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Nitrogen Fertilizers Management for Improving Sugar Beet Quality and Sucrose Production

Lamy M. M. Hamed[1] and Mohamed A. E. Soliman[2]

[1] *Soil and Water Department, Faculty of Agriculture, Cairo University, 12613, Giza, Egypt*
[2] *Soil Department, Faculty of Agriculture, Damietta University, Egypt*

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ABSTRACT

Nitrogen element is the key to achieve high yield and quality of sugar beet. Increasing pricing and pollution of mineral fertilizers, producers/farmers often consider alternative as composted manure. Two successive field experiments were conducted at private farm located in Badaway village, Mansoura, Dakahleia Governorate, Egypt during 2014/2015 and 2015/2016 seasons to evaluate the effect of three mineral N rates (50, 75 and 100 kg N per feddan) and three rates of plant compost (control (Zero), 1 and 2 tons per feddan) on sucrose percentage, root recoverable sugar yield, nitrogen use efficiency (NUE) (sucrose % per kg N) as well as the status of N, P and K in soil after harvest of Monte Bianko sugar beet variety. The obtained results indicated that application of 100 kg N per feddan decreased sucrose % by 2.86 and 9.39, whereas root yield increased by 20.30 and 20.26 % and sugar yield increased by 13.33 and 8.91 % in first and second seasons, respectively, compared to 50 kg N per feddan. Compost positively affect sucrose and root sugar yield. Root yield (39.73 and 42.10 tons fed^{-1}) and recoverable sugar yield (6.77 and 7.07 tons fed^{-1}) as average of the two growing seasons resulted from 75 kg N along with 2 tons compost per feddan and 100 kg N with 2 tons of compost fed^{-1}, respectively, without significant differences. Furthermore, increasing the application of N reducing the NUE, but increased the remained amount of N, P and K in soil after harvesting, while the reverse tendency were observed whereas increasing the application of compost from zero up to 2 tons per feddan enhancing the NUE as well as the remained values of N, P and K in soil.

Key words: Sugar beet, Sucrose percentage, NUE, NPK after harvesting

Introduction

Nitrogen is the essential elements for crop growth and production. In Egypt, sugar beet plays a prominent role for sugar production and considered as one of the two important sugar crops in the world. Sugar beet grower's intent to apply excess mineral nitrogen in beet fields believing in that high vegetative growth of beet plants must reflecting on absolute high root and recoverable sugar yields, where Abdel-Aal and Ibrahim (1990) and Fadel (2002) studied the response of sugar beet to nitrogen fertilization. They found that application of high N fertilizer to sugar beet plants significantly increased root and sugar yield but sugar percentage gradually decreased. Also, Khalil (2010) and Stevens *et al*. (2011) studied the effect of N fertilizer (45 up to 120 kg N fed^{-1}), the results indicated that increasing the applied nitrogen levels up to 120 kg N fed^{-1} significantly increased root and sugar yields, where as sucrose and sugar recovery percentage deceased as N rates increased reflecting the increase of impurities and sucrose loss to molasses as N rate increased. Further, sugar and root yield of sugar beet increased significantly with increasing the N fertilizers levels (El-Gizawy *et al.,* 2014). However, some aspects of nitrogen fertilizer application such as improvement uses of organic manure in contribution with mineral fertilizers need further investigation, where recently, mineral fertilizers are not available in some critical periods plus the environmental pollution of these mineral fertilizers. Among the sustainable growers, there is a great interest about using the organic fertilizers in order to increase the crop health and yield as well as the soil fertility. A lot of researches have been conducted in open fields and revising the power of use this way of management which is growing rapidly. Combining the management of nutrients along with organic and inorganic fertilizers has been reported in increase yields and chemical elements in *Plantago arenaria* (Kolodziej 2006). Integrated use of inorganic fertilizers with organic nutrients sources shown to enhance the power of organic fertilizers and improve the use efficiency of mineral fertilizers which could be a way to minimize it up to certain levels.

To face this situation using organic manures may help in solving this problem and improve crop production. Zawiślak and Rychcik (1997) concluded the results of 25 years traits of sugar beet that when only mineral nitrogen applied root and sugar yield averaged 44.6 and 6.0 ton ha^{-1}, respectively, when organic manure and mineral N were used corresponding yield were 51.1 and 75 ton $ha^{-1.}$ Mohamed (2008) studied the effect of compost manure on sugar beet plants. Results indicated that application of 2 tons of compost

Corresponding Author: Lamy HAMED, Soil and Water Department, Faculty of Agriculture, Cairo University, 12613, Giza, Egypt Email: lamy.hamed@agri.edu.eg

per feddan for sugar beet increased fresh and dry weight of root as well as sugar percentage and sugar yield compared to mineral N.

Therefore, the target of this study is to find out the most proper combination of mineral and organic nitrogen fertilizers that achieved the highest sugar beet yield with best juice quality traits.

Materials and Methods

Experimental design

Two field experiments were carried out at private farm (Badaway village, Mansoura, Dakahleia Governorate, Egypt) with latitude of 31° 2' 16.5588" N and longitude 31° 22' 53.4828" E with elevation 10 m height over the sea level during 2014/2015 and 2015/2016 seasons, to study the effect of mineral and organic nitrogen sugar beet yield. The variety used was Monte Bianko (from Germany), which was provided by the Sugar Crops Research Institute, Agriculture Research Center, Egypt. Mechanical and Chemical analysis of the two experimental sites are presented in Table 1.

Table 1: Physical and chemical parameters of upper 30cm of soil during 2014/2015 and 2015/2016 seasons

Seasons	Clay (%)	Silt (%)	Sand (%)	Soil texture	pH	EC	Organic matter (%)	K (ppm)	P (ppm)	N (ppm)
1st	68.4	19.4	12.2	Clay	7.4	0.9	1.4	314	10.2	19.22
2nd	65.2	22.1	12.7		7.7	1.0	1.8	340	11.1	25.94

Nitrogen fertilizer:

Three nitrogen rates were used in the form of ammonium nitrates (33% N) *i.e.,* 50, 75 and 100 kg N/feddan. Nitrogen rates were divided into two equal doses, the first was applied after thinning (45 days from sowing) and the second was applied 4 weeks later.

Organic fertilizer (plant compost):

Three organic fertilizer rates (zero, 1 and 2 tons fed^{-1}) were used in the form of plant compost that is called Nile Compost (1.5% N), which was incorporated into the soil two weeks before planting. The analysis of the compost is shown in (Table 2).

Table 2: Average physical and chemical properties of Nile compost

Character	Component
Weight of 1 m^3 (kg)	720
Humidity percentage (%)	33
pH (extracTable 1:5)	8.3
EC (extracTable 1:5) (mmol/cm)	2.95
Total Nitrogen (%)	1.5
Aminouim Nitrogen (ppm)	160
Nitrate Nitrogen (ppm)	125
Organic matter (%)	53
Organic carbon (%)	30.9
C/N ratio	17.5
NaCl (%)	1.30
Dobalic acids (%)	14.1
Total phosphorus (%)	0.85
Total potassium (%)	1.45
Fe (ppm)	2114
Mn (ppm)	189
Cu (ppm)	75
Zn (ppm)	26

A split plot design with four replicates was used; nitrogen rates were arranged randomly in the main plots, compost rates in sub plots. The sub plot area was 15 m^2 and consisted of five ridges of 5m in length and 60 cm apart. Sowing was on 19^{th} and 13^{th} of October in 2014/2015 and 2015/2016 seasons, respectively, and the field was irrigated immediately after planting. Seedlings were thinned at 4-6 leaf stage to ensure one plant per hill. Phosphorus fertilizer at a rate of 30 kg P_2O_5/fed in the form of superphosphate (15.5% P_2O_5) was added at sowing in both seasons. And Potassium fertilizer at a rate of 48 kg K_2O/fed in the form of Potassium Sulphate (48% K_2O) was added with the first dose of Nitrogen fertilizer. Other cultural practices were carried out as usual. Harvest of sugar beet plants took place after 205 days from sowing in both seasons of experimentation.

Studied characters

1. **Sucrose percentage** was determined polarimeterically.
2. **Sugar recovery (RS) %**

RS= {Pol% - 0.029 - (0.343 (Na + K) - 0.094 (alpha amino-N)}

Where; Pol % = sucrose %

3. **Recoverable sugar yield** (RSY) (ton fed^{-1})

RSY = Root yield (ton/fed) x Sugar recovery %

4. **Nitrogen use efficiency** in sugar beet production systems is the mass of Sucrose produced per kg of N supply **NUE = kg sucrose / kg N**

Statistical analysis

Data collected were subjected to the proper statistical analysis of variance of split plot design according to the procedures outlined by Snedecor and Chochran (1967). To compare treatment means; L.S.D. at 5% level of significance was used according to Steel and Torrie (1980). All statistical analysis was performed by using analysis of variance technique of (Mstat-C) Computer software package.

Results and Discussion

Effect of mineral fertilization

The results illustrated in table 3 showed that sucrose % was significantly affected by mineral N fertilizer in both seasons, where increasing N rate from 50 up to 100 kg N fed^{-1} significantly decreased sucrose percentage by 2.86 and 9.39 % in the first and second seasons, respectively.

These reductions might have been due to the role of high N rate in enhancing beet growth which was reflected in large size and heavy roots which assumed to contain lower content of sucrose (Aly, 2007 and stevens *et al*., 2011).

On the other hand, nitrogen fertilization positively effect on root yield (ton fed^{-1}) in both seasons (Table 4). Each nitrogen increment was accompanied with a marked increase in root yield. Increasing N rate from 50 up to 75 kg fed^{-1} increased root yield by 2.82 and 2.72 tons, and increasing N rate from 75 up to 100 kg N fed^{-1} increased root yield by 3.80 and 3.77 tons in the first and second seasons, respectively, which reflect the positive effect of N on leaf area index as well as fresh and dry weight of the individual root (Azzazy *et al*., 2007, El-Sarag, 2009 and Mekdad, 2012).

The increase in root yield as N rate increased compensated the reduction in sucrose %, where recoverable sugar yield (Table 4) finally increased as N rate increased. Increasing N rate from 50 up to 100 kg N fed^{-1} significantly increased sugar yield by 13.33 and 8.91 % in the first and second seasons, respectively. Differences between 50 and 75 kg N fed^{-1} in sugar yield were not significantly; while 75 and 100 kg N fed^{-1} were significantly differ in both seasons. These findings are in agreement with those of Hamad (2004) and El-Sarag (2009).

Effect of Organic fertilization

Application of compost significantly affected sucrose percentage and root and sugar yields in both seasons. Increasing compost rate from zero up to 1 ton fed^{-1} increased sucrose percentage by 3.59 and 1.81%, root yield by 11.87 and 7.55% and recoverable sugar yield by 5.81 and 5.03 %, where increase compost rate from 1 up to 2 ton fed^{-1} increased sucrose % by 3.24 and 1.95 %, root yield increased by 11.51 and 11.47 % as well as sugar yield increased by 14.48 and 10.23 % in the first and second seasons, respectively.

Table 3: Sucrose percentage (%) and Nitrogen Use efficiency (NUE) (kg sucrose kg N^{-1}) as affected by mineral and organic nitrogenous fertilizers in 2014/15 and 2015/16 seasons

Nitrogen kg fed^{-1}	Compost ton fed^{-1}	Sucrose percentage (%)		NUE kg sucrose kg N^{-1}	
		1st Season	2nd Season	1st season	2nd season
50	0	17.67	19.15	35.33	38.30
	1	18.11	19.59	36.22	39.18
	2	18.80	19.74	37.60	39.47
Mean		**18.19**	**19.49**	**36.38**	**38.98**
75	0	17.11	17.96	22.81	23.94
	1	17.85	18.18	23.80	24.24
	2	18.42	19.00	24.55	25.33
Mean		**17.79**	**18.38**	**23.72**	**24.50**
100	0	17.07	17.41	17.07	17.41
	1	17.73	17.72	17.73	17.72
	2	18.22	17.86	18.22	17.86
Mean		17.67	17.66	17.67	17.66
Mean of compost	**0**	**17.28**	**18.17**	**25.07**	**26.55**
	1	**17.90**	**18.50**	**25.92**	**27.05**
	2	**18.48**	**18.86**	**26.79**	**27.55**
L.S.D $_{0.05}$ for					
Nitrogen (N)		0.38	0.45	4.89	5.02
Compost (C)		0.38	0.45	N.S	N.S
N x C		**0.65**	**0.78**	**7.27**	**7.93**

Table 4: Root yield (ton fed^{-1}) as affected by mineral and organic nitrogen fertilizers in 2014/15 and 2015/16 seasons

Nitrogen kg fed^{-1}	Compost ton fed^{-1}	Root yield (ton fed^{-1})		Recoverable sugar yield (ton fed^{-1})	
		1st Season	2nd Season	1st Season	2nd Season
50	0	28.46	28.94	5.42	5.41
	1	32.64	32.58	5.57	6.02
	2	36.96	34.60	6.57	6.41
Mean		**32.68**	**32.04**	**5.85**	**5.95**
75	0	31.03	31.51	5.53	5.75
	1	35.23	33.57	5.91	5.74
	2	40.23	39.22	6.81	6.74
Mean		**35.50**	**34.76**	**6.08**	**6.08**
100	0	36.31	36.06	6.08	6.16
	1	39.30	37.65	6.55	6.41
	2	42.31	41.90	7.26	6.88
Mean		**39.30**	**38.53**	**6.63**	**6.48**
Mean of compost	**0**	**31.93**	**32.17**	**5.68**	**5.77**
	1	**35.72**	**34.60**	**6.01**	**6.06**
	2	**39.83**	**38.57**	**6.88**	**6.68**
L.S.D $_{0.05}$ for					
Nitrogen (N)		1.63	2.07	0.28	0.37
Compost (C)		1.63	2.07	0.28	0.37
N x C		2.81	3.59	0.48	0.53

Compost rate of 2 tons fed^{-1} produced the highest sucrose percentages which insure the important role of compost in releasing the major nutrients among them is K which enhanced formation and translocation of sucrose from tops to roots. Similar findings were mentioned by Abd-El Wahab *et al*., (2005) and Mogarzan *et al*., (2007). Also, the obtained substantial increase in root yield due to increasing compost level might have resulted from the favorable effect of compost on fresh and dry weight of individual root (Kapur, 1993 and Kristaponyte, 2003). This positive effect of compost on root yield reflected on sugar yield (Attallah and El-Etreiby, 2002 and Ibrahim, 2006).

Effect of Mineral and Organic fertilization interaction

First and second seasons interactions had a significant effect on the studied traits, where the highest sucrose percentage (18.80 and 19.74%) resulted from 50 kg N combine with 2 tons of compost per feddan, on the other hand, the highest root yield (42.31 and 41.90 tons fed^{-1}) as well as recoverable sugar yield (7.26 and 6.88 tons fed^{-1}) resulted from the application of 100 kg N along with 2 tons of compost per feddan in the first and second seasons, respectively.

Nitrogen use efficiency (kg sucrose kg N^{-1}) under the studied treatments

The data presented in table 3 illustrated the NUE (kg sucrose kg N^{-1}) as affected by different N and compost rate. The obtained results highlighted that increasing the application of N fertilizers reduce the NUE irrespective to the compost rate. While within the same rate of nitrogen, it's clearly that increasing the compost rate from 1 up to 2 enhance the NUE in both seasons. This might be due to the release of mineral from the compost (decay) through the growing season where it could be a source of N. This result agreed with Madejón *et al.* (1996) whom they conclude that use of compost can be an a1ternative of traditional mineral fertilizer. The highest value of NUE (37.60 and 39.47) was recorded under the treatment of 50 kg N fed^{-1} along with 2 ton compost fed^{-1} in first and second seasons, respectively. The nitrogen use efficiency (NUE) ranged from 37.68 to 17.67 kg sucrose kg^{-1} N supply over all compost treatments. These results were in agreements with Tarkalson *et al.* (2012) whom they found that as N supply increased, NUE decreased.

Table 5: N, P, and K (mg kg^{-1}) remained in soil after harvesting

Nitrogen kg fed^{-1}	Compost ton fed^{-1}	N		P		K	
		mg kg^{-1}					
		1st season	2nd season	1st season	2nd season	1st season	2nd season
50	0	14.6	15.3	8.5	8.7	291	298
	1	31.2	32.3	9.8	10.1	299	304
	2	37.2	36.1	11.4	12.1	305	316
Mean		**27.67**	**27.90**	**9.90**	**10.30**	**298.33**	**306.00**
75	0	16.3	18.5	8.9	9.1	314	320
	1	42.5	45.9	9.2	10.4	325	344
	2	46.8	47.9	11.9	12.0	357	370
Mean		**35.20**	**37.43**	**10.00**	**10.50**	**332.00**	**344.67**
100	0	28.1	30.4	9.2	9.1	333	330
	1	49.3	50.1	10.1	9.8	354	361
	2	51.2	50.7	12.3	12.4	393	401
Mean		**42.87**	**43.73**	**10.53**	**10.43**	**360.00**	**364.00**
Mean of compost	**0**	**19.67**	**21.40**	**8.87**	**8.97**	**312.67**	**316.00**
	1	**41.00**	**42.77**	**9.70**	**10.10**	**326.00**	**336.3**
	2	**45.07**	**44.90**	**11.87**	**12.17**	**351.67**	**362.33**

Data presented in Table 5 showed the status of N, P and K in soil after sugar beet harvesting. As general point of view, it's obvious that increasing the rate of N mineral fertilizers from 50 up to 100 kg N fed^{-1} increasing the remained N in soil after sugar beet harvesting irrespective to the compost rate, where the lowest value (14.6 and 15.3 mgk^{-1}) of remained N in soil has been observed under the treatment of 50 kg N per feddan, where the highest value (51.2 and 50.7 mgk^{-1}) were recorded under the treatment of

100 kg N per feddan. Same tendency were observed for both P and K elements where the highest and the lowest values were recorded under 100 and 50 kg N fed^{-1}, respectively. It can be due to increase of available N, P, and K contents in soil after harvesting as indicated on soil fertility and the combination of major nutrients from the inorganic fertilizer.

Regarding to the effect of the organic application of compost, it was clear that increasing the application of compost from zero up to 2 tons per feddan significantly increase the N, P and K elements remained in soil after sugar beet harvesting.

The interaction effect of both applications (mineral and compost) also have positively increase the remained N, P and K elements in soil. The organic sources of N, as well as their combinations with inorganic sources, have been reported to significantly improve plant height, fresh and dry weights of both aboveground parts and roots, and oil yield in basil compared to plots receiving only inorganic N (Kandeel, Nagla, and Sadek 2004; Sifola and Barbieri 2006). The application of compost and microorganisms was also demonstrated to significantly improve growth and essential oil production in *Rosmarinus officinalis* (Aziz *et al.,* 2007). Further studies have been reported that added organic materials together with microbial activity can improve soil health and fertility (Logan *et al*., 1997; Loveland and Webb 2003).

Conclusion

Mineral nitrogen positively affected beet growth and yield, whereas quality traits decreased as N rate increase. On the other hand, increasing compost rate from zero up to 2 tons fed^{-1} increased sucrose percentage, root and sugar yields, NUE and N, P, K remained in soil after harvesting in both seasons.

Economically, application of 75 kg N fed^{-1} with 2 tons of compost produced high root and sugar yield without significant differences compared to 100 kg N fed^{-1}.

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