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Root Yield and Quality of Sugar Beet (*Beta vulgaris* L.) in Response to Foliar Application with Urea, Zinc and Manganese in Newly Reclaimed Sandy Soil

B.B. Mekki

Department of Field Crops Research, National Research Centre, Dokki, Giza, Egypt

Abstract: This study was carried out during two winter seasons 2007/08 and 2008/09 in the Experimental Station of National Research Center, Nobaryia, Beheira Governorate, Egypt in order to investigate the response of root yield and quality of sugar beet (*Beta vulgaris* L.) to foliar application with Urea, Zn and Mn in newly reclaimed sandy soil. Application of 2% Urea, 400 ppm Zn or Mn as sole treatment increased root length and diameter as well as fresh root weigh by 22.89, 70.08 and 157.66 % for Urea compared to control treatment, respectively and by 37.16, 87.08 and 207.66 % for Zn and by 10.50, 59.55 and 185.25 % for Mn as compared to control treatment, respectively. The highest fresh root weight (2.045 kg/plant) was obtained by using 2% Urea +400 ppm Zn followed by the treatment received 2% Urea +400 ppm Zn + 400 ppm Mn. On the contrary, the lowest root fresh weight (0.522 and 1.345 kg/plant) was obtained with control plants and the treatment received 2 % Urea alone. Root and top yields were significantly increased with the treatments received 2% Urea+ 400 ppm Zn + 400ppm Mn, 2% Urea+ 400 ppm Zn and 2% Urea + 400 ppm Mn in comparison to control or the other treatments. The highest root and top yields (57.240 and 32.507 t/ha) was obtained with the treatment 2% Urea+ 400 ppm Zn + 400 ppm, while the lowest (15.059 and 6.176 t/ha) and (23.800 and 7.040 t/ha) with 2% Urea as sole treatment compared with control treatment, respectively. The same trend was noticed in sugar yield (t/ha), cleared that foliar application with 2% Urea+ 400 ppm Zn + 400 ppm Mn produced the highest sugar yield (2.460 t/ha) followed by 2% Urea+ 400 ppm Zn (1. 936 t/ha), while the lowest (0.521 and 0.712 t/ha) was obtained by control and 2% Urea, respectively. The results also indicated that the sucrose % in the Juice was increased with applying 2% Urea, 400 ppm Zn or Mn singly and also in combination with them as one treatment in comparison to control treatment. However, application of 2% Urea+ 400 ppm Zn + 400 ppm Mn produced the highest sucrose in the juice (18.96 %) followed by 2% Urea+ 400 ppm Zn (17.44 %), while the lowest (14.42 %) was obtained without applications (control). TSS% was decreased with applying 2% Urea as single treatment followed by the treatment of 2% Urea +400 Zn or Mn. Purity % was increased up to 87.20 % with foliar spraying with 2% Urea+ 400 ppm Zn followed by (83.64 %) with 2% Urea+ 400 ppm Zn + 400 ppm Mn. On the other hand, the lowest purity (60.08 %) was obtained by control treatment. Na and K contents were increased with applying Urea, Zn and Mn as foliar spray in comparison to control treatment. The treatment of 2% Urea+ 400 ppm Zn + 400 ppm Mn recorded the highest Na and K content, while the lowest was recorded with control and 400 ppm Mn.

Key words: Foliar spray · Manganese · Root Quality · Sandy Soil · Sugar Beet · Urea · Zinc

INTRODUCTION

Sugar beet (*Beta vulgaris* 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 where there are wide newly reclaimed sandy soil at the northern and southern parts of Egypt, that could be cultivated sugar beet without competition with other winter crops due to its tolerance to salinity and ability to produce high

Corresponding Author: Dr. B.B. Mekki, Field Crops Research Department, National Research Centre, Dokki, Giza, Egypt.

sugar yield under saline conditions and limited water requirements in comparison to the other traditional winter crops. Moreover, in Egypt, there was 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. Improvement of sugar beet productivity can be achieved through many factors such as fertilization management and foliar fertilization. During the last decade, foliar application of nutrients has become an established produce in crop production for increasing yield and improving the quality of crop products. Higher values of biomass especially of leaves and roots at budding and flowering stages are observed in the variants with foliar feeding [1]. Foliar nutrition with urea is considered a new direction to improve nitrogen use efficiency through minimizing the applied rate of nitrogen, particularly under the reverse soil conditions. Higher availability of nutrients in organic fertilizer was the main factor contributing to higher biomass of plants [2]. Nemeat Alla and El-Geddawy [3] reported that used foliar spray of micronutrients significantly increased root length of sugar beet. Application of urea foliar may allow increased nitrogen utilization from fertilizer source without a concomitant decrease in symbiotic N_2 fixation, providing that inter conversion of urea under field conditions can be inhibited [4]. Barsoum and Nassar [5] revealed that foliar application of urea at 4% concentration produced highest root length and diameter as well as root and top yields of sugar beet plants. The use of foliar urea and extract of cattle manure may allow increased nitrogen utilization from fertilizer and enhanced growth hormone synthesis in the roots and increased root biomass.

Zinc deficiency appears to be the most widespread and frequent micronutrient deficiency problem in crop and pasture plants worldwide, resulting in severe losses in yield and nutritional quality. Zinc is an essential micronutrient and has particular physiological functions in all living systems, such as the maintenance of structural and functional integrity of biological membranes and facilitation of protein synthesis and gene expression. Among all metals, Zn is needed by the largest number of proteins. Zinc-binding proteins make up nearly 10 % of the proteomes in eukaryotic cells and 36% of the eukaryotic Zn-proteins are involved in gene expression. Zinc deficiency is common in soils of arid and semi-arid regions and zinc is considered as the most limiting factor for producing crops in different regions of the world [6, 7, 8]. While, Zn is the primary plant nutrient, relatively small amounts of Zn are required to support the process of growth and quality of the plants. However, the high lime contents, alkaline soils with low organic matter and imbalanced application of fertilizers may also enhanced Zn deficiencies in the many agricultural crops. Zinc fertilizer practice affect yield, quality and Zn use efficiency in crops [9, 10]. During the last two decades, new generations, varieties and cultivars are being available for different plant species to be grown in soil suffering from Zn deficiency. However, these new cultivars have not been subjected to examination for growth under nutrients stress conditions. Cultivars that can efficiently use Zn might tolerate Zn deficiency to some extent and have higher yields [11, 12, 13].

Moreover, Marschner [14] stated that, micronutrients, especially Zn, act either as metal components of various enzymes or as functional, structural, or regulatory cofactors. Thus, they are associated with saccharide metabolism, photosynthesis, nucleic acid, lipid metabolism and protein synthesis. Who added that, zinc is an essential micronutrient for synthesis of auxin, cell division and the maintenance of membrane structure and function. Zinc also plays an important role in the production of biomass [15] and chlorophyll production [16]. Under typical sugar beet growing conditions there is little emphasis on these nutrients because their release from the soil organic matter and naturally occurring soil minerals is sufficient to meet the sugar beet needs. However, on sandy soils with low organic matter (< 2%) this may not always be the case and deficiencies may appear. Draycott and Christenson [17] reported that sugar beet can become deficient in several micronutrients, but is most responsive to the application of B, Mn and Fe fertilizers when the soil availability of these nutrients is low. Boron and Mn deficiencies are probably most frequent and subsequently are the most studied of all the micronutrient important to the sugar beet production.

Therefore, the main objective of this study was to investigate the effect of foliar application with Urea, Zinc and Manganese on root yield and quality of sugar beet (*Beta vulgaris* L.) in newly reclaimed sandy soil in Egypt.

MATERIALS AND METHODS

Two field experiments were carried out in the Agricultural Experimental Station of the National Research Centre at Nobaryia, Beheira Governorate, Egypt during the two successive winter seasons 2007/08 and 2008/09 to investigate the response of root yield and quality of sugar beet (*Beta vulgaris* L.) to foliar application of Urea, Zn and Mn. The experimental unit area was 10.5 square meters consisting of ten rows (3.5 m long and 30 cm between rows). Seeds of sugar beet (Montarosa cv.) mainly obtained from the Sugar Research Institute, Agricultural Research Center, Giza, Egypt were sown in hills 20 cm between at October 26 in the two successive winter seasons. Thinning was done after 45 days after planting (DAP) to leave one plant per hill till harvest time. Phosphorus and potassium fertilizer were added before sowing at a rate of 500 and 250 kg/ha as super phosphate (15.5% P_2O_5) and potassium sulphate (48-50% K_2O), respectively, while nitrogen fertilizer was added at a rate of 150kg N/ha as ammonium nitrate (33.5%N) in two equal doses at 21 and 35 days after planting (DAP). The experimental soil site are sandy soil in texture, pH 8.43, EC 0.22 dS/m, OM 0.92%, $CaCO_3$ 5.85%, total N 392 ppm, available P 5.8 ppm, K 0.82 ppm, Zn 0.13 ppm, Mn 4.34 ppm and Fe 5.92 ppm. Foliar spraying with Urea (46% N), Zn (Zinc chelate (EDTA) 14% Zn) and Mn (Mn chelate (EDTA) 13% Mn) were applied twice at 60 and 75 days after planting (DAP) and the treatments used as follows:

- Water foliar application (control)
- 2 % Urea
- 400 ppm Zn
- 400 ppm Mn
- 2% Urea + 400 ppm Zn
- 2% Urea + 400 ppm Mn
- 2% Urea + 400 ppm Zn +400 ppm Mn

At harvest time, the following criteria were recorded, root yield (t/ha), root length (cm), root diameter (cm). Sucrose % was determined according to Le-Docte [18], total soluble solids (TSS%) were measured in fresh roots using hand refractmeter, juice purity% was also determined as a ratio between sucrose% and TSS% according to Carruthers and Oldfield [19]. Sodium and potassium % were determined in the juice by using Flame photometer. Sugar yield (t/ha) was calculated as follows:

Sugar yield (t/ha) = Root yield (t/ha) x Sucrose % x Purity %

Purity % in sugar beet Juice was calculated as follows:

Purity % = Sucrose/TSS x 100

Statistical Analysis: The obtained data were statistically analyzed as factorial experiments in complete randomize design according to Snedecor and Cochran [20] and the combined analysis was done according to Steel and Torrie [21], the treatments means were compared using LSD test and 5% of probability.

RESULTS

Growth and Yield: The results presented in Table 1 indicated that root length and diameter as well as fresh root weight of sugar beet plants were significantly differed with Urea foliar application singly or in combination with Zn and Mn as one treatment compared to the control treatment. Application of 2% Urea as sole treatment increased these traits by 22.89, 70.08 and 157.66 % compared to control treatment, respectively. At the same time, foliar application with 400 ppm Zn or Mn micronutrients as sole treatment increased root length and diameter as well as fresh root weigh by 37.16, 87.08 and 207.66 % for Zn and by 10.50, 59.55 and 185.25 % for Mn as compared to control treatment, respectively (Table 1). However, root length was significantly decreased with application of 2% Urea +400 ppm Zn + 400 ppm Mn compared to the treatment received Urea, Zn and/or Mn singly. Data in Table 1 indicated that the sole treatment of Urea or Zn and Mn had no significant effect on root diameter, while the highest fresh root weight (2.045 kg/plant) was obtained with 2% Urea +400 ppm Zn followed by the treatment received 2% Urea +400 ppm Zn + 400 ppm Mn. On the contrary, the lowest root fresh weight (0.522 and 1.345 kg/plant) was obtained with control plants and the treatment received 2 % Urea alone.

Root and top yields were significantly affected by the foliar application with Urea, Zn and Mn (Table 1). Data presented in Table 1 indicated that root and top yield were significantly increased with the treatments received 2% Urea+ 400 ppm Zn + 400ppm Mn, 2% Urea+ 400 ppm Zn and 2% Urea + 400ppm Mn in comparison to control or other treatments. The highest root and top yields (57.240 and 32.507 t/ha) was obtained with the treatment 2% Urea+ 400 ppm Zn + 400ppm, while the lowest (15.059 and 6.176 t/ha) with control treatment and (23.800 and 7.040 t/ha) with 2% Urea as sole treatment. The same trend was noticed in sugar yield (t/ha), data in Table 1 cleared that foliar application with 2% Urea+ 400 ppm Zn + 400ppm Mn produced the highest sugar yield (2.460 t/ha) followed by 2% Urea+ 400 ppm Zn (1. 936 t/ha), while the lowest (0.521 and 0.712 t/ha) was obtained by control and 2% Urea, respectively.

Table 1: Effect of foliar application with urea, Zn and Mn on growth and yield of sugar beet.

Treatments	Root length (cm)	Root diameter (cm)	Root weight (kg/plant)	Root yield (t/ha)	Top yield (t/ha)	Sugar yield (t/ha)
Without application (Control)	23.33a	6.65b	0.522d	15.059d	6.176e	0.521d
2% Urea	28.67ab	11.31a	1.345c	23.800c	7.040e	0.712d
400 ppm Zn	32.00a	12.31a	1.606bc	47.300b	10.880d	1.758b
400 ppm Mn	26.56bc	10.61a	1.489c	28.635c	20.640c	0.963c
2% Urea + 400 ppm Zn	31.67a	12.56a	2.045a	55.506a	24.920b	1.936b
2% Urea + 400 ppm Mn	25.67bc	11.51a	1.567bc	47.443b	24.320b	1.724b
2% Urea + 400 ppm Zn + 400 ppm Mn	23.44c	11.95a	1.822ab	57.240a	32.507a	2.460a
LSD 0.05	3.71	2.20	0.328	6.339	2.033	0.225

Table 2: Effect of foliar spray with Urea, Zn and Mn on Sucrose % and purity of sugar beet

Treatments	Pol %	TSS %	Purity %	Na %	K%
(Control)	14.42	24.00a	60.08	0.43	0.14
2% Urea	15.42	19.40f	79.49	0.53	0.21
400 ppm Zn	16.92	21.97c	77.01	0.46	0.18
400 ppm Mn	16.02	21.00d	76.29	0.43	0.17
2% Urea +400 ppm Zn	17.44	20.00e	87.20	0.54	0.20
2% Urea +400 ppm Mn	16.38	20.90d	78.37	0.52	0.20
2% Urea +400 ppm Zn +400 ppm Mn	18.96	22.67b	83.64	0.55	0.24
LSD 0.05	--	0.48	--	--	--

Quality: Data presented in Table 2 indicated that the sucrose % in the Juice was increased with applying 2% Urea, 400 ppm Zn or Mn singly and also in combination with them as one treatment in comparison to control treatment. However, application of 2% Urea+ 400 ppm Zn + 400ppm Mn produced the highest sucrose in the juice (18.96 %) followed by 2% Urea+ 400 ppm Zn (17.44 %), while the lowest (14.42 %) was obtained without applications (control). On the other hand, the treatments of 400 ppm Zn, 400ppm Mn or 2% Urea +400 ppm Zn seem to be the same values and a slight differences among them (Table 2). Data in Table 2 also indicated the TSS % was significantly decreased with applying Urea, Zn or Mn singly or in combination among them as on treatment in comparison to control treatment. The total soluble solids was decreased with applying 2% Urea as single treatment followed by the treatment of 2% Urea +400 Zn or Mn. Purity % was increased up to 87.20 % with foliar spraying with 2% Urea+ 400 ppm Zn followed by (83.64 %) with 2% Urea+ 400 ppm Zn + 400ppm Mn. On the other hand the lowest purity (60.08 %) was obtained by control treatment. Na and K contents were increased with applying Urea, Zn and Mn as foliar spray in comparison to control treatment. The treatment of with 2% Urea+ 400 ppm Zn + 400 ppm Mn recorded the highest Na and K content, while the lowest was recorded with control and 400 ppm Mn.

DISCUSSION

The present study indicated that, in general some growth characters namely root length and diameter and fresh top weight of sugar beet plants were significantly increased by foliar spraying of Urea, Zn and Mn singly or in combination of them (Table 1). Under typical sugar beet growing conditions there is little emphasis on these nutrients because their release from the soil organic matter and naturally occurring soil minerals is sufficient to meet the sugar beet needs. However, on sandy soils with low organic matter (< 2%) this may not always be the case and deficiencies may appear. Draycott and Christenson [17] reported that sugar beet can become deficient in several micronutrients, but is most responsive to the application of Zn and Mn fertilizers when the soil availability of these nutrients is low. Manganese deficiency is probably most frequent and subsequently are the most studied of all the micronutrient important to the sugar beet production.

The function of Mn at the cellular level of plant is to bind firmly to lamellae of chloroplast, possibly to the outer surface of thylakoid membranes, affecting the chloroplast structure and photosynthesis [22]. They found a significant increase in the photosynthetic electron transport rates coupled to PSII and PSI until the 8mgL^{-1} Mn treatment. The highest Mn treatment was also observed to be associated to the synthesis of a new thylakoid protein and a Mn protein. Burman *et al.* [23] reported that application of urea increased most of these parameters. These results revealed synergistic effects of urea in enhancing leaf area and growth rate, leading to significant improvement in plant growth. The influence of N on plant growth and development is often connected with the process of photosynthesis, because the quantity of N in the highest degree, determines the formation and the functional state of assimilation apparatus of plants including the content of photosynthetic pigments, the synthesis of the enzymes taking part in the carbon reduction and the formation of the membrane system of chloroplasts [24]. The present results, concerning the positive effects of foliar urea application upon the photosynthetic machinery (pigment content and PS II activity), appeared to coincide with those positive effects on the dry mass accumulation in sugar beet plants. This gives us a reason to admit that one of the factors providing higher dry mass accumulation in treated plants was the increased capacity for CO_2 assimilation. Higher availability of nutrients in organic fertilizer was the main factor contributing to higher biomass of plants [2]. Nemeat Alla and El-Geddawy [3] reported that used foliar spray of micronutrients significantly increased root length of sugar beet. Application of urea as foliar spray may allow increased nitrogen utilization from fertilizer source without a concomitant decrease in symbiotic N_2 fixation, providing that inter conversion of urea under field conditions can be inhibited [4].

Regarding, the effect of foliar spray with Urea or Zn and Mn, the present results (Tables 1 and 2) indicated root and top yields as well as sugar yield were significantly affected by Urea foliar spray singly or with in combination with Zn or Mn. Our results are in agreement with those obtained by Barsoum and Nassar [5], who reported that foliar application of urea at 4% concentration produced highest root length and diameter as well as root and top yields of sugar beet plants, while Leilah *et al.* [25] pointed that the use of foliar urea may allow increased nitrogen utilization from fertilizer and enhanced growth hormone synthesis in the roots and increased root biomass. They also stated that foliar application of 1 or 2 % Urea significantly increased root, top fresh weight, sucrose %, TSS %, purity % and sugar yield. Data presented in Table 2 indicated that application of Urea + Zn or Urea + Zn + Mn as one treatment increased the Pol%, TSS % and purity %. These results are in agreement with those obtained by Younis *et al.* [26], who pointed that foliar application of urea fertilizer at 2%, 3% and 4% induced significant progressive increases in glucose, sucrose, polysaccharides and in total saccharides content; the magnitude of increase was most pronounced with 4%, whereas at 5% and 6% levels of urea, a significant progressive decrease in the saccharide fractions determined. Neamatollahi *et al.* [27] reported that application of zinc had significant effect on yield and sugar content and had significant effect on the percent of molasses. Zinc treatments had significant effect on yield and sugar yield. The best level of zinc for sugar beet was 40 kg/ha, with the highest yield and sugar percent. In higher level of zinc (80kg/ha) yield and sugar percent decreased. Application $ZnSO_4$ had significant ($P<0.05$) effect on the percentage of pure and impure sugar depend also the percentage of molasses sugar whereas second level (40kg/ha $ZnSO_4$) had higher percentage of pure and impure sugar and lower the percentage of molasses sugar. El-Saht [28] observed a greater increase in reducing sugars associated with progressively greater decreases in the content of sucrose, polysaccharides and total saccharides in soybean plants with the increase in concentration of urea fertilizer. On the other hand, Leilah *et al.* [29] reported that the increase in nitrogen levels was associated with marked reduction in TSS, sucrose % and purity %. Barsoum and Nassar [6] revealed that foliar application of urea at 4% concentration produced highest root length and diameter as well as root and top yields of sugar beet plants. The use of foliar urea and extract of cattle manure may allow increased nitrogen utilization from fertilizer and enhanced growth hormone synthesis in the roots and increased root biomass. Leilah *et al.* [25] stated that foliar application of 1 or 2% Urea significantly increased root length, root diameter, root and top fresh weight. They also reported also the root and top yields as well as Sucrose %, TSS %, purity % and sugar yield were significantly increased by foliar application of 1 or 2 % Urea. Neamatollahi *et al.* [27] reported that application of zinc had significant effect on yield and sugar content and had significant effect on the percent of molasses. In all varieties, zinc treatments had significant effect on yield and sugar yield. The best level of zinc for sugar beet was 40 kg/ha, with the highest yield and sugar percent. In higher level of zinc (80kg/ha) yield and sugar percent decreased. Application $ZnSO_4$ had significant ($P<0.05$) effect on the percentage of pure and impure sugar depend also the percentage of molasses sugar whereas second level (40kg/ha $ZnSO_4$) had higher percentage of pure and impure sugar and lower the percentage of molasses sugar. Purity % was increased up to 87.20 % with foliar spraying with 2% Urea+ 400 ppm Zn followed by (83.64 %) with 2% Urea+ 400 ppm Zn + 400ppm Mn. The increase in purity % with these treatments may be attributed to the increase in Pol % and decrease the TSS %. On the other hand the lowest purity (60.08 %) was obtained by control treatment. Na and K contents were increased with applying Urea, Zn and Mn as foliar spray in comparison to control treatment. However, the untreated plant produced the lowest Na (0.43%) and K (0.14%), so the reduction in Na an K content lead to increase of total impurities with control treatment than with other treatments.

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