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EFFECTS OF ZINC AND PHOSPHOROS FERTILIZERS ON SUGAR BEET (*Beta vulgaris* cv. SBSI005 Crouse) YIELD IN IRANIAN HIGH ZINC ALKALINE SOIL CONDITION

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Abstract

In order to evaluate the effects of zinc and phosphate fertilizers on sugar beet yield and agronomical characteristics, an experiment was carried out as factorial based on RCBD with four replications in farm of Navaze village, Arak, Iran in 2010. Experimental factors were including of two levels of zinc utilization (Based on soil test 25 kg/ha) and non zinc utilization and also four level of phosphate fertilizer based on soil test, ammonium super phosphate 125 kg/ha, 250 kg/ha, 375 kg/ha and non P application as control. The indexes assessment were including of number of green leaves, number of yellow leaves, number of dry leaves, Percent of leaf water content, leaf area index, root water content, root length, Percent of purity sugar and sugar yield. Result showed the most purity sugar was 625 g/m^2 by apply of 375 kg/ha ammonium super phosphate plus zinc application.

***Key words**: ammonium super phosphate, Iran, sugar beet, zinc.*

INTRODUCTION

Sugar beet (*Beta vulgaris* L.) crop is one of the Chenopodiaceae family famous plants (Watson and Dallwitz, 1992). A cash crop or economically important species of this family is sugar beet. It is normally biennial species, however under certain conditions it can act as annual (Smith, 1987). The sugar beet plant develops a large succulent taproot in the first year and a seed stalk the second year (Smith, 1987). During the first growing season, the vegetative stage, need to enough macro and micronutrients (Duke, 1983). During the second growing season, the reproductive stage, a flowering stalk elongates from the root (Forster et al., 1997).

Recently, Sugar beet is one of the main crops in Iran as one of the most important sources of sugar with large annual consumption. Sugar is as an important resource for energy supply. Sugar beet crop has an important position in crop rotation systems as summer crop not only in the fertile soils, but also in poor, saline alkaline and calcareous soils (Draycoot, 1999).

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 (Cakmak et al., 1999). Zinc is a catalyst in many of the enzyme systems used for protein synthesis and carbohydrate metabolism (Alloway, 2004). It is involved in the chloroplast activity and cell metabolism and plant growth processes. Thus, zinc micronutrient can increase yield quantity and quality in sugar beet. Previous research reports showed sugar beet can remove about 350 g/ha zinc per 50 ton sugar beet. The normal level of zinc in the fresh root is 0.05–2.30 mg/kg in normal soil nutrient condition (Stevens and Mesbah, 2004). Zinc availability is limited by high pH, high free calcium carbonate, sandy texture, low organic matter, and where subsoil has been exposed by land leveling (Draycott, 1996). In high zinc concentrations in soils, Zn can be toxic and plants affected may show symptoms similar to those found in other heavy metal toxicities, such as those of Cd or Pb (Foy et al., 1978). Zinc toxicity also induces chlorosis in young leaves, and this has been suggested to result from a Zn induced Fe or Mg deficiency, based on the fact that the three metals have similar ion radii other common Zn toxicity effects include decreases in tissue water content and changes in the P and Mg concentrations in plant tissues (Marschner, 1995).

Moreover, high zinc concentration decreased N, Mg, K and Mn accumulation in all plants, while phosphorus and Ca concentrations increased in shoot (Cakmak, 2000). Leaves of plants treated with 50 and 100 micromole Zn developed symptoms of Fe deficiency, including decreases in Fe, chlorophyll and carotenoids concentrations. Plants grown with 300 micromole zinc had decreased photosystem efficiency and further growth decreases but did not have leaf Fe deficiency symptoms (Sagardoy et al., 2009).

Phosphorus is a major element in plant nutrition that is most important component of nucleic acids and lipids and is important in the production and transport of sugars in sugar beet plant. Phosphorus is effectiveness in sugar beet early root development (Kharchenko, 1983). It is a critical macro nutrient required for numerous functions in plant, including energy generation, nucleic acid synthesis, photosynthesis, glycolysis, respiration, carbohydrate metabolism and nitrogen fixation (Abel et al.*,* 2002; Vance et al.*,* 2003).

Meanwhile, P deficiency is considered as one of the greatest limitations in agricultural production (Schachtman et al.*,* 1998; Lynch and Brown, 2008). It has been estimated that 5·7 billion hectares of land worldwide are deficient in P. Concentrations of phosphate in soil solutions are generally lower than10 ppm, which are well below the critical level that is needed for the optimal performance of crops (Batjes, 1997).

This problem of P deficiency might be mitigated by the application of concentrated fertilizers that provide soluble Pi or balance nutrition elements for plants. One of the main mechanisms is the ability of the root to absorb P from the soil under zinc soil balance. Sufficient phosphorus and zinc balance ensures rapid root growth and good uptake of other nutrients. Phosphorus is very immobile in the soil and is only taken up within 1-2 mm from the root. Placement of phosphorus will often give higher uptake efficiency and result in a higher availability of phosphorus. Phosphorus deficiency inhibits growth of the sugar beet plants by change the leaf color from dark green to dull blue-green (Ellis et al., 1964). Research indicates that yield increases are expected from phosphorus applications when soil test levels are below 15 ppm (Batjes, 1997).

The objective of our research was to emphasize the effect of different levels of zinc and phosphorus recourses on sugar beet yield and sugar percentage ratio.

MATERIALS AND METHODS

To study the effect of different levels of zinc and phosphorus fertilizer amounts on sugar beet yield and sugar percentage an experiment was conducted at Navazen (49° 46´N, 34°06´E and elevation 1710 m above sea level), Arak, Iran in 2010.

The soil was clay loam (clay: 42%, silt: 39% and sand: 19%), with EC of 0.6 ds/m, Zn absorbability of 2.3 ppm and organic matter of 1.1% at the 0-60 cm soil depth. The experiment was a factorial arrangement in a completely randomized block design with three replications. Treatments were included two levels of zinc (Z) utilization (Based on soil test), Z1 and Z2 were as no zinc consumption and 25 kg/ha $ZnSO_4$ as soil application before planting, respectively. Four level of phosphate (P) fertilizer (P1 to P4) was based on soil test, utilization of ammonium super phosphate chemical fertilizer (ASP) 125, 250, 375 kg/ha and non phosphorus utilize as control.

Table 1. Soil properties in the experimental site at the start of the study (2009)

Soil depth (cm)	0-60
Total N (%)	12.0
pH	7.00
P2O5 (ppm)	5.70
K20 (ppm)	123.0
Organic matter (%)	1.10
Zn (ppm)	2.3

In this experiment the sugar beet variety was SBSI005 Crouse. The field was plowed in autumn 2009 and then was used of two cross over disk in spring 2010. Seeds were hand sown on June 10^{th} and harvesting time was 10^{th} October 2010 in 2.5×6 m plots with a inter row space of 0.5 m.

Nitrogen and potassium fertilizers were added before sowing at a rate of 300 and 200 Kg/ha as a form of urea (46% N) in three equal portions and potassium sulfate (50% K_2O) respectively. Thinning operation was done twice to leave one plant/hill till harvest.

The indexes assessments were measured carefully. Sugar beet characteristics were including number of green, yellow and dry leaves, Percent of leaf and root water content by using the methods of Weatherly (1949), leaf area index (LAI), and root length (cm) at pre harvest time (100 days after sowing date). In addition, percentage of white sugar and sugar yield (kg/m^2) were determined from the three middle rows for each plot and then the sugar yield was also calculated by multiplying root yield x Sucrose % at harvesting time (10th October 2010). The data were treated by analysis of variance using the software SAS and mean were compared by DMRT.

RESULTS AND DISCUSSIONS

Number of green, yellow and dry leaf

Regarding to analysis of variance data results, Phosphorus and Phosphorus zinc interaction treatment had significant effect on number of green leaves 100 days after sowing date. Consequently, yellow leaf number was affected by zinc, phosphorus and both treatments interaction. Number of dried leaves at 100 days after planting (abnormally early dried leaves) also was affected at interaction of treatments and P and Z treatment separate (Table 2).

Sugar beet cell contaminations by zinc have harmful effects on the growth and metabolism of plant leaves. Increase in zinc application (Z2) could amplify the number of yellow (from 3.5 to 4.5) and dried (from 1.25 to 2.6) leaves in sugar beet specially when use of phosphorus fertilizer for 250 kg/ha was accrued in field. As a very imperative note, any incensement in P from 250 to 375 kg/ha can reduce the harmful effects of high zinc availability regarding the P and Zn negative relations in soil.

Leaf Area index

The results showed that the aapplication of zinc had no significant effect on LAI in 100 days after sowing date. Phosphorus treatments and P and Zn interaction had not significant effects on LAI. Data in table 3 showed LAI in case of P2 (250 kg/ha ASP application) and P3 (375 kg/ha ASP application) was highest (11.34 to 12.34) without significant difference. It seems, low level of available P in soil (2.3 ppm) is the most important cause for reduce the LAI in sugar beet (Table 3).

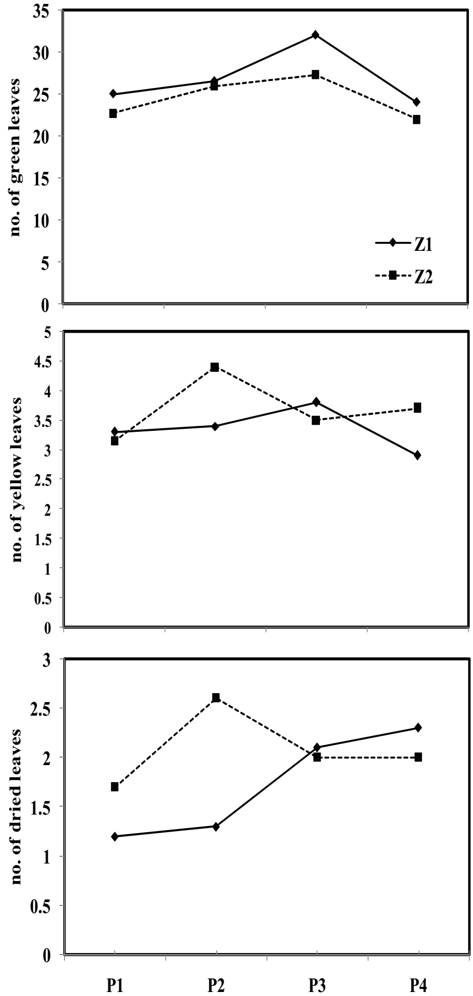

Figure1. Effect of P levels on number of green, yellow and dried leaves under different zinc application. Z1= control and Z2= 25 kg/ha $ZnSO_4$ in soil application. P1=125, P2=250, P3=375 kg/ha ASP and P4= Control

Leaf and root water content

In this field experiment the interaction effects between zinc and phosphorus treatments and also sole treatment effects had not significant differences in leaf and root water content

(Table 2). RWC of mature leaves and roots on 100 days old were unaffected by nutrient imbalance independently by zinc and phosphorus treatments simultaneously.

Table 2. Analysis of variance for effect of zinc and phosphorus on sugar beet

S.O.V	D.F	Mean square								
		No.green leaves	No.yellow leaves	No. dry leaves	LAI	leaf water content	root water content	root length	Sugar %	Sugar yield
Replication	3	16.35 ns	0.34 ns	0.08 ns	3.39 ns	1.72 ns	4.43 ns	0.56 ns	4.38ns	0.08ns
Zinc	1	47.04 ns	0.10 *	0.75 **	2.14 ns	8.40 ns	8.00 ns	11.64 ns	1.11ns	0.02ns
Phosphorus	3	70.15 **	0.77 **	0.99 **	9.72 *	6.31 ns	2.86 ns	9.50 ns	2.52ns	0.09*
Z.P. int.	3	6.18 *	0.85 **	0.72 **	2.31 ns	2.19 ns	2.68 ns	2.35 ns	1.44ns	0.03*
Error	21	31.19	0.13	0.03	2.57	5.07	6.04	5.48	2.38	0.03
Cv%		21.74	10.14	9.55	14.62	3.66	3.11	9.05	18.37	3.11

**: significant differences at P 0.01 level, *: significant differences at P 0.05 level and ns: Non-significant.

Table 3. Mean comparisons for sugar beet characteristics

Treatment	No.green leaves	No.yellow leaves	No. dry leaves	LAI	Leaf water Content %	root water content %	Root Length cm	Sugar %	Sugar yield Kg/m2
Z1(Control)	26.90 a	3.34 b	1.78 b	11.22 a	84.92 a	79.58 a	26.45 a	17.19 a	0.87 a
Z2(25 kg/ha)	24.75 a	3.70 a	2.09 a	10.70 a	85.94 a	78.58 a	25.24 a	17.57 a	0.92 a
P1(125kg/ha)	23.86 b	3.21 b	1.41 b	10.02 b	86.24 a	78.36 a	25.95 a	16.81 a	0.94 a
P2 (250 kg/ha)	29.05 a	3.89 a	2.06 ab	11.34 ab	84.16 a	79.31 a	27.35 a	18.03 a	0.92 a
P3 (375 kg/ha)	29.62 a	3.66 a	2.09 ab	12.34 a	85.69 a	79.76 a	25.07 a	17.50 a	0.98 a
P4 (Control)	23.01 b	3.32 a	2.17 a	10.12 b	85.64 a	78.89 a	25.01 a	17.02 a	0.74 b
Z1P1	25.07 ab	3.27 bcd	1.17 d	10.84 a	85.72 a	78.25 a	26.87 a	16.21 a	0.96 a
Z1P2	26.50 ab	3.37 bcd	1.25 c	11.96 a	84.32 a	79.55 a	27.77 a	18.06 a	0.94 a
Z1P3	32.00 a	3.80 b	2.12 b	12.58 a	85.10 a	80.40 a	25.00 a	17.18 a	0.88 ab
Z1P4 (Control)	24.02 ab	2.92 d	2.30 b	9.49 a	84.52 a	80.12 a	26.15 a	17.32 a	0.71 b
Z2P1	22.65 c	3.15 cd	1.65 c	9.20 a	86.75 a	78.47 a	25.02 a	17.41 a	0.92 a
Z2P2	26.00 ab	4.40 a	2.60 a	10.72 a	84.00 a	79.07 a	26.92 a	18.00 a	0.90 a
Z2P3	27.25 ab	3.52 bc	2.05 b	12.11 a	86.27 a	79.12 a	25 15 a	18.13 a	1.09 a
Z2P4	22.00 c	3.72 bc	2.05 b	10.76 a	86.75 a	77.65 a	23.87 a	16.72 a	0.77 b

Data by different letters indicate statistically significant differences using Duncan Multiple range at P 0.01. Z1 = control and Z2= 25 kg/ha $ZnSO_4$ in soil application. P1=125, P2=250,P3=375 kg/ha ASP and P4= Control

Root length

Sugar beet root length had not significant affected by phosphorus and zinc treatment and their interaction (Table 2). In general, P2 (250 kg/ha ASP application) treatment had more root length than P1 (125 kg/ha ASP application), P3 (375 kg/ha ASP application) and control. However, the lowest were recorded with Z2P4 interaction treatments. The differences between root length in P2 (250 kg/ha ASP application) and other phosphorus treatment levels were not significant in these traits (Table 2 and 3).

Sugar percentage and sugar yield

The nutrient treatments and their interaction (P. Z and PZ int.) had not significant effect on sugar percentage in sugar beet root extract under recent field assy. Sugar yield in this field study was affected ($P<0.05$) by P treatment and P.Z interaction significantly (Table 2). Thus, means comparisons for sugar yield showed the application of P increased sugar yield from 0.74 to 0.98 kg/m^2. Application $ZnSO_4$ had not significant effect on the percentage of sugar in recent field condition (Figure 2).

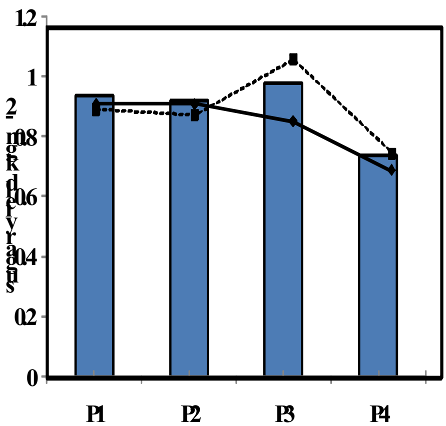

Figure 2. Effect of P levels under different zinc application (histograms) and interaction effects (lines) of P.Z on sugar yield. Z1= control and Z2= 25 kg/ha $ZnSO_4$ in soil application. P1=125, P2=250, P3=375 kg/ha ASP and P4= Control

CONCLUSIONS

The sugar beet is an important crop that extremely affected by zinc over dosage in alkaline soils with high Zn level (2.3 times more than threshold level) has sharply negative interaction effects with phosphorus amounts. Maximum sugar yields in high zinc soils was achieved by utilization of more Phosphorus fertilizer by 375 kg/ha about 1.09 kg/m^2 and lowest sugar yield was achieved by 25 kg/ha zinc application about 0.77 kg/m^2 under no more put in phosphorus fertilizer according to soil test results 5.7 ppm for P and zinc 2.3 ppm.

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