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Some Correlative Relationships among Nitrate Content, Yield and Quality of Sugar Beet Fertilized with Organic and Inorganic Fertilizers

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Abstract: Field trials were conducted to investigate the effect of organic manure (composted) and nitrogen on sugar beet yield and to evaluate the correlative relationships among nitrate content, yield and quality of sugar beet parameters. The relationships between root production and N addition to soil in fertilizer or compost showed that the regression coefficients for the yield responses to mineral and compost N were similar and suggested there was equality in N value between the fertilizer and the composted product. Crop yield increased in linear relation to N addition although much larger root production was observed with increasing rate of N application in compost compared with the range of N application rates supplied for inorganic fertilizer. The lowest sugar beet yield treatments were the control, inorganic fertilizer, and compost at 5 m^3 fd^{-1} treatments; they contained reasonable sugar percentages but could not compensate their low root production ability to out-yield higher sugar yield. The results showed that that Alpha amino-N the component is related to sugar detracting, where it lowers the QZ parameter. Except for the relation between sugar percentages in roots, the data revealed strong significant correlation between sap nitrate content, root (P <0.001 ***), R^2 = 0.822, shoot (P <0.001 ***), R^2 = 0.064, total yield (P <0.001 ***), R^2 = 0.165, and extractable sugar. The sap nitrate content reached an eight-fold increase in some treatments which could potentially detract the commercial value of the crop to the sugar beet processor which was confirmed by the results of sugar extraction quality parameters.

Key words: Nitrogen fertilizer · Nitrate · Organic manure · 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 505000 feddan (one feddan (fd) = 4200 m^2) with an average of 16 t fd^{-1} in 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. Compost, far from being merely include a group of wastes, should be regarded as a natural resource to be conserved and used rather than discarded [1]. 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 [2]. 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 [3].

In Egypt, various studies have assessed the benefits of organic manures including compost on the physical characteristics of Egyptian soils and in increasing crop

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yields [4]. 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. 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. This is undesirable because the nitrites can react with sulphur dioxide that leads to an increase in ash content in white sugar, and also causes a significant reduction in sulfidation efficiency and a substantial increase in the color of sugar juices. The nitrites and nitrates also adversely affect the quality of molasses used as feed materials. Sugar beet is a relatively becoming an important crop in Egypt and it demands moderate quantities of organic manure and nitrogen and lower water requirements compared with sugar cane; however, due to some environmental problems like nitrate leaching in the desert lands and the lack of organic manure, it is important to find alternative organic resources. Therefore, the aim of this work is to study the effect of N fertilizer rates alone or combined with compost on yield, nitrogen equivalency value and root sap nitrate in newly reclaimed soil.

MATERIALS AND METHODS

Field trial was conducted in the winter seasons on a private farm, Nubaria District; Behaira Governorate (84 km Alex-Cairo desert road), in a newly reclaimed desert soil. The objective of the trial was to investigate the effect of organic manure (composted) and nitrogen on sugar beet yield and to evaluate the fertilizer equivalency value of the compost. The area of the trial was 0.25 ha (0.59 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; Ni 2.9 ppm). The experiment included 20 treatments which were 5 nitrogen fertilizer levels i.e.; 0, 15, 30, 45 and 60 kg fd^{-1} and 4 composte levels *i.e.* 5, 10, 15 and 20 m^3 fd^{-1} with and without adjusted N fertilizer rate (F = 30 kg N fd^{-1}). The experimental design in the trial was complete randomized block. Sugar beet cultivar Alexa was sown in hills 25 cm apart on October 24*th* and 31*th* 2016 and 2017, respectively at rate of 2 kg fd^{-1} by hand in ridges. Harvest was done at early April. Root and shoot yields fd^{-1} were determined from a central area of 10.5 m^2 at each plot. Sap nitrate concentration was determined by Nitra-check meter. The N equivalency value was estimated by the following equation according to [6]:

$$\text{N equivalency (\%)} = \frac{1/b\ (y - a)}{\text{N}} \text{x}100$$

Where a is the regression intercept value), b is the regression coefficient, y is the mean root yield recorded for the plots supplied with compost at a rate of 10 m^3 fd^{-1} and N is the rate of N application at 10 m^3 fd^{-1} of sludge compost.

Chemical composition of the roots Twenty roots from each plot were randomly taken to determine root quality and technological characteristics at Quality Control Laboratory, El-Nubaria Sugar Factory and El-Behera, Egypt. Sucrose % was determined using Saccharometer according to the method described in AOAC (2012). According to Cooke and Scott [8] impurities (potassium (K), sodium (Na), and alpha amino nitrogen (α-amino N) were estimated. Moreover, juice purity using Eq. 1 was estimated [8]. After that, sugar yield ha^{-1} was calculated according to Deviller [9].

Statistical Analysis: The analysis of variance of complete randomized block design was carried out using MSTAT-C Computer Software [10], after testing the homogeneity of the error according to Bartlett's test, the combined analysis for both seasons was done. The means of the different treatments were compared using the least significant difference (LSD) test at $P<0.05$.

RESULTS AND DISCUSSION

Highly significant effects of the treatments were found by ANOVA ($P<0.001$); (Table 1). Nitrogen fertilizer application on its own did not result in any significant effects on yield or sap nitrate concentration, Highest root yield and sap nitrate was observed at 30 kg N fd^{-1}, although shoot yields were progressively increased by fertilizer addition up to the highest rate applied (60 kg N fd^{-1}). Compost applied at 5 m^3 fd^{-1}, with or without N fertilizer (30 kg N fd^{-1}), did not significantly increase yields over the control. Higher application rates of compost, with or without the adjusted rate of N fertilizer, significantly increased yields over the lower rate of compost. At the highest rate of compost, yields of roots and shoots were respectively, 20.1 and 23.1 t fd^{-1}, compared with 5.1 and 8.4 t fd^{-1} from 60 kg N fd^{-1}, and 3.4 and 3.8 t fd^{-1} from the untreated control. Thus, there were substantial yield benefits from compost addition.

Table 1: Effects of compost and N fertilizer on sugar beet yield characteristics.

Treatment	Root yield (t fd^{-1})	Fresh weight (t fd^{-1})	Total yield (t fd^{-1})	Sap nitrate (mg l^{-1})
Control	3.38 d	3.75 e	7.12 d	51.0 f
15 kg N fd^{-1}	3.89 cd	5.25 e	9.14 d	83.5 ef
30 kg N fd^{-1}	5.34 cd	5.82 e	11.16 d	255.0 cde
45 kg N fd^{-1}	4.42 cd	6.65 de	12.50 d	108.0 def
60 kg N fd^{-1}	5.10 cd	8.44 cde	15.62 cd	61.2 f
Compost 5 m^3 fd^{-1}	4.92 cd	5.41 e	10.34 d	109.5 def
Compost 5 m^3 fd^{-1} + F	7.00 c	8.44 cde	15.44 cd	133.5 def
Compost 10 m^3 fd^{-1}	10.94 b	12.83 bc	23.75 bc	352.5 abc
Compost 10 m^3 fd^{-1} + F	10.84 b	11.25 bcd	22.09 bc	228.5 cde
Compost 15 m^3 fd^{-1}	12.30 b	14.06 b	26.36 b	444.0 a
Compost 15 m^3 fd^{-1} + F	13.34 b	14.69 b	28.02 b	334.5 abc
Compost 20 m^3 fd^{-1}	18.40 a	19.69 a	41.09 a	420.5 a
Compost 20 m^3 fd^{-1} + F	20.10 a	23.12 a	43.22 a	380.5 ab
Grand mean	9.23	10.72	20.45	227.8
cv %	21.98	28.63	26.83	27.9
Probability	<0.001***	<0.001***	<0.001***	<0.001***
LSD at 0.05	2.91	4.40	7.87	138.5

Note: Numbers in each column followed by different letters are significantly different at P<0.05; (F = 30 kg N fd^{-1})

Table 2: Sugar beet chemical composition of roots.

Variety	Sugar %	Na %	K %	Alpha amino-N	Q.Z %	Extractable sugar kg fd^{-1}
Control	15.1	2.4	2.8	1.3	85.74	510.38
60 kg N fd^{-1}	14.2	2.5	6.5	2.3	75.07	724.20
Compost 5 m^3 fd^{-1}	14.0	3.5	4.6	1.8	80.07	688.80
Compost 10 m^3 fd^{-1}	13.5	3.2	5.3	1.7	80.88	1476.90
Compost 15 m^3 fd^{-1}	12.9	3.7	6.2	2.5	72.89	1586.70
Compost 20 m^3 fd^{-1}	13.9	2.6	5.8	2.3	75.27	1888.80

Several investigators reported similar results with different organic manures, farm yard manure increased the sugar yield 10% when applied at the rate of 20 tones ha^{-1} compared to control plots [11]. Ostrowska and Kucinska [12] confirmed that organic fertilizers increased sugar beet yield more than mineral fertilizers. Abd El-Gawad *et al.* [13] found that fresh and dry yields fd^{-1} were higher at 60 m^3 organic manure fd^{-1}. Moreover, Gazia [14] 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}. Similarly, Hassan [15] yield, sucrose content, purity % and the concentrations of NPK and micronutrients (Fe, Mn and Zn) in roots.

Sugar Beet Quality: Data presented in Table 2 show that sugar beet fertilizer treatments exhibited clear differences in quality parameters, which affected sugar extraction parameters. It is worthy to note that the lowest sugar beet yield treatments were the control, inorganic fertilizer and compost at 5 m^3 fd^{-1} treatments contained reasonable

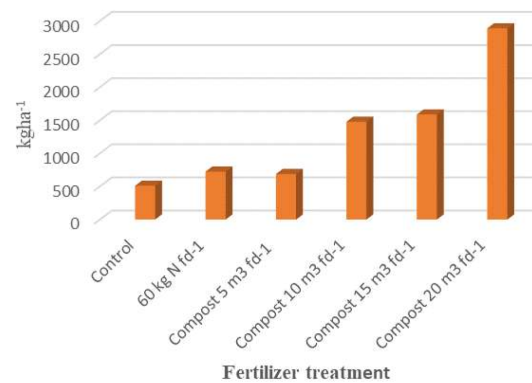

Fig. 1: Effect of fertilizer treatments on extractable sugar kg fd^{-1}

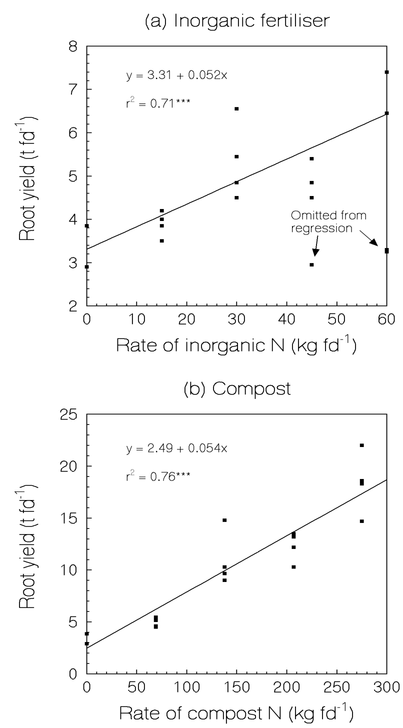

Fig. 2: Yield of sugar beet roots in relation to the rate of N application in (a) inorganic fertilizer and (b) compost.

sugar percentages but could compensate its low root production ability to out yield higher sugar yield. It seems that Alpha amino-N the component is related to sugar detracting, where it lowers the QZ parameter. The obtained results are in accordance with those obtained by [16], who reported similar results in root yield, sugar contents and sugar recovery.

Nitrogen fertilizer equivalency value of the composted product for sugar beet production was

Table 3: Relationship between sap nitrate in sugar beet leaves and different sugar beet parameters

Parameters	Sap nitrate (mg l^{-1})
Root yield (ton fd^{-1})	$R^2 = 0.822$ P <0.001 *** y = -24.468220086 + 36.5561989854*x -0.7044850983*x^2
Shoot weight (ton fd^{-1})	$R^2 = 0.064$ P <0.0000 *** y = -23.416798809 +29.3606106734*x - 0.4032135196*x^2
Total yield (ton fd^{-1})	$R^2 = 0.165$ P <0.001 *** y = -33.119439611 +16.6846644553*x - 0.1400555745*x^2
Sugar %	$R^2 = 0.06464867788$ Ns y = 13.7752302149 +0.00707608942*x - 1.6116664e-5*x^2

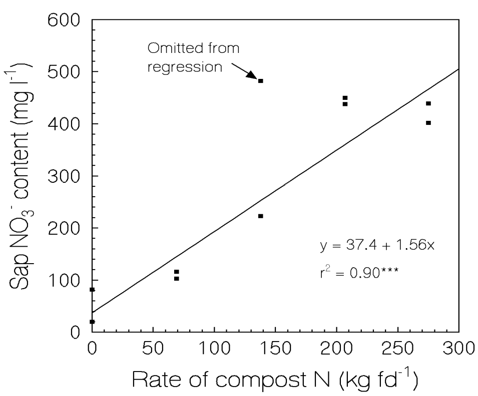

Fig. 3: Nitrate concentration in sugar beet sap in relation to the rate of N application in compost

determined. The relationships between root production and N addition to soil in fertilizer or compost were calculated. The regression coefficients for the yield responses to mineral and compost N were similar and suggested there was equality in N value between the fertilizer and the composted product (Fig. 2). Crop yield increased in linear relation to N addition although much higher root production was observed with increasing rate of N application in compost compared with the range of N application rates supplied for inorganic fertilizer.

Sap nitrate concentration in beet root was also raised significantly by compost application (Table 1 and Fig. 3). The measurement of plant nitrate status confirmed the significant plant available N content in compost, but in the case of sugar beet high nitrate content may reduce the economic value of the crop to the beet processor. B¹k *et al.* [17] reported that free amino acids, betaine, nitrate and nitrite are soluble nitrogen compounds entering the sugar production process with sugar beet. These compounds impede the conduct of the manufacturing process and adversely influence the quantity and quality of produced white sugar, as well as the quality of molasses and pulp, which are valuable feed materials. When evaluating the quality and processing suitability of sugar beet, only the free amino acid content is taken into account, although other soluble nitrogen compounds also significantly affect the sugar production process.

Correlative Studies: Data presented in Table 3 show that except the relation between sugar percentage in roots, the results showed strong significant correlation between sap nitrate content and root, shoot, total yield and extractable sugar. Significant relationship between sap nitrate content and root yield was (P <0.001 ***), R^2 or = 0.822, while the relationship between sap nitrate content and shoot weight was (P<0.0001***), $R^2 = 0.064$ and the relationship between sap nitrate content and total yield was (P <0.001 ***), $R^2 = 0.165$.

CONCLUSION

The study showed substantial yield benefits from compost addition and it suggested that there was equality in N value between the fertilizer and the composted product. The measurement of plant nitrate status confirmed the significant plant available N content in compost may lead to high nitrate content and reduce the economic value of the crop to the beet processor under the conditions of this experiment, there was an eight-fold increase in sap nitrate concentration which could potentially detract the commercial value of the crop to the sugar beet processor.

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