Assiut J. Agric. Sci., (46) No. (6) 2015 (1-14) *ISSN: 1110-0486*
Website: http://www.aun.edu.eg/faculty_agriculture/arabic *E-mail: ajas@aun.edu.eg*

Influence of Potassium Fertilization and Foliar Application of Zinc on Sugar Beet Plants Grown on a Calcareous Sandy Soil

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Abstract:

This study was conducted at El-Ghorieb Exp. Farm, Assiut University, Assiut, Egypt, during 2010/2011 and 2011/2012 seasons to investigate the effect of potassium fertilization (48 and 72 kg K_2O fed.$^{-1}$) and the foliar spray with three zinc chelate levels zero, 75, and 150 mg l^{-1} as Zn-EDTA (15% Zn) on yield and quality as well as Fe, Mn and Zn contents of sugar beet plants grown on a calcareous sandy soil.

- All plant characteristics and quality traits of sugar beet i.e., top and root fresh and dry weights, sucrose content, sugar recovery, recoverable sugar yield, as well as Fe, Mn and Zn contents were significantly increased by increasing the K level from 48 to 72 kg K_2O fed.$^{-1}$ in both seasons.

- Increasing the potassium level caused an increase in the sucrose percentage. Moreover, a remarkable increase in the recoverable sugar percentage was observed as K level increased. Potassium fertilization showed a significantly increase on sugar beet yields at 48 kg N fed.$^{-1}$ level as well as 72 kg K_2O fed.$^{-1}$ for top yield and recoverable sugar yield.

- With regard to zinc foliar application, significant decreases on impurities and increases on sugar loss to molasses and sucrose percentage were observed. It also had an insignificant effect on the recoverable sugar percentage. In most cases, increasing Zn level up to 150 mg l^{-1} significantly increased the sugar beet yields fed.$^{-1}$

- Potassium fertilization x zinc foliar application interaction had a significant effect on Na content in beet roots in both seasons. Moreover, significant effects were observed only on K content in beet roots and sugar losses to molasses in the first season as well as top yield fed.$^{-1}$ in the second season. It could be concluded that application of the K fertilization at 72 kg K_2O fed.$^{-1}$ along with the foliar application of zinc had a positive effect in increasing all growth traits of sugar beet.

Keywords: *Sugar beet, potassium, zinc, foliar application and calcareous sandy soil.*

Received on: 31 /12/2015 **Accepted for publication on:** 18/1/2016

Referees: Prof. Mohamed A. El-Desoky Prof. Elsaadi A. Ali

Introduction:

The availability of plant nutrients are strongly related to the properties of soils. Calcium carbonate is one of the most important factors that limit the nutrient availability in soils. Calcareous soils which contain significant quantities of free lime ($CaCO_3$) are common in arid and semi-arid climate affecting over 600 million hectares of world soils (Leytem and Mikkelsen, 2005). These soils are also important for the production of field crops. Micronutrient deficiency is one of the most important abiotic stresses in plants grown on calcareous soils (Xudan, 1986).

Sugar beet (*Beta vulgaris* L.) is considered the second sugar beet crop, after sugar cane, for sugar production in Egypt. It has an important position in Egyptian crop rotation as a winter crop. It is able to grow not only in fertile soils, but also in poor, saline, alkaline and calcareous soils. The strategy of sugar production is to expand sugar beet cultivation in calcareous soils where some nutrients, especially micronutrients, are short in supply for normal growth and high yield of roots and sugar.

Sugar beet is classified as a high potassium requiring crop (Johanson *et al*., 1971). Potassium plays an important role in the transport of metabolites in the phloem, particularly into storage tissues. It is the most abundant cation in the cytoplasm. Plants that accumulate large reserves of protein, carbohydrate and sugar in their storage tissues have high K requirements. Potassium and its accompanying anions make a major contribution to the osmotic potential of cells and tissues of glycophytic plant species. It has a role in the nutritional balance which increases the organic compounds through the photosynthesis (El-Harriri and Gobarh, 2001, Gobarh and Thalooth, 2001).

Zinc is an essential microelement to plants. Its presence in concentrations below a critical minimum level hinders plant growth and development. It plays an important role in the production of biomass. Furthermore, zinc may be required for chlorophyll production, pollen function, fertilization and germination (Cakmak, 2008). It is an essential component of various enzyme systems for energy production, protein synthesis and growth regulation (Mengel and Kirkhy, 1987). Two long-known effects of zinc deficiency are on photosynthesis and carbonic anhydrate activity. However, many other cellular processes and components are altered by zinc deprivation (Marschner, 1995). Zinc-deficient plants also exhibit delayed maturity. Zinc is not mobile in plants. So, its deficiency symptoms occur mainly in new growth. Its poor mobility in plants suggests the need for a constant supply of available zinc for optimum growth.

Zinc availability is limited by high pH, high free calcium carbonate, sandy texture and low organic matter as well as where subsoil has been exposed by land leveling. It may be further reduced by heavy P application. These conditions are common in many Egyptian sugar beet growing areas and Zn fertilization is routinely recommended for other crops in these areas. Several studies have been shown that a small amount of micronutrients, particularly Zn that is applied by foliar spraying can significantly increase the yield of crops (Moustafa *et al*., 2011). Also, foliar nutrition is an option when nutrient deficiencies cannot be corrected by direct applications of the nutrients to the soil (Sarkar *et al*., 2007). The application of Zn to sugar beet plants grown on a calcareous soil with marginal Zn availability resulted in increased root and sugar yields (Stevens and Mesbah, 2005). The purpose of this work is to investigate effects of potassium fertilization and Zn foliar application on growth, yield and quality as well as iron, manganese and zinc uptake by sugar beet plants grown on a calcareous sandy soil.

Materials and Methods:

Two field experiments were conducted on a calcareous sandy soil at El-Ghorieb agricultural experimental farm of Assiut University, Assiut, Egypt, during 2010/2011 and 2011/2012 seasons to study the effect of potassium and foliar application of Zn on growth, yield and quality as well as Fe, Mn and Zn uptake by sugar beet grown on a calcareous sandy soil. Some physical and chemical properties of the experimental soil that were determined according to the methods described by Jackson (1967) before sowing are present in Table 1. The soil was treated with 31 kg P_2O_5 fed.$^{-1}$ as calcium superphosphate (15.5% P_2O_5) during soil preparation. Randomized complete block design (RCBD) using a split-plot arrangement with three replications. Three levels of Zn (zero, 75 and 150 mg l^{-1}) in a chelate form of Zn-EDTA (15% Zn) were assigned to the main plots.

Foliar application of Zn was carried out on the plants at 60 and 90 days after planting at a level of 300 and 600 l fed.$^{-1}$, respectively. Two potassium levels (48 and 72 kg K_2O fed.$^{-1}$) as potassium sulphate (48% K_2O) were randomly arranged in the sub-plots. The area of each plot was 10.5 m^2 (3.5 m length x 3 m width) with 6 ridges of 50 cm apart and 3.5 m in length. The preceding crop was wheat in both seasons. Sugar beet seed balls of multi-germ Kawemira cv. were sown in hills of 20 cm apart at a rate of 2-3 balls hill^{-1} on the 3rd and 5th of October in 2010/2011 and 2011/2012 seasons, respectively. The plants were thinned to one plant per hill at the 4-6 leaf stage. Nitrogen fertilization was applied at a level of 100 kg fed.$^{-1}$ as ammonium nitrate (33.5% N) in three doses of 20, 40 and 40 kg N fed.$^{-1}$ immediately after thinning one month and two months after thinning, respectively. The potassium fertilizer was applied after thinning. The normal cultural practices of growing sugar beet were applied. Two weeks before harvest, the irrigation of sugar beet was stopped in both seasons. At maturity (190 days from sowing), a sample of ten guarded plants from each plot was randomly taken to record the data of top and root fresh weight (g plant.$^{-1}$). The tops and roots were separated and dried at 70°C for 3 days and at 105°C for two hours in air forced-draft oven to determine their dry weight. Dry root samples were ground and chemically analyzed. Iron, Mn and Zn were determined in the digest using a GBC model 300 atomic absorption spectrophotometer.

Table (1): Some physical and chemical properties of representative soil samples of the experimental site before sowing (0-30 cm depth) for the two growth seasons.

Soil property		2010/2011 season*	2011/2012 season*
Particle - size distribution			
Sand	(%)	85.45	86.98
Silt	(%)	8.00	8.32
Clay	(%)	6.55	4.70
Texture grade		Sand	Sand
EC (1:1 extract)	(dS m^{-1})	1.48	1.53
pH (1:1 suspension)		8.36	8.29
Organic matter	(%)	0.098	0.094
Total $CaCO_3$	(%)	24.74	22.78
Soluble ions			
Ca^{++}	(mmol l^{-1})	16.46	16.94
Mg^{++}	(mmol l^{-1})	8.80	9.28
Na^{+}	(mmol l^{-1})	1.71	1.89
K^{+}	(mmol l^{-1})	0.19	0.21
HCO_3^{-}	(mmol l^{-1})	6.56	7.92
Cl^{-}	(mmol l^{-1})	5.92	6.89
$SO_4^{=}$	(mmol l^{-1})	3.64	2.92
Total N	(%)	0.019	0.018
$NaHCO_3$-extractable P	(mg kg^{-1})	4.45	4.70
NH_4OAC-extractable K	(mg kg^{-1})	48.56	51.34
KCl-extractable N	(mg kg^{-1})	29.62	30.46
DTPA-extractable Fe	(mg kg^{-1})	3.18	3.68
DTPA-extractable Mn	(mg kg^{-1})	1.19	1.44
DTPA-extractable Zn	(mg kg^{-1})	0.39	0.42
DTPA-extractable Cu	(mg kg^{-1})	1.10	1.79

* Each value represents the mean of 3 replications.

At harvest (205 days from sowing), plants of each sub plot were harvested to determine top and root yield (ton $fed.^{-1}$). A sample of 25 kg of roots was randomly taken from each plot and sent to the beet laboratory at Abo-Korkas sugar factory to determine root quality parameters including:

1- Alpha amino nitrogen (α-amino-N) as well as sodium (Na) and potassium (K) concentrations were determined using an autoanalyzer as described by A.O.A.C. (1995). The results were calculated as mmol 100 g^{-1} beet paste.

2- Sucrose content was estimated in fresh samples of sugar beet roots using Saccharometer according to the method descried by Le-Docte (1927).

3- Sugar loss percentage was calculated using the following formula according to Reinefeld *et al.* (1974):

Sugar loss percentage = 0.29 + 0.343 (K+Na) + 0.094 α-amino-N.

4- Sugar recovery (S.R. %) was calculated using the following equation according to Cooke and Scott (1993):

Sugar recovery (S.R. %) = Sucrose % - Sugar loss %.

5- Recoverable sugar yield (R.S.Y.) was calculated using the following equation:

Recoverable sugar yield (ton fed.$^{-1}$) = Root yield (ton fed.$^{-1}$) x sugar recovery %

6- Quality index % = (Sugar recovery % x 100)/sucrose %.

7- Sugar loss yield (ton fed.$^{-1}$) = root yield (ton fed.$^{-1}$) x sugar loss %.

8- Nutrient uptake = nutrient concentration in root x root dry weight.

The analysis of variance was carried out according to Gomez and Gomez (1984) using MSTAT computer software. The data of each season are along to be present herein. Means of the different treatments were compared using the least significant difference (LSD) test at the 0.05 level of probability.

Results and Discussion:

Effect of potassium fertilization:

Top and root fresh and dry weights were significantly affected by increasing the K level in both seasons (Table 2). The increase in the root and top fresh and dry weights caused by K fertilization could be attributed to the stimulating effect of K on the photosynthesis process in the plants and in turn, the translocation of sugar and carbohydrates of assimilates from tops to roots, which lead to increases in the root and sugar yield (El-Kholy *et al*., 2006). Potassium is a very mobile element in plant tissues and moves from older tissues to the growing points of the tops and roots. The beneficial effect of K fertilization on growth, yield and quality of sugar beet was emphasized by previous studies carried out by El-Shafai (2000), Zalat and Nariman Youssif (2001), Attia (2004), Abdel-Motagally and Attia (2009) and Abdel-Motagally (2009).

The soluble non-sugars, K, Na and α-amino-N (mmol 100 g^{-1} beet paste) are regarded as impurities because they interfere with sugar extraction. The results showed that the impurity (K, Na and α-amino-N) concentrations were not affected by increasing the K fertilization level (Table 3). Also, the K concentration was not influenced by applying the K fertilization in both seasons.

Most of the quality characteristics (sucrose %, sugar recovery % and recoverable sugar yield) of sugar beet significantly increased with increasing the potassium fertilization level from 48 to 72 kg K_2O fed.$^{-1}$ in both seasons (Table 3). The highest mean value of sucrose (17.3%) and sugar recovery (14.6%) was obtained by using 72 kg K_2O fed.$^{-1}$ in the first season. Also, the highest value of the recoverable sugar yield (3.5 ton fed.$^{-1}$) was obtained by using 72 kg K_2O fed.$^{-1}$ in both seasons. The increase in recoverable sugar yields may be attributed to the role of K in nutrient uptake as well as nutritional balance which increases organic compounds through the photosynthesis process (Attia, 2004). Similar results were obtained by Abdel-Motagally (2009), Abdel-Motagally and Attia (2009) and El-Sarag and Moselhy (2013). Iron, Mn and Zn concentrations and uptakes in sugar beet roots increased with increasing the K fertilization level from 48 to 72 kg K_2O fed.$^{-1}$ in both growth seasons (Table 4).

Effect of foliar spray with zinc:

Gradual increases in fresh and dry weights of roots and tops occurred with increasing Zn concentrations from 0.0 to 150 mg l^{-1} in both seasons (Table 2). The increase in top and root fresh weights gained by Zn application might be due to the role of Zn in assisting the utilization of phosphorus and nitrogen in plants as reported by Enan (2004). The increase in dry weight plant^{-1} induced by Zn application may be due to the role of Zn in the metabolism of carbohydrates in plants. Abdel-Motagally (2009) and Menisy (2009) found that the foliar spray with Zn, Mn and Fe chelate caused an increase in top and root dry weights of sugar beet.

The foliar application of Zn-chelate showed a significant effect on the α-amino-N content in both seasons (Table 3). The lowest mean value of the α-amino-N content was obtained using the highest applied level of Zn (150 mg l^{-1}), while the control treatment gave the highest content. Also, Zn application exhibited a significant effect on Na content in both seasons. Highest Na content in roots of 4.85 and 4.83 mmol 100 g^{-1} beet paste resulted from spraying Zn at 150 mg l^{-1} in the first and second seasons, respectively. The differences in the root Na content between the applied levels of 75 and 150 mg l^{-1} Zn were significant in both seasons. On the other hand, the foliar application of Zn significantly increased the K content of sugar beet roots in both seasons. The highest applied level of zinc (150 mg l^{-1}) induced the highest concentration of K in sugar beet roots. These results are confirmed with those of Abd El-Gawad *et al.* (2004) who found a significant Zn effect on K the content of sugar beet roots. The highest mean values of yield and quality parameters of sugar beet i.e. sucrose %, S.R. %, R.S.R. ton fed.$^{-1}$ were recorded at the highest foliar applied level of Zn (150 mg l^{-1}). Moreover, the foliar application of Zn resulted in a significant effect on the sugar loss to molasses in both seasons.

In general, Zn sprayed at a level of 150 mg l^{-1} gave significant highest values of sugar loss to molasses in the second season. The increase in sugar loss to molasses accompanied with higher applied levels of Zn may be due to the increase in the impurities of Na, K and α-amino-N content of sugar beet roots. Also, the foliar application of Zn at 150 mg l^{-1} showed significant higher mean values of the recoverable sugar yield than the other two treatments (i.e. control and 75 mg l^{-1}). In other words, the lowest and the highest mean values of recoverable sugar yield were produced from the control and 150 mg l^{-1} Zn treatments, respectively. This effect might be due to the increase in both root yield and sucrose percentage. The beneficial applied effect of Zn as a foliar application on the sugar beet yield was also reported by Nemeat-Alla and El-Geddawy (2001), Enan (2004) and Menisy (2009). It could be concluded that the highest applied level of Zn (150 mg l^{-1}) as a foliar spray results in an increase in yield or quality of sugar beet plants grown on the newly reclaimed soils (calcareous sandy soils). The beneficial effects of zinc in improving sugar beet production could be attributed to its enhancement effects on increasing plant metabolic activity. Generally, zinc is an enzyme co-factor and is essential for the activity of respiratory enzymes and the production of auxin which increases the growth yield and improves the quality of sugar beet roots. Similar results were obtained by Nemeat-Alla and El-Geddawy (2001) and Abdel-Motagally (2009).

Iron, Mn and Zn concentrations and uptakes by sugar beet roots significantly increased with increasing the foliar spray with Zn from 75 to 150 mg l^{-1} compared to the control treatment in both seasons. The positive effect of Zn on sugar beet growth, yield and quality traits was reported by several investigators. Gobarb and Thalooth (2001) reported that the addition of some micronutrients such as Fe, Mn and Zn was important in order to compensate their deficiencies during the growth period and to increase yield components and yield quality of sugar beet.

Effect of Potassium and Zinc Interaction:

The interaction of K fertilization and foliar spray with Zn had a significant effect on the plant characteristics while it showed insignificant effects on the quality traits of sugar beet except for the sugar recovery yield in the first season. The highest mean values of root fresh weight, root dry weight, sucrose, sugar recovery and recoverable sugar yield were obtained by applying 72 kg K_2O fed.$^{-1}$ in combination with spraying 150 mg l^{-1} Zn in both seasons. This effect could be due to the superior effects resulted from the higher level of each main effect (Tables 2, 3 and 4). The highest mean values of these traits were obtained when the highest K and Zn applied levels were used. It could be concluded that the best K and Zn fertilization levels for attaining the maximize sugar yield and the best technological quality of sugar beet crop are 72 kg K_2O fed.$^{-1}$ and 150 mg l^{-1} of zinc as a foliar spray of Zn-chelate.

Finally it is concluded that the application of K with the foliar spray of Zn to sugar beet plants, especially when it is grown on a calcareous soil, is very important which leads to increases in the root yield, yield components and sugar yield as well as decreases in Na, K and α-amino-N in root juice, hence, the impurities decrease and consequently the juice purity increases. These results are due to the high pH (Kacer and Katkat, 2007). The solubility of micronutrients is particularly low and the micronutrients deficiencies are often shown on the plant grown on these soils. Also, as result of Zn supply, the nutrient (K, Fe, Mn and Zn) distribution in roots and shoots and their balance ratio increased because Zn has synergetic effect on nutrient uptake and utilization by sugar beet plants. In calcareous soils, high levels of calcium carbonate are present. Thus, Zn should be applied to improve the yield and nutrient balance of sugar beet. Increasing the Zn applied level up to 150 mg l^{-1} as a foliar spray combined with applying 72 kg K_2O fed.$^{-1}$ was the best treatment to achieve a balanced nutrient status and getting a better yield of sugar under calcareous soil conditions.

Conclusions:

It could be concluded that application of the K fertilization at 72 kg K_2O fed.$^{-1}$ along with the foliar application of zinc had a positive effect in increasing all growth traits of sugar beet.

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تأثير السماد البوتاسي والرش الورقي بعنصر الزنك علي نباتات بنجر السكر الناميه في تربه رملية جيرية

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الملخص:

أجريت هذه الدراسة بمحطة البحوث والتجارب الزراعية بالغريب – كلية الزراعة – جامعة أسيوط خلال موسمي ٢٠١٠/٢٠١١ ، ٢٠١١/٢٠١٢ لدراسة تأثير التسميد البوتاسي والرش بعنصر الزنك علي محصول وجودة بنجر السكر ومحتواه من بعض العناصر الغذائية تحت ظروف الأراضي الرملية الجيرية – تم استخدام تصميم القطاعات كاملة العشوائية في ترتيب القطع المنشقة مرة واحدة في ثلاث مكررات حيث وزعت معدلات الرش بالزنك المخلبي (١٥% زنك) (صفر، ٧٥، ١٥٠ جزء في المليون) في القطع الرئيسية في حين وزعت معدلات التسميد البوتاسي ٤٨ و ٧٢ كجم بو٢أ للفدان) عشوائياً في القطع المنشقة.

أوضحت النتائج المتحصل عليها:

١– أدت زيادة معدلات التسميد البوتاسي إلي ٧٢ كجم بو٢أ للفدان إلي زيادة معنوية لصفات الوزن الأخضر والجاف لكل من العرش والجذور ومحصول السكر بالطن/فدان في موسمي الزراعة ولا يوجد فرق معنوي في نسبة الشوائب (الصوديوم ، البوتاسيوم ، الألفا أمينو نيتروجين) مقارنة بـ ٤٨ كجم بو٢أ/فدان.

٢– أدت إضافة الزنك المخلبي رشاً علي المجموع الخضري إلي زيادة محصول الجذور والسكر (الطن/فدان) وأيضاً النسبة المئوية للسكروز في العصير فضلاً علي الصفات الخضرية والمحصولية وكذلك علي جودة المحصول من حيث تقليل نسبة الشوائب وكمية السكر المفقود في المولاس في موسمي الزراعة.

٣– وجد أن التفاعل بين التسميد البوتاسي والرش الورقي بالزنك المخلبي قد أدي إلي زيادة معنوية في جميع الصفات الخضرية والمحصولية وصفات الجودة.

٤– تأثر تركيز الحديد والمنجنيز والزنك باضافه عنصر الزنك بالمقارنة بالمعاملة الغير مسمدة كما أدي التسميد الورقي بالزنك المخلبي إلي زيادة الممتص من العناصر المذكورة.

من نتائج هذه الدراسة يمكن التوصية باستخدام ٧٢ كجم بو٢أ والرش الورقي بعنصر الزنك المخلبي بمعدل ١٥٠ جزء في المليون للحصول علي أعلي محصول من الجذور والسكر وأعلي معامل جودة وأقل فقد للسكر في المولاس تحت ظروف الأراضي الرملية الجيرية.