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The Agronomic and Economic Value of Different Biowastes Applied to Field Crops

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Abstract: Large cities like Cairo and Alexandria produce large quantities of biowastes (raw sludge, digested sludge and composted sludge The traditional organic fertilizers are Farmyard manure (FYM) and chicken manure (CM). Sludge sampling program and analysis have been completed on all Cairo and Alex in order to characterize the quality of raw, digested and composted sludges compared to the currently used organic manures. The results gave confidence that all sludges were quite acceptable for agricultural use. An extensive field trials program with a wide range of arable field and fruit crops was grown over 6 successive seasons. Vegetables and root crops were excluded. The yields of crops fertilized with sludge were consistently equal to and often greater than those obtained by the farmer practice (FYM or CM). The results have shown 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. The calculation of fertilizer value in EGP on the basis of market prices in Egypt showed that nitrogen addition value ranged between 81 and 225 EGP, P between57and 133 while K ranged between 120 and 480 EGP per one ton applied according to the biowaste type and source. The Economic value of total fertilizer inputs applied to the soil per one ton indicates that the total NPK value ranged between 258 and 838 LE. It could be concluded from this study that the biowastes application could save partial NPK crop requirements and needs fertilizer compensation. The advantage of field crop fertilization with different biowastes is evident from the agronomic and economic scene. The sludge quality surveys have shown the relative consistency of sludge quality at each WWTP, compared with the very variable quality of farmyard manure. However, the management and control of the sludge treatment and distribution operations need to be improved to ensure that ths management strategy is sustainable, environmentally acceptable, cost-effective and minimizes the potential risks to human health.

Key words: Biowastes · Sludge · Livestock manure · Fertilizer value · Economic value

INTRODUCTION

The implementation of wastewater projects in the major cities of Egypt Cairo will result in large quantities of bio-solids (raw sludge, digested sludge and composted sludge) being produced and requiring disposal routes must be environmentally and socially acceptable and cost-effective. Agriculture may offer the most sustainable

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and beneficial outlet for bio-solids, but there are concerns about protecting the environment and human health and its practicality. The principal environmental concerns are due to the inevitable presence of potentially toxic elements (PTEs - mainly heavy metals) and human pathogens [1]. Bio-solids should be regarded as a natural resource to be conserved and reused, rather than discarded. Its use in agriculture is widely regarded as the newly reclaimed soils in Egypt are characterized by low fertility, high salt content and poor moisture retention. Several investigators indicated the efficiency of different bio-solids in improving soil characters or increasing the productivity of such soils [2, 3]. Abd El Lateef [4] indicated that chemical analysis of manure contained more than 71.9, 73.1 and 91.4% dry solids for FYM, plant compost and chicken manure, respectively indicating that they were generally similar. Therefore, the plant compost and chicken manure have comparable soil conditioning properties as the conventional bulky organic manure at equivalent rates of application to soil. Chicken manure contained 44% more N compared with the average content in FYM and five fold increase compared to the plant compost. Plant compost and FYM supplied similar amounts of total P in the dry solids. K excreted in the wastes of domestic livestock is largely retained in the bedding material that forms the main bulk matrix of FYM. This work is part of The Cairo Sludge Disposal Study which has been initiated under the Mediterranean Environmental Technical Assistance Program, funded by the European Investment Bank and promoted by the Cairo Wastewater Organization*,* in order to resolve at least part of the difficult problem of bio-solids disposal in the Cairo, which otherwise will become an overwhelming problem once all of the wastewater treatment plants (WWTPs) become operational with the full capacity. The objective is to demonstrate the practical and safe reuse of bio-solids produced by Cairo and thus serve as a demonstration program and information source for similar towns and cities in Egypt and warm climates beyond. Cairo Wastewater Treatment Plants currently produce air-dried raw or digested sludge which is pushed to drying beds and stocked pile for six months prior to usage. Under Egyptian conditions to maintain a relatively high organic matter content in the product for its soil conditioning value, so complete stabilization is not necessary. Therefore, the primary objective of the study is to evaluate how sludge as a replacement for farmyard manure and chicken manure performs and show that sludge performed at least as well as traditional methods from the agronomic and economic scene and that it can be used safely.

MATERIALS AND METHODS

A 3-year program of sludge sampling and analysis has been completed on all Cairo's WWTPs in order to characterize the quality of the biowastes including sludges, Farmyard manure and chicken manure. The biowastes have been analyzed for a wide range of determinants, including nutrients, heavy metals and pathogens. The Cairo Study established 30 field trials, covering about 200 feddans (83 hectares). A wide range of arable crops have been grown over successive winter and summer seasons, including wheat, barley, fodder and grain maize, berseem, soya bean, faba bean, sesame, sorghum and cotton. Vegetables and root crops were excluded. Farms were selected as trial sites to evaluate the agricultural use of sewage sludge, encompassing the major soil types and crop husbandry practices within the nominal sludge 'marketing' area around Cairo. Six main sites were selected around Cairo and three are being established near Alexandria. A total of 17 demonstration field trials were established with composted sludge from Alexandria involving several crops. Cairo Wastewater Treatment Plants currently produce air-dried raw or digested sludge which is pushed to drying beds and stocked piles for six months prior to usage. Under Egyptian conditions to maintain a relatively high organic matter content in the product for its soil conditioning value, so complete stabilization is not necessary.

Samples of the sludges and manures applied to the field trials were taken and analyzed for a wide range of parameters. These analyses were necessary to determine the additions of nutrients and heavy metals to the trials and they also provide a valuable perspective of sludge product quality as would be used by farmers, compared with the quality of the liquid sludges from which they are derived. Nitrogen was determined by micro-Kjeldahl according to the [5]. After wet digestion of the samples, according to [6], P was determined by spectrophotometry, K by flame photometer [7] and Fe, Mn, Cu and Zn were determined by atomic absorption spectrophotometry. Other analyses were according to the methods described by [7].

Statistical Analysis: The chemical analysis data were subjected to descriptive statistics according to the MSTAT program [8].

RESULTS

Chemical Properties of Dried Biowastes: The analysis of different manures and sludges showed Interestingly that, the mean volatile solids content of the solar-dried sludges was smaller than in the liquid sludges, suggesting that during the drying process volatile solids were lost through spontaneous anaerobic digestion. This is not unreasonable since sludge may be observed as gas (bubbles of methane) when the sludges are still in a liquid state in the drying beds. Also, in a semi-dry state in stockpiles, sludge (raw and digested) may heat up due to aerobic decomposition (natural composting). These processes are important in stabilizing raw sludges and will also provide additional sanitization of the sludge (Table 1).

Fertilizer Value of Biowastes: Thus the mean N contents of the dried sludges contained less total N than the liquid sludges In general, the N content of the liquid sludges was about 2.5 % ds, whereas that of the dried sludges was about 1.5 % ds. (Table 2). Phosphorus and K are conserved in the dry sludge and concentrations were similar to that in the liquid sludges. Similarly, the mean concentrations of heavy metals in the solar-dried sludges were broadly similar to sludge quality in operational practice. All of the materials were very dry (about 90 % ds), although the chicken manure tended to have more variable moisture content as this was supplied relatively fresh. The density of the sludges ranged from 0.63 to 0.82 t m^{-3} and an average density of 0.7 may be taken as representative of all sludges for operational purposes. Density of sludge is an important consideration since farmers traditionally apply manures by volume and this needs to be converted to a weight basis in order to calculate nutrient and heavy metal loadings (Table 3).

To illustrate the importance of this, Tables 2 and 3 present the concentrations of nutrients and heavy metals in sludge and manures on the basis of volume, fresh dry sludge and dry solids, respectively. For example, for solar dried Abu Rawash sludge:

1 m^3 contains 12 kg N and 485 g Zn
1 t contains 16 kg N and 656 g Zn
1 t ds contains 18 kg N and 752 g Zn

Fertilizer nutrient values for the sludges and traditional manures, derived from the arable field trials (were calculated according to mass additions but were subsequently converted to a volumetric basis for consistency with farming practices in Egypt. However, for assessing the quantities of heavy metals supplied in sludge to the land, this should be on a dry solids basis. Different biowastes macro and micronutrients additions to the soil are illustrated in Figs. 1-3.

A comparison of heavy metals concentrations in sludge from WWTP in Cairo with published data from other countries (Table 1) shows Cairo sludge to be of equivalent or superior quality for land application. The main exception, as would be expected, is Helwan sludge. Even here, however, metal content does not preclude the use of the sludge on farmland when compared with the most stringent national standards on the quality of sludge for recycling in agriculture (Table 1). Other notable exceptions included Ni in sludge from Shoubra El Kheima and Cr in Berka sludge, whichwase both greater than European and US norms, but not excessively compared with national limits. In overall assessment, the data from the sludge quality study indicate that the concentrations of heavy metals in sewage sludges from four of the major WWTP in Cairo are within European and US norms and are generally well below the most stringent of the EC and US limits for metals in sludge. The small concentrations of heavy metals measured in samples of composted sludge product from Alexandria demonstrate that this material is of exceptionally high quality, but until these analyses were performed, there was a general presumption that this sludge was also heavily contaminated because 40% of Egyptian industry is located in Alexandria.

In conclusion, the fertilizer value of the different biowastes indicated that Nutrient content of Sewage sludge provides agronomic valuable amounts of N and P, in addition to other major and minor elements required for plant growth, including Fe, Mn, Zn and Cu, which frequently limit crop yields in Egyptian soils, especially on the reclaimed lands. Typically, solar-dried sludge from Cairo's WWTPs contains 1.7% and 0.8% of total N and P, respectively. The total K content is relatively small in comparison and approximately 0.3%. Organic manures are applied to land on a volumetric basis in Egypt and 1 m^3 of solar-dried sludge typically supplies 11.5 kg N and 6.0 kg P (19 kg N t^{-1} and 10 kg P t^{-1} on a dry solids basis).

The relatively rich source of K in FYM could be attributed to the bedding used in preparing FYM compared with other manures. Therefore, compensation of the soil with this major plant nutrient is recommended to maintain crop productivity through supplying FYM or

Table 1: Chemical properties (mean values and 95% confidence limit) of solar-dried sludges from different WWTP and of livestock manures from local sources (Units: density as t m^3; ds, VS, N, P, K and Fe as %, other elements as mg kg^{-1})

WWTP	Density	ds	VS	N	P	K
Abu Rawash	0.74	87.2±6.1	51.9±14.7	1.61±0.49	0.57±0.28	0.23±0.07
Berka	0.69±0.08	90.7±5.0	37.2±6.8	1.71±0.27	0.88±0.29	0.24±0.08
Helwan	0.82	93.3±4.5	27.0±5.9	0.85±0.13	0.61±0.45	0.19±0.04
Zenein	0.63±0.07	89.1±6.6	42.0±6.8	1.79±0.31	1.06±0.35	0.38±0.17
Alexandria	nd	88.5±10.0	25.2±14.8	1.63±0.52	1.09±0.39	0.38±0.18
FYM	0.63±0.23	90.9±5.3	23.8±9.3	0.85±0.27	0.69±0.28	0.70±0.17
Chicken manure	nd	79.2±29.5	53.1±33.1	2.53±1.41	1.35±2.07	0.75±0.86

Table 1: continued

WWTP	Fe	Mn	Zn	Cu	Ni	Cd	Pb	Cr	Co
Abu Rawash	1.10±0.40	286±145	656±301	168±51	51.3±32.3	2.57±0.70	102.2±62.3	36.6±30.6	15.1±10.4
Berka	1.32±0.23	187±46	614±202	246±92	60.2±21.1	3.36±1.69	90.9±50.5	156.0±74.5	21.5±26.0
Helwan	1.08±0.31	180±99	489±301	148±75	28.6±17.3	2.01±2.22	38.2±20.5	93.6±60.3	6.7±0.7
Zenein	1.12±0.22	259±89	618±225	174±38	46.3±25.7	3.11±1.29	80.2±50.2	69.3±44.6	12.9±7.2
Alexandria	1.09±0.26	219±50	524±212	239±100	39.9±25.1	3.73±1.68	56.7±43.7	53.2±40.8	12.8±5.6
FYM	1.33±0.48	264±136	99±43	88±55	33.3±12.7	2.79±1.45	21.5±12.9	49.5±18.1	9.8±5.0
Chicken manure	0.24±0.19	196±92	174±293	125±215	47.8±71.8	1.82±0.78	15.8±8.2	9.2±7.4	4.8±1.5

Table 2: Nutrient and other elemental additions to soil in 1 m^3 of sewage sludge from different WWTPs and in livestock manures

Parameter		Abu Rawash	Berka	Helwan	Zenein	Alexandria	Farmyard manure	Chicken manure
VS	kg m^{-3}	384	257	221	265	176	150	319
N	kg m^{-3}	12	12	7	11	11	5	15
P	kg m^{-3}	4	6	5	7	8	4	8
K	kg m^{-3}	2	2	2	2	3	4	5
Fe	kg m^{-3}	8	9	9	7	8	8	1
Mn	g m^{-3}	212	129	148	163	153	166	118
Zn	g m^{-3}	485	424	401	389	367	62	104
Cu	g m^{-3}	124	170	121	110	167	55	75
Ni	g m^{-3}	38	42	23	29	28	21	29
Cd	g m^{-3}	2	2	2	2	3	2	1
Pb	g m^{-3}	76	63	31	51	40	14	9
Cr	g m^{-3}	27	108	77	44	37	31	6
Co	g m^{-3}	11	15	5	8	9	6	3

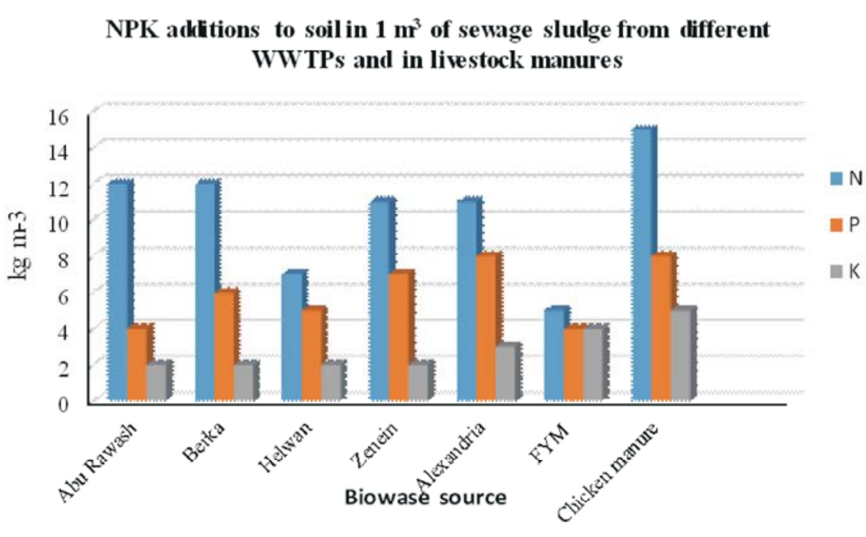

Fig. 1: NPK additions to soil in 1 m^3 of sewage sludge from different WWTPs and in livestock manures

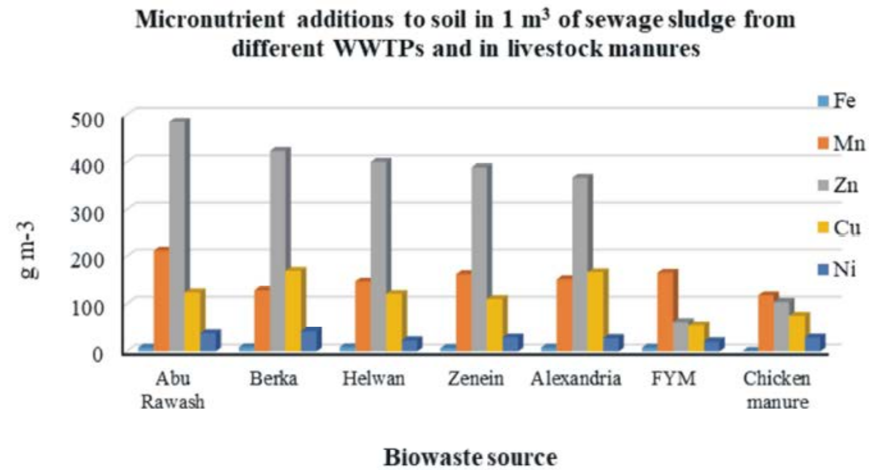

Fig. 2: Micronutrient additions to soil in 1 m^3 of sewage sludge from different WWTPs and in livestock manures

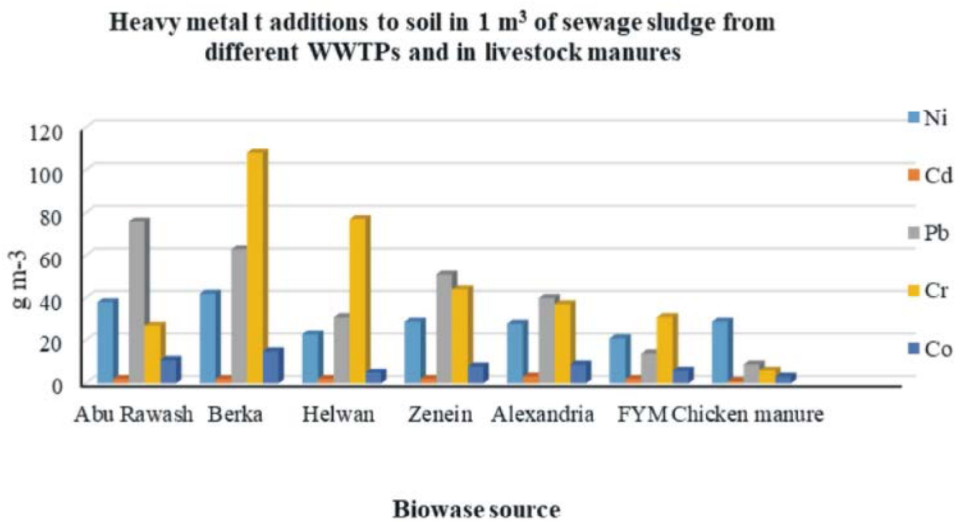

Fig. 3: Heavy metal t additions to soil in 1 m^3 of sewage sludge from different WWTPs and in livestock manures

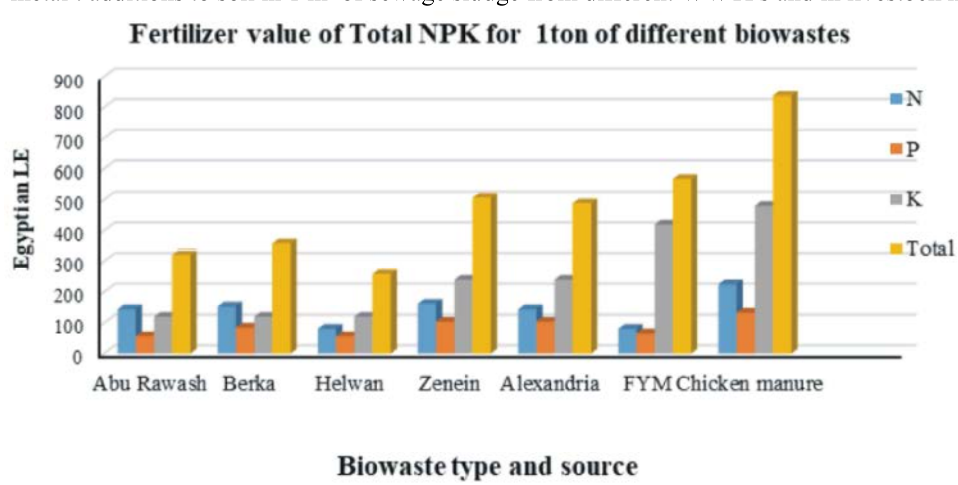

Fig. 4: Fertilizer value of different biowastes (Sludges from Abu Rawash, Berka, Helwan , Zenein and Alexandria) compared with FYM and chicken manure

Table 2: Nutrient and other elemental additions to the soil in 1 t of sewage sludge from different WWTPs and in livestock manures, as spread

Parameter		Abu Rawash	Berka	Helwan	Zenein	Alexandria	Farmyard manure	Chicken manure
VS	kg t^{-1}	519	372	270	420	252	238	531
N	kg t^{-1}	16	17	9	18	16	9	25
P	kg t^{-1}	6	9	6	11	11	7	14
K	kg t^{-1}	2	2	2	4	4	7	8
Fe	kg t^{-1}	11	13	11	11	11	13	2
Mn	g t^{-1}	286	187	180	259	219	264	196
Zn	g t^{-1}	656	614	489	618	524	99	174
Cu	g t^{-1}	168	246	148	174	239	88	125
Ni	g t^{-1}	51	60	29	46	40	33	48
Cd	g t^{-1}	3	3	2	3	4	3	2
Pb	g t^{-1}	102	91	38	80	57	22	16
Cr	g t^{-1}	37	156	94	69	53	50	9
Co	g t^{-1}	15	22	7	13	13	10	5

Table 3: Nutrient and other elemental additions to soil in 1 t dry solids of sewage sludge from different WWTP and in livestock manures

Parameter		Abu Rawash	Berka	Helwan	Zenein	Alexandria	Farmyard manure	Chicken manure
VS	kg t^{-1} ds	595	410	289	471	285	262	670
N	kg t^{-1} ds	18	19	9	20	18	9	32
P	kg t^{-1} ds	7	10	7	12	12	8	17
K	kg t^{-1} ds	3	3	2	4	4	8	9
Fe	kg t^{-1} ds	13	15	12	13	12	15	3
Mn	g t^{-1} ds	328	206	193	291	247	290	247
Zn	g t^{-1} ds	752	677	524	694	592	109	220
Cu	g t^{-1} ds	193	271	159	195	270	96	158
Ni	g t^{-1} ds	59	66	31	52	45	37	60
Cd	g t^{-1} ds	3	4	2	3	4	3	2
Pb	g t^{-1} ds	117	100	41	90	64	24	20
Cr	g t^{-1} ds	42	172	100	78	60	54	12
Co	g t^{-1} ds	17	24	7	14	14	11	6

Table 4: Calculations of fertilizer value (EGY LE) of different biowastes (Sludges from my Abu Rawash, Berka, Helwan, Zenein and Alexandria) compared with FYM and chicken manure

Parameter	Abu Rawash	Berka	Helwan	Zenein	Alexandria	FYM	Chicken manure
N	144	153	81	162	144	81	225
P	57	86	57	105	105	67	133
K	120	120	120	240	240	420	480
Total (EGY LE)	321	359	258	507	489	568	838

inorganic K fertilizer in the crop rotation. Abd El-Lateef *et al.* [9, 10] reported substantial macro and micronutrients applied either to sugar beat or clover through organic manures although the additions are rather small but in the long term will be significant under continuous application and will be beneficial to the soil. Moreover, similar results were obtained by [11] and [12], they attributed the enhancing effect of manure to the gradual and slow release of nutrients to the soil as well as to improving the soil's physical properties to the benefit of the crop. The superiority of chicken manure over the other two sources was confirmed by [13]. They showed that the application of poultry manure significantly promoted sesame growth and yield. Seed yield ha^{-1} was increased as the manure rate was increased. In another study, it was found that organic manures application could provide further evidence of the significant N fertilizer replacement value of organic manures on reclaimed desert soils. Moreover, Chicken manure was 50% as effective as an N source compared with inorganic N and compost was 30% as effective.

The Economic Value of Biowastes: The calculation of fertilizer value in EGP on the basis of market prices in Egypt showed that nitrogen addition value ranged between 81 and 225 EGP, P between57and 133 while K ranged between 120 and 480 EGP per one ton applied according to the biowaste type and source. The Economic value of total fertilizer inputs applied to the soil per one ton indicates that the total NPK value ranged between

258 and 838 LE. It could be concluded from this study that biowastes application to field crops has substantial agronomic value for most of the biowastes applied. Biowastes application could save partial NPK crop requirements and needs fertilizer compensation. The advantage of field crop fertilization with different biowastes is evident from the agronomic and economic scene.

REFERENCES

1. Smith, S.R., 1996. Agricultural Recycling of Sewage Sludge and the Environment. CAB International, Wallingford, UK.
2. Abd El-Lateef, E.M., 2003. The effects of sewage sludge application on the yield and quality of berseem and forage maize in newly reclaimed soil. 2nd I international Symposium of Ecological Sanitation. April 7-11 Lubeck, Germany, pp: 651-654.
3. Abd El Lateef, E.M., A.A. Abd-Elmonsef, M.S. Abd El-Salam, M.A. Farrag and T.A. Elewa, 2020. Effect of mechanized compost application on forage yields of berseem and fodder maize under centre pivot irrigation system. Am-Euras. J. Agron., 13(1): 01-06.
4. Abd El-Lateef, E.M., M.S. Abd El-Salam, T.A. Elewa and A.M. Wali, 2018. Effect of organic manures and adjusted N application on cowpea (*Vigna unguiculata* L. Walp) yield, quality and nutrient removal in sandy soil. Middle East J. Appl. Sci., 8(1): 7-18.
5. AOAC, 2000. Association of Official Analytical Chemists, 17th ed. of A.O.A.C. international published by A.O.A.C. international Maryland, U.S.A., pp: 1250.
6. Chapman, H.D. and F.E. Pratt, 1961. Methods of Analysis of Soil. Plant and Water. University of California, USA.
7. Jackson, M.L., 1967. Soil Chemical Analysis. Prentice Hall of India, New Delhi, pp: 251-280.
8. MSTAT-C., 1988. MSTAT-C, a microcomputer program for the design, arrangement and analysis of agronomic research. Michigan State University, East Lansing.
9. Abd El-Lateef, E.M., M.S. Abd El-Salam, T.A. Elewa and A.A. Farrag, 2019. Effect of organic manure and nitrogen level on sugar beet (*Beta vulgaris var. sac- charifera* L.) yield and root nitrate content. Am-Euras. J. Agron., 12(1): 1-5.
10. Abd El-Lateef, E.M., Asal M. Wali, Howida H. Khedr and M.S. Abd El-Salam, 2020. Forage yield and quality of Egyptian clover (*Trifolium alexandrinum* L.) fertilized with biowastes under calcareous soil conditions. European Journal of Applied Sciences, 12(4): 114-122.
11. Sahu, G., N. Chatterjee, M. Bera, G.K. Ghosh, S. Mondal, P.K. Biswas and M.C. Kundu, 2017. Integrated nutrient management in sesame (*Sesamum indicum*) in red and lateritic soils of West Bengal. Int. J. Plant Anim. Environ. Sci., pp: 137-146 Available online at www.ijpaes.com DOI: 10.21276/Ijpaes http://dx.doi.org/10.21276/ijpaes.
12. Singh, H., R.P. Singh, B.P. Meena, B. Lal, M.L. Dotaniya, A.O. Shirale and K. Kumar, 2018. Effect of integrated nutrient management (INM) modules on late sown Indian mustard [*B. juncea* (L.) Cernj. & Cosson] and soil properties. J. Cereals Oilseeds, 9(4): 37-44.
13. Ogbonna, P.E. and Y.G. Umar-Shaba, 2012. Influence of poultry manure application on growth and yield performance of accessions of sesame (*Sesamum indicum* L.) in a derived savanna transition zone of Southeastern Nigeria. Afr. J. Agric. Res., 7(30): 4223-4235.