludge when applied at normal agronomic rates are necessary to modify the chemical composition of treated agricultural soil [7].

In Egypt, Substantial quantities of sludge are being produced from Greater Cairo as the infra-structure for wastewater treatment became fully operational. Agricultural utilization potentially offers a significant opportunity to beneficially recycle the valuable macro-nutrients, trace elements and organic matter contained in the sludge to farmland for crop production as well as providing a cost-effective and sustainable outlet for the residual sludge produced by wastewater treatment. In addition to these beneficial attributes, however, it is widely recognised that sludges also contain certain potentially toxic contaminants and pathogenic agents which could place human health and the environment at risk unless effectively treated, controlled and managed.

Grape (*Vitisvinifera* L.) is considered the first major fruit crop in its production all over the world. In Egypt, grapes rank second among fruit crops while citrus being the first [8]. Mineral fertilizers and other chemicals that commonly used in agricultural production, not only have harmful effects on the environment, but also they can alter the composition of fruits, vegetables and root crops [9]. When grapes are grown in saline or calcareous soil conditions it suffers from weak water retention, low availability of macro and micro nutrients, low productivity and low quality product.Organic fertilizers instead of mineral fertilizers has become potentially attractive because of the harmful effect and high cost of mineral fertilizers [10]. In addition, the organic materials improve soil structure, aeration and retention of moisture and reduce soil pH [11]. Organic fertilization is another option for supplying macro and micro nutrients necessary for plant growth [12]. Organic fertilization increased growth and improved nutritional status of grapevines [13]. Fertilizing various grapevine cultivars with organic manures beside the inorganic nitrogen source was accompanied by improving growth and leaf mineral content as well as yield and berry quality than using nitrogen as an inorganic source only [14, 15].

Therefore, the objective of this work al is to evaluate the effect of sludge on well-established vines on grown on reclaimed desert land and to determine the potential of sludge as a replacement for the conventional application of FYM.

MATERIALS AND METHODS

Two field trials were carried out in the winter of seasons on a private farm in the Belbais District, 8 km east of Bilbeis, south of Ismailia canal, Sharkia Governorate, in a newly reclaimed saline sandy calcareous soil (EC 6.3 ds m^{-1}, Ca CO_3 5.6 -19 %), (Table, 1). The irrigation water is moderately saline, at around 2,000 mg TDS l^{-1}, and the soil suffers from residual and increasing salinity. The sludge applied annually by the pit method. The pits are positioned within the row between every other vine and in subsequent years, the position of the pit alternated between either side of the vines. The analysis of soil and organic manures were conducted according to [16, 17].

In order to determine the actual agronomic value and fertilizer inputs of the different manures, samples of different manures were collected in the field prior to application and were analyzed. Typical inputs of manure components and nutrients based on the average composition data were calculated on a volumetric and converted to mass addition basis. Actual N, P and K loadings in manures as well as micronutrients inputs were calculated. The calculation of nitrogen appliedper vine were 120 and 240 g for raw sludge, 280 and 560g for digested sludge and 33 and 66 g per vine for FYM at 10 and 20 kg organic manure per vine, respectively.

Table 1: Physico-chemical properties of soil samples from profile inspection pits at the field trial site.

						Cation concentration (me l^{-1})				Anion concentration (me l^{-1})		
Depth (cm)	Gravels (% >2mm)	$CaCO_3$ (%)	Gypsum (%)	pH	EC (dS m^{-1})	Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	HCO_3^{-}	Cl^{-}	SO_4^{2-}
0-20	25.6	5.6	0.23	8.81	6.3	30.2	11.1	25.1	1.2	2.4	29.3	35.9
25-80	28.8	18.0	0.09	8.66	7.1	35.6	12.1	30.4	1.7	3.6	28.1	48.1
80-150	19.2	19.2	0.14	8.83	7.5	40.1	9.3	33.6	1.3	3.8	35.1	45.4

Table 2: Sewage sludge sources and chemical analysis.

Manure	Source	N	P	K	Fe	Mn	Zn	Cu	Cr	Cd	Pb	Ni	Co
Raw sludge	Berka	1.20	0.72	0.14	0.78	283	403	160	27	11.5	156	58	22
Digested sludge	Zenein	2.80	1.59	0.15	1.54	400	890	220	30	3.7	214	10.5	56
FYM	Local	0.33	1.23	1.11	0.21	300	132	37	30	8.7	10	10	25
Egyptian cod 2005*	-	-	-	-	-	2800	1500	1200	39	300	420	-	

*Maximum limits for principle heavy metal concentrations in sewage sludges (mg kg^{-1} ds) utilized on agricultural land

Grapevariety Ninette, was used and vine spacing was 2 m between rows, 3 m between vines in row. Dates of sludge applications were,1 February 2017 and 3 February 2018. The inorganic fertilizers were applied to the soil at the start of growing season as calcium superphosphate (15.5% P_2O_5) and elemental S. The rate of fertilizer application-formulation containing 4:1 by weight of calcium superphosphate and sulphur was applied. The fertilizers applied by irrigationwere ammonium nitrate, potassium sulphate; weekly flushing with phosphoric acid. While by foliar spray the fertilizer applications were trace elements (chelated Zn 14% and Fe at 200 g fed^{-1}, urea 100 g fed^{-1}dissolved in 200l). Recommended rate = 0.2 kg of formulationvine^{-1}. The date of fertilizer application (superphosphate and sulphur) 18 February 2017 and February 2018. Trace elements applied 3 times. The type of irrigation was Drip and the frequency of irrigation was Daily following normal practice. The experimental design was complete randomized block design. Number of treatments was 8,number of replicate plots per treatment was 4 and Number of vinesplot^{-1} was 60 (single row). Total number of vines was 1,680 and the total trial area was 2.5 fed (1.05 ha).

Sampling Procedure: Five replicate vinesplot^{-1} were sampled andleaf samples were taken for analysis of major and trace elements at expansion. Plant nutrients at leaf expansion on all plots = 32 samples while heavy metals on leaf samples (composite by treatment). The nutrient concentration was determined according to [17].

- Harvest date was7 July 2017 and 15 July 2018 and the following characters were determined:
- Number bunchesvine^{-1}
- Bunch length
- Mean Weightbunch^{-1}
- Total yield plot^{-1}and converted to feddan

Plant Chemical Analysis: Sugar analysis of fruit in field by refractometer on all plots.

Statistical Analysis: The analysis of variance of complete randomized block design was carried out using MSTAT-C Computer Software [18], Means of the different treatments were compared using the least significant difference (LSD) test at P<0.05.

RESULTS AND DISCUSSION

Macronutrients Applied to Grapevine Through Organic Manures: Data presented in Table (3) and Fig. (1) show NPK additions due to the organic manures application per feddan. Nitrogen addition fed^{-1} ranged between 23.1 and 392kg for FYM and Digested sludge at 7 and 14 t fed^{-1}. While P rangedbetween 50.4 and 222.6 for raw and digested sludge at 7 and 14 tfed^{-1}, respectively. Reversal magnitude was reported for Kwhere FYM added the greatest input of K at both manure application rates than those applied by sludge at any rate.

Regarding the micronutrient and heavy metals addition through organic amendments application to grapevine data in Table (4) and Figs. (2 and 3) show that Fe applied to per feddan ranged between (54.6-325.6), Mn between (1.981-5.600), Zn (0.924-12.460), Cu (0.259-3.080), Cr(0.189-0.420), Cd (0.0259-0.121), Pb (0.070-2.996) and Ni (0.070-0.812) kg fed^{-1} according to the manure type and level applied to grapevine. Except Cd addition per feddan, digestedsludge at 20 kgvine^{-1} added the greatest quantities of micronutrients and heavy metals. However such quantities are too small and did not pose any threat to the soil or the plants.In this respect Elsokkary and El-Keiy [19] and Elsokkary *et al*. [20] found that sludge application increased the concentrations of (P, K, Fe, Mn, Cu, Zn, Co, Ni, Pb and Cd) in leaves and grain of alfalfa, wheat, fababean and

Table 3: Macronutrients applied to grapevine through organic manures.

Manure ratekg tree-1	Manure rate fed-1(t)	N	P	K
Raw sludge 10 kg	7	84.0	50.4	9.8
Raw sludge 20 kg	14	168.0	100.8	19.6
Digested sludge 10 kg	7	196.0	111.3	10.5
Digested sludge 20 kg	14	392.0	222.6	21.0
FYM 10 kg	7	23.1	86.1	77.7
FYM 20 kg	14	46.2	172.2	155.4

Table 4: Micronutrient and heavy metals addition through organic amendments application to grapevine.

		g fed^{-1}						
Manure	Fe kg fed^{-1}	Mn	Zn	Cu	Cr	Cd	Pb	Ni
Raw sludge 10 kg	54.6	1981	2821	1120	189	80.5	1092	406
Raw sludge 20 kg	109.2	3962	5642	2240	378	161.0	2184	812
Digested sludge 10 kg	107.8	2800	6230	1540	210	25.9	1498	73.5
Digested sludge 20 kg	325.6	5600	12460	3080	420	51.8	2996	147
FYM10 kg	14.7	2100	924	259	210	60.9	70	70
FYM20 kg	29.4	4200	1848	518	420	121.8	140	140

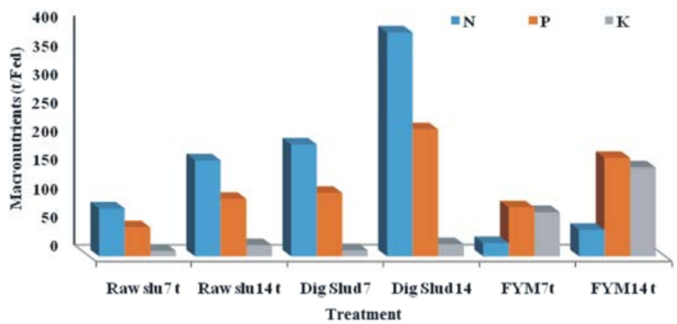

Fig. 1: Macronutrientsapplied to grapevine by different organic manures.

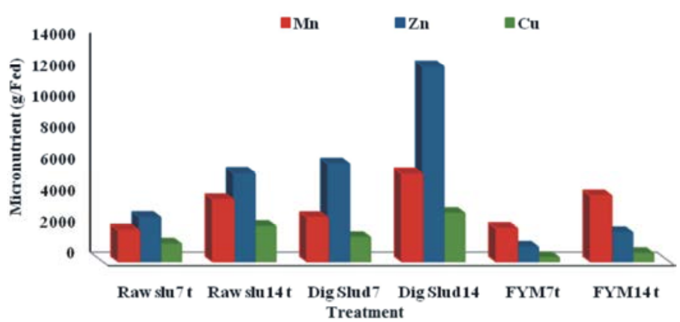

Fig. 2: Micronutrients applied to grapevine by different organic manures.

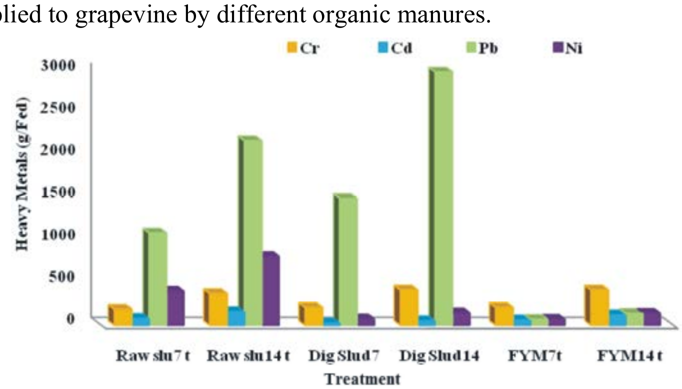

Fig. 3: Heavy metals addition of organic manures applied (gfed^{-1}).

Table 5: Growth characteristics and yield of grapevine.

Treatment	Rate vine^{-1}	Grape yield fed^{-1} (t)	No. of bunches vine^{-1}	Mean bunch weight (g)	Total soluble solids (% refract.)	Total yield vine^{-1} (kg)	Length of fruiting laterals (cm)	No. of branch vine^{-1}	No. of main laterals vine^{-1}
Control	Untreated	1.46	5.35	328	18.32	2.09	96.07	12.20	4.10
Inorganic fert.	Rec. rate	3.84	12.05	456	18.82	5.49	112.40	15.60	5.65
Raw sludge	10 kg	3.61	11.45	450	18.76	5.15	117.48	16.30	4.80
Raw sludge	20 kg	5.51	15.95	505	16.26	7.88	133.57	19.65	6.65
Digested sludge	10 kg	4.48	12.85	489	18.47	6.39	122.03	18.12	6.48
Digested sludge	20 kg	6.66	17.30	565	17.55	9.52	123.35	17.65	6.55
FYM	10 kg	4.92	13.85	517	15.3	7.03	117.48	16.90	5.90
FYM	20 kg	5.13	12.25	596	17.71	7.32	117.05	16.85	5.35
F probability		<0.001***	<0.001***	0.001**	0.010*	<0.001***	0.004**	0.003**	<0.001***
LSD at 0.05		1.27	3.97	166	1.96	1.81	14.88	2.99	1.1
CV (%)		37.34	32.95	19.93	9.52	37.33	11.31	16.72	19.31

Table 6: Yield characteristics of grapevine

Treatment	Grape yield fed^{-1}(t)	No. bunches vine^{-1}	Bunch weight (g)	Yield vine^{-1} (kg)	Length of fruiting laterals (cm)	No. of branches vine^{-1}	No. of main branch laterals vine^{-1}
Control	1.21	5.7	313.8	1.80	127.4	20.0	3.93
Fertilizer	4.01	12.1	475.0	5.73	125.6	19.1	5.68
RS 10 kgvine^{-1}	3.94	12.5	451.5	5.63	124.5	18.5	4.78
RS 20 kg vine^{-1}	5.62	15.9	510.0	8.03	121.3	18.4	6.83
DS 10 kg vine^{-1}	4.76	13.6	495.0	6.80	118.8	16.2	6.48
DS 20 kg vine^{-1}	6.39	16.6	560.0	9.13	116.1	17.5	6.75
FYM 10 kg vine^{-1}	5.22	14.4	517.5	7.46	109.9	15.1	5.95
FYM 20 kg vine^{-1}	5.48	12.8	610.0	7.83	96.0	11.8	4.95
Grand mean	4.58	12.9	491.6	6.55	117.4	17.1	5.67
CV (%)	35.4	26.3	18.7	35.1	9.2	17.5	21.30
F probability	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***
LSD at 0.05	1.50	3.1	109.1	2.13	12.1	4.4	1.87

soybean. However, no visual symptoms of metal toxicity showed on the different plant species. Also, Hussein [6] reported that sludge application significantly increased the Ca, Mg, K, N, Fe, Mn, Cu and Zn in corn, sugar beet and cotton plants.

Grape Vine Growth and Yield Characteristics: Data presented in Table (5) point out to fruit yield and vine productivity indicators measured. The ANOVA conducted across all treatments indicated that statistically significant differences were present within each of the crop growth characteristics measured. With the exception of sugar content, the unamended control plots performed least well for all growth parameters. Analysis of the data pertaining to the organic amendments alone, indicated that there were no statistically significant differences in the crop characteristics as a result of the different manure types, but the yield from the highest rate of digested sludge almost doubled the yield of grapes compared with fertilizer alone. Grape yield, bunch weight and total yield per vine were significantly greater in those plots which had received 20 kg manure per vine compared with 10 kg manure per vine. This would suggest that applications at the higher rate would be worthwhile in terms of crop productivity, at an operational scale.

The second harvest from this trial was taken in July 2018 and the crop yield and growth characteristics data are presented in Table (6). This trial has been treated annually for two years with either 10 or 20 kg per vine sludge or FYM. Testing of the data by ANOVA indicated that for all growth parameters measured, the untreated control plots performed least well. Crop yield per feddan from the inorganic fertilizer treatment was not significantly different from the organic manures applied at 10 kg per vine. However, all the organic materials applied at 20 kg per vine gave rise to significantly larger yields than all other treatments (Figs. 4 and 5). Comparison of the influence of the organic amendments alone on crop growth indicated that there was no statistically significant difference between the effect of raw and digested sludge or FYM on any of the crop characteristics. All the manures produced significantly higher yields, more bunches per vine and larger individual bunches when applied at 20 kg per vine compared with 10 kg. Crop yields

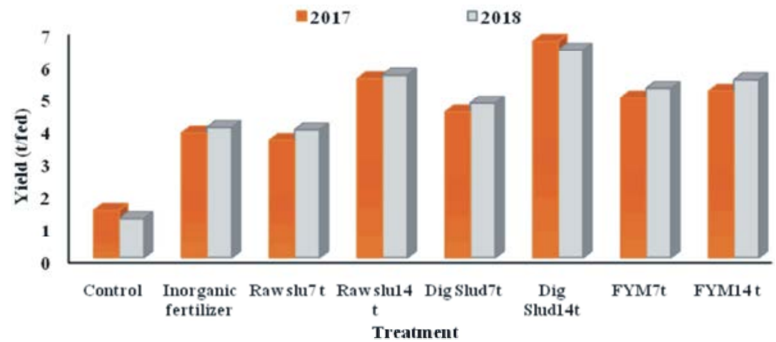

Fig. 4: Effect of different organic manure levels on grape yield (t fed^{-1}).

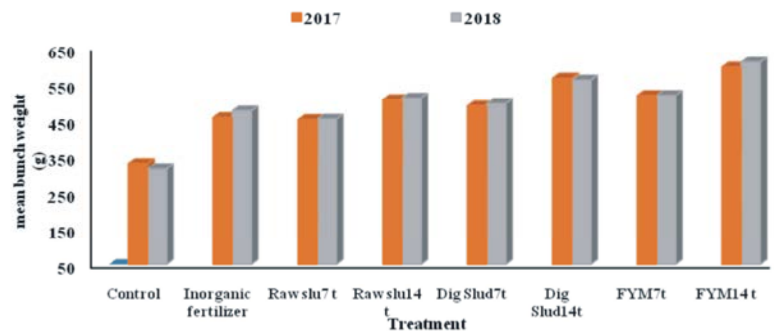

Fig. 5: Effect of different organic manure levels on grape mean bunch weight (g).

and the responses to the applied treatments were consistent with those obtained in the previous year and suggest that the larger rate of 20 kg per vine applied annually would be worthwhile in terms of increased crop productivity. Shaheen *et al*. [8] concluded that requirements for superior seedless grapevines by organic compost and bio-fertilization are sufficient to improve nutritional status of grapevines and gave a suitable yield with high bunch properties and quality of the berries. In addition organic fertilization increased growth and improved nutritional status of grapevines [13]. Fertilizing various grapevine cultivars with organic manures beside the inorganic nitrogen source was accompanied by improving growth and leaf mineral content as well as yield and berry quality than using nitrogen as an inorganic source [12-15]. Further monitoring of this trial would be worthwhile to evaluate longer term cumulative and residual effects, so as to identify optimum rate and frequency of application. The addition of sludge to soil is known to improve the soil physical properties as evidenced by (a) increasing water content, (b) increasing water retention, (c) enhanced aggregation, (d) increased soil aeration, (e) greater permeability, (f) increased water infiltration and (g) decreased surface crusting. Antoline *et al*. [21] reported that application of sludge decreased soil pH and increased total soluble salts, organic carbon and cation exchange capacity of the soil. Also, they found that application of sludge increased soil DTPA-extractable heavy metals (Cd, Cu, Mn, Pd and Zn) and increased $N\text{-}NH_4^+$ content of the soil. Mendoza *et al*. [22] reported that organic matter and extractable (Cu, Zn, Ni, Pb, Mn and Fe) increased with addition of sludge to the soil while soil pHdecreased.

Chemical Analysis: Chemical analysis of young grapevine leaves (sampled 27 May) was carried out to assess any trace element deficiencies, since this was an observed problem on this farm and common on many reclaimed soils. The results are summarised in Table (7). There were no significant effects on macronutrient concentrations (NPK) or on Cu, although there were effects on Fe, Mn and Zn, but these do not appear to follow any pattern. The high concentrations of Zn in the leaves are probably as a result of the foliar application of trace elements. Increased N contents in the tissues of grapes grown in the season after Digested sludge application, compared with normal farmer practice, show that sludge N also has important residual value. The slow release of N from sludge has three potential benefits:

Table 7: Chemical composition of grape leaves

	Macronutrients (%)			Micronutrients and heavy metals (mg kg^{-1})								
Treatment	N	P	K	Fe	Mn	Zn	Cu	Ni	Cd	Pb	Cr	Co
Control	1.99	0.20	1.11	77.2	37.2	20.1	5.59	0.37	0.044	4.75	0.80	0.12
Inorganic fert.	2.23	0.20	1.07	81.5	38.6	14.2	5.75	0.22	0.053	3.74	0.60	0.08
RS 10 kgtree^{-1}	2.11	0.23	1.10	75.8	37.8	18.6	5.27	0.22	0.079	3.76	0.63	0.07
RS 20 kg tree^{-1}	2.24	0.22	1.14	71.2	29.8	15.0	4.90	0.25	0.092	3.37	0.71	0.07
DS 10 kg tree^{-1}	2.09	0.21	1.09	67.5	40.0	19.7	5.95	0.22	0.037	3.79	0.69	0.09
DS 20 kg tree^{-1}	2.35	0.21	1.05	73.8	38.6	17.5	5.49	0.23	0.083	3.21	0.81	0.07
FYM 10 kg tree^{-1}	2.25	0.19	1.13	67.0	42.6	16.0	5.20	0.27	0.026	3.04	0.52	0.08
FYM 20 kg tree^{-1}	2.10	0.20	1.22	54.2	34.4	18.4	5.19	0.28	0.162	3.62	0.60	0.08
Grand mean	2.17	0.21	1.11	70.6	37.2	17.3	5.41	0.25	0.075	3.62	0.66	0.08
F probability	0.102*	>0.05	>0.05	>0.05	>0.05	0.017*	>0.05	>0.05	>0.05	>0.05	>0.05	>0.05
LSD at 0.05	0.15	ns	ns	ns	ns	3.27	ns	ns	ns	ns	ns	ns
CV (%)	6.3	15.8	7.3	20.9	24.6	16.2	12.0	32.1	112.8	29.3	25.5	32.0

- Provision of effective N fertilizer replacement value for the next crop.
- Conservation of N in the soil for crop uptake.
- Reduction in N leaching losses compared with soluble inorganic N fertilizers during irrigation events.

Certain elements usually occur in sewage sludge in larger concentrations than soil, and will therefore slowly accumulate in soil. These are regulated to protect the environment and include Zn, Cu, Ni, Cd, Pb, Cr and Hg. However, the behaviour of each of the elements can be very different according to their chemistry and interaction with the sludge and soil matrix. Thus, Pb, Cr and Hg are very immobile in sludge-treated soil, they are not taken up by crops and are unlikely to present an environmental problem from the use of sewage sludge in agriculture in Egypt, particularly with reference to the moderate-to-low concentrations of these elements found in Cairo sewage sludges, relative to environmental standards. On the other hand, Zn, Cu, Ni and Cd are more labile in sludge-treated soil and concentrations in crops can be significantly increased if the soil content is raised by sewage sludge application. The application of FYM consistently increased the K status of crops relative to the other soil amendments and controls when high quality material was supplied. FYM is a valuable source of this major plant nutrient in Egyptian agriculture. Whilst sludge is an effective replacement for N and P, it tends to be lacking in K, Nevertheless, the efficiency of N and P utilization from sludge for fruit production would be improved by balancing inputs of these nutrients in sludge with FYM or mineral K fertilizer, to provide a supplementary source of this nutrient in the crop rotation, particularly on reclaimed soils. Nevertheless, sludge is likely to be a more consistent and predictable fertilizer material than FYM, which is potentially of highly variable quality and is often in short supplysimilar results on different field crops were reported by[19,20] found that sludge application increased the concentrations of (P, K, Fe, Mn, Cu, Zn, Co, Ni, Pb and Cd) in leaves and grain of alfalfa, wheat, fababean and soybean. However, no visual symptoms of metal toxicity showed on the different plant species. Hussein [6] reported that sludge application significantly increased the Ca, Mg, K, N, Fe, Mn, Cu and Zn in corn, sugar beet and cotton plants. Also he found that, the yield of the three crops increased by application of sludge. Antoline *et al*. [21] found that N content in grain of barley increased as a result of addition of sludge to the soil. Also, they noticed that grain heavy metals (Cd, Cr, Mn, Ni, Pd, Cu and Zn) of barley increased with addition of sludge to the soil. Mendoza *et al*. [22] reported that the concentration of (Cu, Mn, Pb and Fe) increased in leaves of sorghum grown in soil amended with sludge.

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