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Effect of Integrated Organic Sources and Mineral N on Sugar Beet Yield, Quality and Bio Ethanol Production

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Abstract: Field trials were conducted to investigate the effect of N application as sub-optimal level (66 % of the recommended rate) when combined with three organic manures (plant compost farmyard manure (FYM) and chicken manure) at four levels (3, 6, 9 and 12 t fd^{-1}) in newly reclaimed sandy soil. Significant effects were reported among manure types were recorded on sugar beet plant height, root length root, shoot and biological yields per plant and per feddan. The data show that regardless the organic manure type it is favorable to apply the organic manures up to 9 tons $feddan^{-1}$ (15 m^3 fd^{-1}). The results did not reveal significant differences among different fertilizer resources used in the trial on beet quality except the character amino N. These results assure the fact that rationalized use of N through the reduced rate used effectively contribute in higher sugar extraction. Fertilizing sugar beet with farmyard manure resulted in producing the greatest bio-ethanol production fd^{-1} followed by chicken manure and the lowest produced from sugar beet fertilizing with plant compost. Bio ethanol yield ranged between 678 and 837 kg fd^{-1} or between 814 and 1004 liters fd^{-1} according to the organic manure applied. It could be concluded from this study the practicality and possibility of safe use of these bio- solids in minimizing the risks of inorganic fertilizers Moreover, it permits risk reduction through access to energy eco-friendly products and reducing imported energy products.

Key words: Bio-solid · Bioethanol production · Quality · Sugar beet · Yield

INTRODUCTION

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. Sugar beet (*Beta vulgaris var. saccharifera* L.) is an important sugar crop which can replace or integrate with sugar cane for sugar yield sufficiency. 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 559744 feddan (one feddan (fd) = 4200 m^2) with an average of 20 tones per feddan in 2016 (Agricultural Economics of Egypt, 2016). Sugar beet is candidate to expand in the newly reclaimed soils in Egypt which is characterized by low fertility, high salt content and poor moisture retention [1]. However, such soils are of poor quality and needs ameliorating with organic manures to build up or improve the quality of these soils. Several investigators have assessed the benefits of organic manures including compost on the physical characteristics of Egyptian soils and in increasing crop yields [2, 3]. Sugar beet seems to be sensitive to nitrogen fertilizer especially the high doses that may detract the sugar and affect extraction processes [4]. The overdosing of N fertilizer to sugar beet may result in extraction problems [5]. They reported that neither nitrates nor nitrites can be removed during purification process and therefore they are encountered in all steps of white sugar production. Hozayn *et al*. [5] reported that improving sugar beet productivity and sugar extracting process is considered main target by adjusting N rate and the appropriate source of N and emphasized that the application the proper source of nitrogen could effectively maximize the potential sugar production.

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Recently, due to the shortage of energy products energy crops attracted the attention. Bioethanol as a promising alternative fuel can be a suitable alternative to replace fossil fuels [6]. World ethanol production has reached 51.4 million m^3 in 2006 increasing 10 % annually from 28 million m^3 in 2000 [7]. Bioethanol is made from plant material that is broken down and fermented by yeast and can be produced from any crop that produces fermentable sugars, which also includes sugar cane, sugar beets and unused portions of other crops such as fruit waste. Ethanol used today in biofuels is typically made from fermenting and then distilling starch crops, such as corn or wheat [8]. Bioethanol biomass from agriculture represent one of the largest and most diversified sources to be exploited and more specifically, ethanol and diesel [9, 10].

Therefore, the aim of this work is to investigate sugar beet production as sugar or energy crop with sub optimal N application in combination with different manure types and levels in newly reclaimed sandy soil.

MATERIALS AND METHODS

Field trials were conducted in the winter seasons of 2016/17 and 2017/18 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 (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 fd^{-1}) in newly reclaimed sandy soil. The experiment included 24 treatments which were two nitrogen fertilizer levels *i.e.* 0 and 40 kg fd^{-1} and three organic manure (plant compost farmyard manure and chicken manure) and four levels (3, 6, 9 and 12 t fd^{-1}) with and without reduced N fertilizer rate. The experimental design in the trial was split-split plot design where organic manure levels occupied the main plots , the manure levels were in the sub plots while nitrogen fertilizer treatments were in the sub-sub plots. The area of the trial was 0.2 ha (0.48 feddan), 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 4^{th} and 14^{th} in 2013 and 2014, respectively at rate of 2 kg fd^{-1} by hand in ridges. Harvest was done at mid-April. Root and shoot yields fd^{-1} were determined from a central area of 21 m^2. The following characters were determined at harvest: plant height, root length, root diameter (cm), root yield $plant^{-1}$ (g), shoots yield $plant^{-1}$ (g), biological yield $plant^{-1}$ (g).

At harvest, plants in the four inner ridges of each plot were collected and cleaned, therefore roots were separated and weighed in kilograms and converted to estimate root yield fd^{-1} (t) shoots yield fd^{-1} (t) and biological yield fd^{-1} (t). A sample of 10 kg of roots were taken at random from each plot and sent to the Beet Laboratory at Nubaria Sugar Factory to determine quality. Alpha amino nitrogen (α-amino N), sodium (Na) and potassium (K) concentrations were estimated according to the procedure of Sugar Company by Auto Analyzer described by [11]. Sucrose (expressed as Pol %) was estimated in fresh samples of sugar beet root by using Saccharometer according to the method described by [12]. Gross sugar yield fd^{-1} (t) = root yield fd^{-1} (t) x sucrose %. root quality *i.e.*, sucrose percentage.

Chemical analysis of the bio-solids was carried out on dried and ground samples. Nitrogen was determined by micro-Kjeldahl according to the method described by [13]. After wet digestion of the samples according to [13], P was determined by spectrophotometry, K by flame photometer according to the method described by [14] and Fe, Mn, Cu and Zn were determined by atomic absorption spectrophotometry.

Bioethanol Determination: A composite sample of 50 kg of each organic manure treatment was taken and milled to obtain juice. Thereafter, bioethanol was determined using fermentation by yeast according to [15].

The analysis of variance of split plot experiment was carried out using MSTAT-C Computer Software [16], 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

Data presented in Table (1) show significant differences among different organic manures 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.

Table 1: Effect of different bio solids on sugar beet characters

Organic manure	Plant height (cm)	Root length (cm)	Root diameter (cm)	Root yield plant^{-1} (g)	Shoots yield plant^{-1} (g)	Biological yield plant^{-1} (g)	Root yield fd^{-1} (t)	Shoot yield fd^{-1} (t)	Biological yield fd^{-1} (t)
Plant compost	38.2	15.3	8.3	484.8	93.2	577.9	33.9	6.5	40.4
Farmyard manure	47.5	22.5	8.8	597.7	112.7	706.3	41.8	7.9	49.7
Chicken	44.5	14.6	9.2	526.5	127.7	658.3	36.9	8.9	45.8
LSD at 0.05	2.7	1.5	0.46	66.7	23.5	78.4	4.6	1.4	5.4

Table 2: Effect of different bio solids levels on sugar beet characters.

Organic manure levels fd^{-1} (t)	Plant height (cm)	Root length (cm)	Root diameter (cm)	Root yield plant^{-1} (g)	Shoots yield plant^{-1} (g)	Biological yield plant^{-1} (g)	Root yield fd^{-1} (t)	Shoot yield fd^{-1} (t)	Biological yield fd^{-1} (t)
3	41.0	14.5	7.84	390.8	101.04	504.4	37.35	7.09	44.44
6	46.0	18.4	8.50	536.9	96.88	629.6	37.58	6.78	44.36
9	44.6	17.4	9.05	601.9	114.00	715.9	42.13	7.98	50.11
12	44.3	18.3	9.34	580.4	127.92	712.5	40.62	8.95	49.57
LSD at 0.05	2.7	1.9	0.46	66.42	23.47	78.4	4.64	1.64	5.42

Table 3: The interaction effect (bio-solids source × N level).

Organic manure	Nitrogen fertilizer N fd^{-1}(kg)	Plant height (cm)	Root length (cm)	Root diameter (cm)	Root yield plant^{-1} (g)	Shoots yield plant^{-1} (g)	Biological yield plant^{-1} (g)	Organic manure effect in sugar beet yield plant^{-1}
Plant compost	0	36.25	14.08	7.00	323.33	73.00	396.33	323 (50%)
	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 4: Effect of interaction between (nitrogen x organic manure source) on sugar beet characters

Organic manure	Nitrogen fertilizer N fd^{-1}(kg)	Root yield fd^{-1} (t)	Shoot yield fd^{-1} (t)	Biological yield fd^{-1} (t)	Organic manure effect in root yield fd^{-1}
Plant compost	0	22.6	5.1	27.7	22.6 (50)
	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)
	40	49.1	12.0	61.1	
LSD at 0.05		3.6	2.9	13.4	

Farm yard manure increased the sugar yield 10% when applied at the rate of 20 tons ha^{-1} compared to control plots [17]. Ostrowska and Kucinska [18] confirmed that organic fertilizers increased sugar beet yield more than mineral fertilizers. Abd El-Gawad *et al*. [19] found that fresh and dry yields fd^{-1} were higher at 60 m^3 organic manure fd^{-1}. Moreover Gazia [20] and Hassan [21] 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 fd^{-1}.

Data presented in Table (2) show the effect of bio solids levels on sugar beet characters. The data show that application of bio solids over 3 tons fd^{-1} significantly increased all sugar beet studied characters. The differences between the levels 9 and 12 tons fd^{-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 tons fd^{-1}(15 m^3 fd^{-1}).

Data presented in Table (3) show that application the reduced N rate of 40 kg N surpassed the application of the treatment without N regardless organic manure type or rate. As expected, all the studied characters values were greater when 40 kg N was applied compared with 0 kg N fd^{-1}.

Data presented in Table (4) show that significant effects due to the interaction between bio solids application and N level. The interaction between organic manure application and N resulted in significant increases

Table 5: Effect of interaction between (nitrogen × bio solids levels) on sugar beet characters

Type fertilizers	Levels fd^{-1} (t)	Nitrogen fertilizer N fd^{-1} (kg)	Plant height (cm)	Root length (cm)	Root diameter (cm)	Root yield $plant^{-1}$ (g)	Shoot yield fd^{-1} (t)	Root yield fd^{-1} (t)	Biological yield fd^{-1} (t)
Plant compost	3	0	36.3	14.7	5.6	193.3	3.7	13.5	17.3
		40	33.0	11.3	8.3	343.3	6.5	24.0	30.6
	6	0	36.7	12.7	6.1	343.3	4.7	24.0	28.7
		40	44.7	19.0	9.3	701.7	6.1	49.1	55.2
	9	0	35.0	11.0	8.1	376.7	6.8	26.4	33.2
		40	45.3	19.0	10.1	716.7	9.2	50.2	59.4
	12	0	37.0	18.0	8.2	380.0	5.3	26.6	31.9
		40	37.3	16.7	10.3	823.3	9.9	57.6	67.6
Farmyard manure	3	0	43.3	17.0	7.8	373.3	6.9	26.1	33.0
		40	47.3	21.7	8.2	561.7	7.5	39.3	46.8
	6	0	51.0	24.7	9.2	606.7	7.2	42.5	47.4
		40	54.7	29.7	10.7	910.0	9.7	63.7	73.4
	9	0	41.3	18.3	7.6	386.7	5.4	27.1	32.4
		40	48.7	22.3	8.7	761.7	11.0	53.3	64.3
	12	0	44.7	21.7	8.1	400.0	6.2	28.0	34.2
		40	49.0	24.7	10.0	781.7	9.3	54.7	64.1
Chicken manure	3	0	35.3	11.0	7.7	271.7	5.1	19.0	24.2
		40	44.7	12.33	9.5	550.0	13.4	38.5	51.9
	6	0	44.0	13.0	8.3	406.7	6.4	28.5	34.9
		40	48.0	18.0	8.7	493.3	6.6	34.5	41.2
	9	0	45.0	15.7	8.4	338.3	5.6	23.7	29.3
		40	50.7	17.7	10.6	900.0	11.7	63.0	74.7
	12	0	39.0	13.3	8.5	386.7	6.4	27.1	35.8
		40	49.7	16.0	12.0	865.0	16.2	60.6	76.8
LSD at 0.05			ns	4.1	1.8	154.3	ns	6.4	11.8

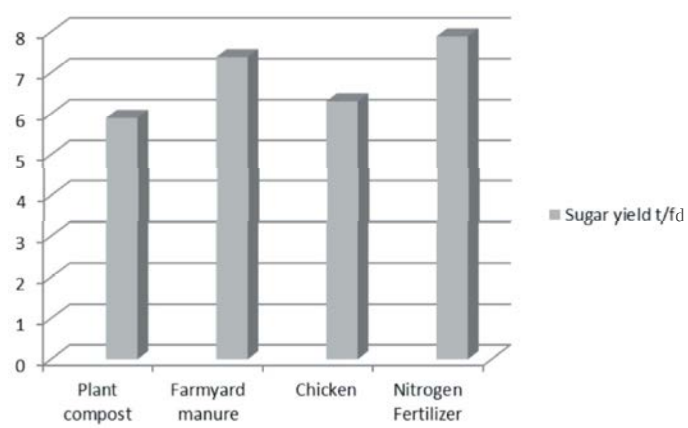

Fig. 1: Effect of different bio solids levels on sugar yield fd^{-1}(t)

in all the studied characters, in general application of the organic manure 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 contribution of organic manures in sugar beet yield $plant^{-1}$ were 50.0, 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 organic manure as inputs of sugar beet production.

Data presented in Table (5) 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 fd^{-1} while application of farmyard manure at 6 t and fertilization with 40 kg N fd^{-1} gave the highest beet yield $plant^{-1}$ and per feddan. Such superiority for the farmyard manure was

Table 6: Effect of different bio solids levels on sugar beet quality characters

Organic manure	Quality	Polarity (sugar %)	K%	Na %	Amino N %	Tar %	Gross sugar yield fd^{-1}(t)
Plant compost	85.1	17.4	4.7	1.1	2.18	4.16	5.9
Farmyard manure	86.3	17.7	4.1	1.0	2.17	2.82	7.39
Chicken manure	84.1	17.1	4.2	1.6	2.56	3.95	6.31
Nitrogen fertilizer	86.1	16.7	4.1	1.1	1.28	3.95	7.89
CV%	1.8	1.8	7.6	38.2	32.9	32.6	5.8
LSD at 0.05	ns	ns	ns	ns	0.96	ns	1.3

Table 7: Effect of bio solids on ethanol production from sugar beet (ton & liter fd^{-1})

Organic manure	Bioethanol production fd^{-1} (Kg)	Bioethanol fd^{-1}(L)
Plant compost	678	814.0
Farmyard manure	837	1004.0
Chicken	737	884.4
LSD at 0.05	93.1	111.4

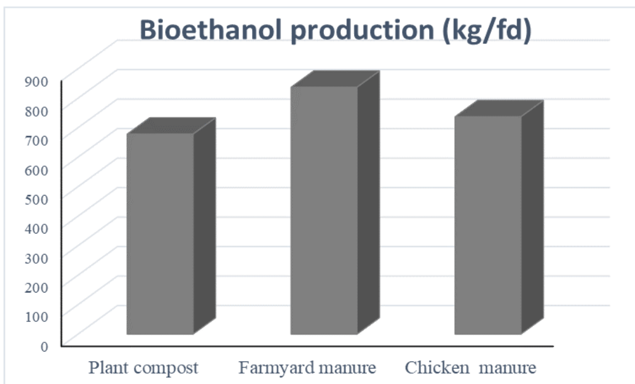

Fig. 2: Effect of different organic manure on bio ethanol production fd^{-1}(t)

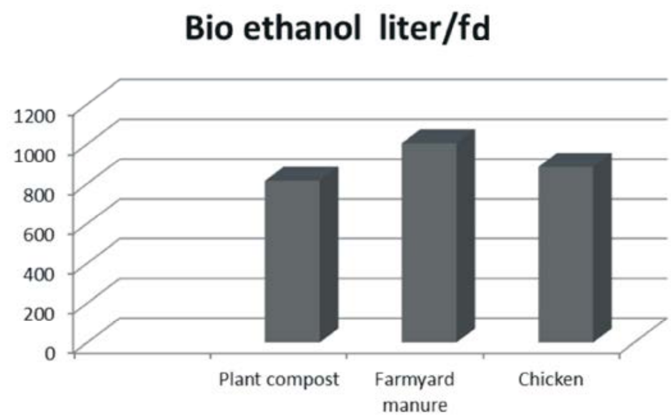

Fig. 3: Effect of different bio solids on bio ethanol production fd^{-1}(L)

reported by [18] who confirmed that organic fertilizers increased sugar beet yield more than mineral fertilizers. Abd El-Gawad *et al*. [19] found that fresh and dry yields fd^{-1} were higher at 60 m^3 organic manure fd^{-1}.

Effect of Different Bio Solids Levels on Sugar Beet Quality Characters: Data presented in Table (6) and Fig. (1) did not reveal significant differences among different fertilizer resources used in the trial in beet quality except the Amino N % character. In general, the N fertilizer treatment possessed the highest purity parameter (quality%) and the lesser root impurities values such as potassium, sodium, amino acids and tar %. Such superiority in these parameters compared with the other bio solids resulted in higher gross sugar yield. These results assure the fact that rationalized use of N through the reduced rate used effectively contribute in sugar extraction. The obtained results are in accordance with those obtained by Carter [22] who stated that α amino nitrogen is consider one of the main impurities and undesirable character which decrease the quality. Both K and Na are impurities and their ratio interfere with the crystallization process and interfere with the crystallization process with a reduction in refined sugar. Also, [23] and [24] came to similar conclusion.

Effect of Different Bio Solids on Bio Ethanol Production from Sugar Beet: Data presented in Table (7) and Figs. (2 and 3) show the production of ethanol from sugar beet after harvest. The results indicate that the production of bioethanol from sugar after harvest. Bioethanol production significantly differed according to the bio solid used. It ranged between 678 and 837 kg fd^{-1} or between 814 and 1004 liters fd^{-1}. Fertilizing sugar beet with farmyard manure resulted in producing the greatest bio-ethanol production fd^{-1} followed by chicken manure and the lowest produced from sugar beet fertilizing with plant compost. It is estimated that from the context that each gram of sucrose that is recovered from sugar beets can be converted into approximately half a gram of ethanol. Sugar beets are generally about 17% sucrose by mass, although genetic modifications, selective breeding and irrigation increase this number substantially, up to 21% [25]. In 2009 25.8 tons or about 23, 400 kg of sugar beets were harvested per acre of land cultivated [26], which represents approximately 1930 kg of ethanol could be produced. Ogbonna *et al.* [27] reported that sugar beet yield of ethanol reached 72-86% of the sugar beet juice fermented.

CONCLUSION

The obtained results generally clear that the best rates of the organic manures addition ranged between 6 and 9 tons of organic fertilizer which may minimize the risk of inorganic fertilizers application . Sugar beet crop proved to be as an eco-friendly energy source for bioethanol production which reduce imported energy products.

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