International Journal of
Agriculture, Forestry and Life Science, 3 (1) 2019, 106-114

e-ISSN: 2602-4381 Received: 06.01.2019 Accepted: 13.03.2019 Published (online): 13.03.2019

ORIGINAL PAPER

FERTILIZER INPUTS IMPACT OF DIFFERENT BIO-SOLID SOURCES ON SUGAR BEET YIELD IN SANDY SOIL

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Abstract

In order to determine different bio solid nutrient (macro and micronutrients) inputs and sugar beet productivity, field trials were conducted to investigate the effect of N application as sub-optimal level (66% of the recommended rate) when combined with three bio-solids (plant compost farmyard manure (FYM) and chicken manure) at four levels (3, 6, 9 and 12 t fed^{-1}) in newly reclaimed sandy soil. The results showed that the total N content on a dry solids basis, indicated that chicken manure contained 31% more N compared with the average content in FYM and 79% compared to the plant compost. Plant compost and FYM supplied similar amounts of total P in the dry solids. FYM applied to the field trials contained more than four times the amount of K (0.62% ds) compared with other bio solids (0.14% ds). As expected, the concentrations of trace elements in the plant compost are larger than for FYM. The estimated N application from plant compost ranged between (8.0-32.0), Farmyard manure (22.6 – 90.4) and chicken manure (30.7 - 122.8) kg N fed^{-1} according to the rate of application. Chicken manure contained the greatest rates of Fe, Mn and Zn per ton or cubic meter. However, FYM contained the greatest Cu rates applied to the soil. Application of farmyard manure to sugar beet significantly surpassed either plant compost or chicken manure in plant height, root length root, shoot and biological yields per plant and per feddan. The data show that regardless the bio solid type it is favorable to apply the organic manures up to 9 t fed^{-1} (15 m^3 fed^{-1}). The greatest root and shoot yields per plant and per feddan was attained when FYM was combined with the reduced rate of N. The data also show the consistency of these biosolids as inputs for sugar beet production. The inspection of the data revealed that biosolid application effect could contribute in sugar beet yield $plant^{-1}$ with 50, 42.4 and 48.9 % and 50.41 and 50% per feddan for plant compost, farmyard manure and chicken manure, respectively showing the practicality and possibility of safe use of these bio-solids in minimizing the risks of inorganic fertilizers. It could be concluded from this study that biosolids apply substantial macro and micro nutrients with agronomic and economic value to such poor soils. Supplementation with this major plant nutrient is recommended where they are frequently applied to soil to maintain crop productivity.

Fed= Feddan=4200m^2

Key words: Organic manures, sugar beet, yield

INTRODUCTION

Sugar beet (*Beta vulgaris var. saccharifera* L.) ranks the second important sugar crops after sugar cane, producing annually about 40% of sugar production all over the world. In Egypt, it has been a large importance in the newly reclaimed sandy soils at the northern and southern parts of Egypt, that could be cultivated with sugar beet without competition with other winter crops. There is a gap between sugar consumption and production due to steady increases in the country population and average consumption of sugar beside limited cultivated area. Increasing sugar crops cultivated area and sugar production per unit area are considered the important national target to minimize the gap between sugar consumption and production. The total sugar beet cultivated area reached about 505 thousand feddan with an average of 16 t fed^{-1} Minstry of Agric.(2016). Recently, sugar beet has an important position in winter crops not only in the fertile soils, but also in poor, saline, alkaline and calcareous soils. The great importance of sugar beet crop is not only because of its ability to be grown in the newly reclaimed areas as an economic crop, but also for its higher production of sugar under these conditions as compared with sugar cane.

The newly reclaimed soils in Egypt are characterized by low fertility, high salt content and poor moisture retention (Balba, 1995). The areas under reclamation are mostly calcareous, saline and sandy soils. Since animal manures are not readily available for soil application, alternative materials such as organic wastes from the food industry and composts should be tested and used to meet the organic matter requirement of these soils (Chondie, 2015). Application of organic materials: farmyard and chicken manures are traditionally used by many investigators as soil conditioners and fertilizers for increasing growth and yield of many field crops and vegetables (Mohammed, 2004;Kumar et al., 2012). In addition to playing important role in improving the physical properties of soils, especially the sandy and calcareous ones, organic manures are valuable resources rich in P, N and micronutrients essential for plant growth, that are slowly released after degradation by microorganisms. Recently, El Sheikha (2016) concluded that integrated use of organic manure and recommended dose of chemical fertilizers resulted in significant improvement in crop yields and quality despite being an active practice in nutrient management.

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 increase the productivity of such soils.

The application of compost to the soil improve the chemical, physical, and biological characteristics of soils. It improves water retention and soil structure by increasing the stability of soil aggregates (Adugna, 2016). Moreover, effects of the organic matter applied to the soil in compost are seen in increased efficiency of mineral fertilizer utilization by crops and improved performance (El Sheikha, 2016).

In Egypt, various studies have assessed the benefits of organic manures including compost on the physical characteristics of Egyptian soils and in increasing crop yields (Zaki et al., 2012) In many areas, there has been a rapid and continuing expansion of agriculture through the reclamation of desert lands to increase food production and living space for the expanding population. The soils in these areas are inherently poor and the demand for manure and other sources of organic fertilizer is high.

Therefore, the aim of this work is to determine different bio solid nutrient (macro and micro nutrients) inputs when combined with sub optimal N application on sugar beet productivity in newly reclaimed sandy soil.

MATERIALS AND METHODS

Field trial was conducted in the winter seasons of 2015/16 and 2016/17 on the Agricultural Production and Research Station, National Research Centre, Nubaria Province, Behaira Governorate, Egypt, in a newly reclaimed desert soil. The objective of the trial was to investigate the effect of N application as sub-optimal level 40 kg fed^{-1} (66% of the recommended rate) when combined with three bio-solids (plant compost, farmyard manure and chicken manure) at four levels (3, 6, 9 and 12 t fed^{-1}) in newly reclaimed sandy soil. The experiment included 24 treatments which were two nitrogen fertilizer levels *i.e.* 0 and sub optimal level 40 kg fed^{-1} and three biosolids (plant compost farmyard manure and chicken manure) and four levels (3, 6, 9 and 12 t fed^{-1}) with and without the sub optimal level. The experimental design in the trial was split-split plot design. The area of the trial was 0.2 ha (0.48 fed), the physical and chemical analysis of the soil was (pH 8.5; EC 0.24 dsm^{-1}; OM 0.73; N 1400 ppm; P 132 ppm; K 826 ppm; Fe 3694 ppm; Mn 56.8 ppm; Zn 17.8 ppm; Cu 3.78 ppm; Cd 0.02 ppm; Pb 1.36 ppm and Ni 2.9 ppm). Sugar beet cultivar Farida was sown in hills 25 cm apart on November 4th and 14th in 2016 and 2017, respectively at rate of 2 kg fed^{-1} by hand in ridges. Harvest was done at mid-April. Root and shoot yields fed^{-1} were determined from a central area of 21 m^2. The following characteristics were determined at harvest: plant height (cm), root length (cm), root diameter (cm), root yield plant^{-1}, shoots yield plant^{-1}, biological yield plant^{-1}.

In order to determine the actual agronomic value and fertilizer inputs of the different biosolids, samples of different manures were collected in the field prior to application and were analyzed. Typical inputs of biosolid 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 bio solids as well as micronutrients inputs were calculated.

The analysis of variance of split-split plot experiment was carried out using MSTAT-C Computer Software (MSTAT-C, 1988), after testing the homogeneity of the error according to Bartlett's test, combined analysis for both seasons were done. Means of the different treatments were compared using the least significant difference (LSD) test at $P<0.05$.

RESULTS AND DISCUSSION

Bio solids characteristics

The biosolid samples were collected in the field prior to application and were analyzed.

The chemical analysis of bio solids applied to the field trials is reported in Table (1). Typical inputs of biosolid components and nutrients based on the average composition data were calculated and are listed in Tables (2 and3) on a volumetric and converted to mass addition basis. Actual N loadings in bio solids to specific field trials are listed in Table (4). The bio solids contained more than 70 % dry solids with a typical content. The volatile and organic matter contents were representative of the tested bio solids Table(1). The dry solids and organic matter contents of plant compost and chicken manure were generally similar to FYM (Table 2). Therefore, the plant compost would be expected to have comparable soil conditioning properties as the conventional bulky organic manure at equivalent rates of application to soil. The total N content on a dry solids basis, indicated that chicken manure contained 31% more N compared with the average content in FYM and 79% 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. Consequently, FYM is a relatively rich source of K compared with sludge, including bio solids products. Indeed, the FYM applied to the field trials contained more than four times the amount of K (0.62% ds) compared with bio solids (0.14% ds). Supplementation with this major plant nutrient is recommended where the other bio solids is frequently applied to soil to maintain crop productivity by also supplying FYM or inorganic K fertilizer in the crop rotation. As expected, the concentrations of trace elements in the plant compost are larger than for FYM. The estimated N application from plant compost ranged between (8.0-32.0), farmyard manure (22.6- 90) and chicken manure (30.7 - 122.8) kg N fed^{-1} according to the rate of application (Table 4).

Micronutrient addition in the different bio solids applied

Data presented in Table (5) and Figures (1 and 2) show the 4 key micronutrients Fe, Mn, Zn and Cu loading rates when applied by the different bio-solids. The data clearly show that chicken manure contained the greatest rates of Fe, Mn and Zn per ton or cubic meter. However, FYM contained the greatest Cu rates applied to the soil. Although such loading rates are relatively small but on the long term will be substantial in the case of the continues application and will be beneficial to the soil.

Table 1: Chemical analysis of bio-solids (Units: ds, VS, N, P, K and Fe as %; other elements as mg kg^{-1})

Manure	ds	VS	N	P	K	Fe	Mn	Zn	Cu
Plant compost	73.1	59.8	0.37	0.72	0.14	0.78	283	40.3	16.0
Chicken manure	91.4	66.0	1.73	1.23	0.14	0.84	440	52.4	16.0
FYM	71.9	68.0	1.20	0.55	0.62	0.49	390	8.0	35.0

Table 2: Dry solids addition in the bio-solids applied t fed^{-1}

Rate t fed^{-1}	Plant compost	Chicken manure	FYM
3	2.19	2.74	2.16
6	4.38	5.48	4.32
9	6.57	8.22	6.48
12	8.76	10.97	8.62
ds (%)	58.8	59.2	71.9
Density (w/v)	0.64	0.60	0.64

Table 3: Nitrogen content of bio-solids applied

Manure	N content (% ds)	Dry solids (%)	Density [(1)] (t m^{-3})	kg N t^{-1}	kg N m^{-3}
Plant compost	0.37	71.9	0.7 (0.60-0.73)	2.66	1.86
Chicken manure	1.73	59.2	0.60 (0.54-0.63)	10.24	6.14
FYM	1.20	58.8	0.64 (0.62-0.67)	7.06	4.52

[(1)]Mean (n = 5) and range

Table 4: Nitrogen additions in bio-solids applied

Volumetric addition t fed^{-1}	Plant compost kg N fed^{-1}	Chicken manure kg N fed^{-1}	FYM kg N fed^{-1}
3	8.0	30.7	22.6
6	16.0	61.4	45.2
9	24.0	92.1	67.8
12	32.0	122.8	90.4

Table 5 : Micronutrient addition in the different bio-solids applied

Manure	Micronutrient addition g t^{-1}				Micronutrient addition g m^{-3}			
	Fe	Mn	Zn	Cu	Fe	Mn	Zn	Cu
Plant compost	570	206.9	29.45	11.7	416	144.8	20.62	8.41
Chicken manure	767	402.2	47.9	14.62	461	241.3	28.7	8.77
FYM	352	280.4	5.75	25.17	225	179.5	3.7	16.1

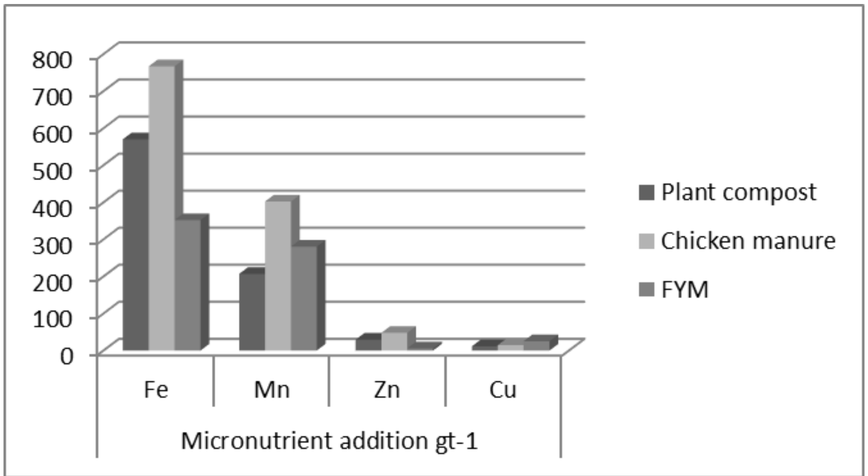

Figure 1: Micronutrient addition g t^{-1} in the different bio-solids applied

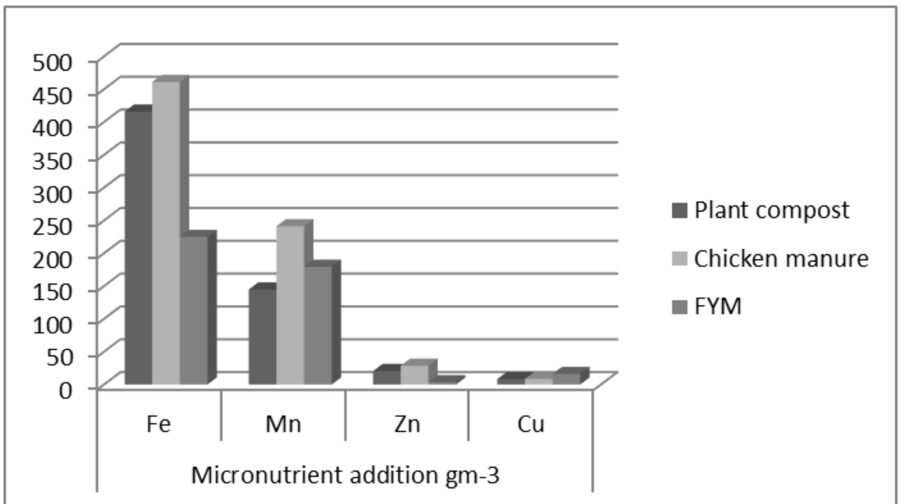

Figure 2: Micronutrient addition g m^{-3} in the different bio-solids applied.

Effect of bio solids on sugar beet yield characteristics

Data presented in Table (6) show significant differences among different biosolids tested in all sugar beet studied characters. In general application of farmyard manure to sugar beet significantly surpassed either plant compost or chicken manure in plant height, root length root, shoot and biological yields per plant and per feddan. Meanwhile, application of chicken manure surpassed plant compost. Several investigators indicated the direct effects of organic fertilizers on sugar beet yields and indicated that among organic fertilizers farm yard manure is the most important one, because it contains all macro and micro nutrients required for plant growth but in small amounts. Farm yard manure increased the sugar yield 10% when applied at the rate of 20 tones ha^{-1} compared to control plots (Javaheri et al., 2005). Ostrowska and Kucinska (1995) confirmed that organic fertilizers increased sugar beet yield more than mineral fertilizers. Abd El-Gawad et al. (1997) found that fresh and dry yields fed^{-1} were higher at 60 m^3 organic manure fed^{-1}. Moreover, Gazia (2001) found that farmyard manure significantly affected the root and shoot yields. Also, sugar yield significantly increased due to FYM at a rate of 20 t fed^{-1}. Similarly, Hassan (2005) indicated that the application of the organic fertilizers induced increases in the root yield, sugar yield, sucrose content, purity % and the concentrations of NPK and micronutrients (Fe, Mn and Zn) in roots.

Table 6: Effect of different bio-solids on sugar beet characteristics

Biosolids	plant height (cm)	Root length (cm)	Root diameter (cm)	Root yield plant^{-1} (g)	Shoots yield plant^{-1} (g)	Bio. yield plant^{-1} (g)	Root yield fed^{-1} (ton)	Shoot yield fed^{-1} (ton)	Biological yield fed^{-1} (ton)
Plant compost	38.17	15.29	8.25	484.79	93.17	577.96	33.93	6.52	40.45
Farmyard manure	47.50	22.50	8.78	597.71	112.71	706.25	41.83	7.88	49.71
Chicken manure	44.54	14.63	9.20	526.46	127.71	658.33	36.85	8.93	45.78
LSD at 0.05	2.70	1.48	0.46	66.72	23.47	78.40	4.64	1.64	5.42

Data presented in Table (7) show the effect of bio solids levels on sugar beet characteristics. The data show that application of bio solids over 3 t fed^{-1} significantly increased all sugar beet studied characteristics. The differences between the levels 9 and 12 t fed^{-1} were insignificant on sugar beet studied characters. Therefore, regardless the bio solid type it is favorable to apply the organic manures up to 9 t fed^{-1} (15 m^3 fed^{-1}).

Table 7: Effect of different bio-solids levels on sugar beet characteristics

Biosolids levels t fed^{-1}	Plant height (cm)	Root length (cm)	Root diameter (cm)	Root yield plant^{-1} (g)	Shoots yield plant^{-1} (g)	Bio. yield plant^{-1} (g)	Root yield fed^{-1} (ton)	Shoot yield fed^{-1} (ton)	Biological yield fed^{-1} (ton)
3	40.96	14.46	7.84	390.83	101.04	504.38	37.35	7.09	44.44
6	46.04	18.38	8.50	536.88	96.88	629.58	37.58	6.78	44.36
9	44.63	17.42	9.05	601.88	114.00	715.88	42.13	7.98	50.11
12	44.29	18.25	9.34	580.42	127.92	712.50	40.62	8.95	49.57
LSD at 0.05	2.70	1.48	0.46	66.42	23.47	78.40	4.64	1.64	5.42

Data presented in Table (8) show that application the reduced N rate of 40 kg N surpassed the application of the treatment without N regardless biosolid type or rate. As expected, all the studied characters values were greater when 40 kg N was applied compared with 0 kg N fed^{-1}.

Table 8: Effect of nitrogen application to different bio solids on sugar beet characteristics

Nitrogen application (kg N fed^{-1})	Plant height (cm)	Root length (cm)	Root diameter (cm)	Root yield plant^{-1} (g)	Shoots yield plant^{-1} (g)	Bio. yield plant^{-1} (g)	Root yield fed^{-1} (ton)	Shoot yield fed^{-1} (ton)	Biological yield fed^{-1} (ton)
0	41.9	15.8	7.7	379.2	86.4	465.5	26.5	6.0	32.6
40	46.0	18.5	9.6	675.8	133.5	815.6	47.3	9.3	56.6
LSD at 0.05	1.9	1.05	0.33	57.5	20.8	67.9	4.0	1.5	4.8

Data presented in Tables (9 and 10) show that significant effects due to the interaction between bio solids application and N level. The interaction between biosolid application and N resulted in significant increases in all the studied characters, in general application of the biosolid singly without N application did not compensate the effect of N absence. The greatest root and shoot yields per plant and per feddan was attained when FYM was combined with the reduced rate of N. The inspection of the data in the same table revealed that biosolid application effect could contribute in sugar beet yield plant^{-1} with 50, 42.4 and 48.9% and 50.41 and 50% per feddan for plant compost, farmyard manure and chicken manure, respectively. Such results indicate the consistency of these biosolids as inputs of sugar beet production.

Table 9: The interaction effect (bio-solids source XN level)

Bio-solids	Nitrogen fertilizer (kg N fed^{-1})	Plant height (cm)	Root length (cm)	Root diameter (cm)	Root yield $plant^{-1}$ (g)	Shoots yield $plant^{-1}$ (g)	Bio. yield plant-1 (g)	Biosolid effect in sugar beet yield $plant^{-1}$g(%)
Plant compost	0	36.25	14.08	7.00	323.33	73.00	396.33	323 (50.0%)
	40	40.08	16.50	9.51	646.25	113.33	759.58	
Farmyard manure	0	45.08	20.42	8.18	441.67	91.67	525.00	312 (42.4%)
	40	49.92	24.58	9.38	753.75	133.75	887.50	
Chicken manure	0	40.83	13.25	8.22	350.83	84.17	443.33	352 (48.9%)
	40	48.25	16.00	10.18	702.08	171.25	873.33	
LSD at 0.05		7.75	8.4	2.4	25.55	33.6	222	

Table 9: Continued

Bio-solids	Nitrogen fertilizer (kg N fed^{-1})	Root yield fed^{-1} (ton)	Shoot yield fed^{-1} (ton)	Biological yield fed^{-1} (ton)	Biosolid effect in root yield fed^{-1}
Plant compost	0	22.6	5.1	27.7	22.6 (50.0)
	40	45.2	7.9	53.2	
Farmyard manure	0	30.9	6.4	36.8	21.9 (41.4)
	40	52.8	9.4	62.1	
Chicken manure	0	24.6	5.9	31.0	24.6 (50.0)
	40	49.2	12.0	61.1	
LSD at 0.05		3.6	3.0	13.4	

The data presented in Table (10) show the interaction effect among bio-solids source and level as well as, N level. Significant effects in root length, root diameter, root and biological yield per plant as well as root, shoot and biological yields per feddan were reported. The results show that the greatest sugar beet yields were obtained per plant and per feddan when plant compost and chicken manure were applied at 9 t and fertilized with 40 kg N fed^{-1} while application of farmyard manure at 6 t and fertilization with 40 kg N fed^{-1} gave the highest beet yield $plant^{-1}$ and fed^{-1}. Such superiority for the farmyard manure was reported by Ostrowska and Kucinska (1995) who confirmed that organic fertilizers increased sugar beet yield more than mineral fertilizers. Also, Abd El-Gawad et al. (1997) found that fresh and dry yields fed^{-1}were higher at 60 m^3 organic manure fed^{-1}.

Table 10: Effect of interaction between (nitrogen x bio solids levels) on sugar beet characteristics

Type fertilizers	Levels ton fed^{-1}	Nitrogen fertilizer (kg N fed^{-1})	Plant height (cm)	Root length (cm)	Root diameter (cm)	Root yield plant^{-1} (g)	Shoots yield Plant^{-1} (g)	Bio. yield plant^{-1} (g)	Shoot yield fed^{-1} (ton)	Root yield fed^{-1} (ton)	Biological yield fed^{-1} (ton)
Plant compost	3	0	36.3	14.7	5.6	193.3	53.3	246.7	3.7	13.5	17.3
		40	33.0	11.3	8.3	343.3	93.3	436.7	6.5	24.0	30.6
	6	0	36.7	12.7	6.1	343.3	66.7	410.0	4.7	24.0	28.7
		40	44.7	19.0	9.3	701.7	86.7	788.3	6.1	49.1	55.2
	9	0	35.0	11.0	8.1	376.7	97.0	473.7	6.8	26.4	33.2
		40	45.3	19.0	10.1	716.7	131.7	848.3	9.2	50.2	59.4
	12	0	37.0	18.0	8.2	380.0	75.0	455.0	5.3	26.6	31.9
		40	37.3	16.7	10.3	823.3	141.7	965.0	9.9	57.6	67.6
Farmyard manure	3	0	43.3	17.0	7.8	373.3	98.3	471.7	6.9	26.1	33.0
		40	47.3	21.7	8.2	561.7	106.7	668.3	7.5	39.3	46.8
	6	0	51.0	24.7	9.2	606.7	103.3	676.7	7.2	42.5	47.4
		40	54.7	29.7	10.7	910.0	138.3	1048.3	9.7	63.7	73.4
	9	0	41.3	18.3	7.6	386.7	76.7	463.3	5.4	27.1	32.4
		40	48.7	22.3	8.7	761.7	156.7	918.3	11.0	53.3	64.3
	12	0	44.7	21.7	8.1	400.0	88.3	488.3	6.2	28.0	34.2
		40	49.0	24.7	10.0	781.7	133.3	915.0	9.3	54.7	64.1
Chicken manure	3	0	35.3	11.0	7.7	271.7	73.3	345.0	5.1	19.0	24.2
		40	44.7	12.33	9.5	550.0	191.7	741.7	13.4	38.5	51.9
	6	0	44.0	13.0	8.3	406.7	91.6	498.3	6.4	28.5	34.9
		40	48.0	18.0	8.7	493.3	95.0	588.3	6.6	34.5	41.2
	9	0	45.0	15.7	8.4	338.3	80.0	418.3	5.6	23.7	29.3
		40	50.7	17.7	10.6	900.0	166.7	1066.7	11.7	63.0	74.7
	12	0	39.0	13.3	8.5	386.7	91.7	511.7	6.4	27.1	35.8
		40	49.7	16.0	12.0	865.0	231.7	1096.7	16.2	60.6	76.8
Significance			ns	*	**	*	ns	*	*	*	*

CONCLUSION

It could be concluded from this study that bio-solids apply substantial macro and micro nutrients with agronomic and economic value to such poor soils. Supplementation with this major plant nutrient is recommended where they are frequently applied to soil to maintain crop productivity. Although micronutrient addition loading rates in the different bio-solids applied are relatively small but on the long term will be substantial in the case of the continues application and will be beneficial to the soil.

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