Efficiency of Corn (*Zea mays* L.) Varieties Grown in Zinc_Deficient Calcareous Soil

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Abstract

Greenhouse experiment was carried out to screen ten corn varieties for zinc efficient and inefficient grown in Zn deficient silty clay loam soil which characterized by high pH, high level of calcium carbonate and low organic matter. In general zinc deficiency produced plants with low leaf area, plant height , root depth and low shoot and root dry matter production. Corn varieties were different in their Zn efficiency. Under Zn deficiency Bakistani/1 variety showed better Zn efficiency based on root dry weight, plant height and root depth efficiencies (ranking first), and also had better leaf area (ranking second) and shoot dry matter production (ranking third) among the ten varieties. Zinc supply increased Zn, P and K content in roots and shoots of corn plants.

Keywords: calcareous soils , Zn deficient, efficient , screening .

Introduction

Zinc deficiency in soils is a widespread problem in crop plants, especially cereals grown particularly in calcareous soils of arid and semi-arid regions (Welch et al.,1991). Soil amendment of zinc fertilizers in calcareous soils are widely used agronomic practice for farmer but not a sustainable approach or easy measures for correction of Zn deficiency (Cakmak et al.,1996a). There are significant and large differences between cereal varieties in their ability to grow where soil Zn availability is suboptimal. Zinc–efficient cereal plants respond to Zn-deficiency by releasing phytosiderophores into the rhizosphere to mobilize Zn (Rengel,1997b). Screening for zinc-efficient variety for Zn-deficient soil is an important practical approach for the correction or avoidance of Zn deficiency in cereals and it is a sustainable approach to overcome Zn deficiency in plants.

The aim of the present study was to evaluate and screening ten varieties of corn in north part of Iraq for Zn-efficient and Zn-inefficient corn varieties in calcareous soil.

Materials And Methods

Soil collection and analysis:

In fall, 2012, Zinc deficient soil was collected from the surface (0.0-30.0 cm.) of the field experiment station soil at the College of Agriculture and forestry of Mosul University. The soil was air-dried, passed through a 2mm sieve and was analyzed for

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pH, $CaCO_3$, organic matter, and texture (Table1) using standard procedures (Page, 1982).Plant available concentration of Zn in soil were determined also according to the method stated by Tandon, (1999), by extraction with DTPA (diethylene triamine penta acetic acid) using a soil: solution ratio of 1:2 and shaking time of two hours. Micronutrient extracted (Zn) was determined by atomic absorption spectrophotometer. Available N,P and K in soil were determined according to the method stated by Ryan et al.,(1996).

Greenhouse experiment:

An equivalent of 8 Kg air-dry soil was weighed in plastic pots (diameter = 22cm, length =22cm). Ten corn varieties were used in the experiment under greenhouse conditions. Eight seeds were sown in each pot. After germination plants were thinned to 4 plants per pot. Plant were grown for 6 weeks with two levels of Zn (+Zn= 8 mg Zn Kg-1soil as ZnSO4.7H2O and with out(-Zn)) fertilization together, with basal treatment of 25 mg N Kg-1soil and 11.0 mg P Kg-1soil , using both urea and super phosphate .All the nutrients were mixed thoroughly with the soil before sowing. Each treatment was replicated three times. Distilled water was used to water the plants.

Table (1): Physicochemical properties of top soil sample (0-30) cm.

pH	7.95
Total $CaCO_3$ gm. Kg^{-1}soil	235.0
Organic matter gm. Kg^{-1}soil	9.5
Available Zn mg. Kg^{-1} soil	0.178
Sand (g. Kg^{-1})	167.00
Silt (g. Kg^{-1})	467.00
Clay (g. Kg^{-1})	366.00
Soil texture	Silty clay loam
Moisture at Field capacity (%)	26.00
Available N (g. Kg^{-1})	0.118
Available P (mg. Kg^{-1} soil)	6.0
Available K (mg. Kg^{-1} soil)	440

Time of watering plants was determined by weighing the pots daily and adding water to obtain the original wet weight (75% of field capacity). The plants were irrigated in a way that attempted to maintain uniform water distribution throughout the pot. PVC watering tube, one inch in diameter was installed in the pot at potting so that one end on the bottom of the pot and the upper end was connected to plastic cup. Half of the required water was applied through the cup, and the other half of the water was applied directly to the soil surface.

At harvest the plants were cut at the soil surface, and both shoots and roots were dried at 70 °C for 48h, and weighed. Zinc concentration in root and shoot were determined using the method described by Chapman and Pratt, (1961). Total Zn content was calculated by multiplying root or shoot Zn concentration with root or shoot dry weights. The Zn –efficiency in corn varieties was calculated as the ratio of [(root or shoot) dry weight and other growth parameters at –Zn to the value of the growth parameter used at +Zn at optimal rate] ×100 (Cakmak et al., 1998). The concentrations of P and K in roots and shoots were determined according to the methods stated by Tandon,(1999).Leaf area was calculated in the plants samples, according to the method described by Thomas, (1975), and as show in the equation below:

Leaf area = length X width X 0.95

Statistical analysis:

A factorial experiment with two factors (10 varieties X 2 Zn fertilization rates) and 3 replicates were used. The data were tested and efficiencies (%) were calculated.

Results And Discussion

Physical and chemical characteristics of soil:

Various physicochemical properties of soil are presented in (Table 1). Soil was calcareous which contained more than 230 gm kg-1soil CaCO3 and characterized by very low organic matter content 9.5 gm kg-1soil and had high pH value 7.95 . Concentration of DTPA-extractable Zn in soil was 0.178 mg kg^{-1}soil which was less than the adequate amount of Zn in calcareous soils (1.0 mg kg^{-1} soil) as stated by Soltanpour and Schwab, (1977), and it was also low than the critical level for calcareous soils (0.5 mg kg^{-1} soil) obtained by Sims and Johnson, (1991). The soil texture was silty clay loam with high fractions of both silt and clay and low fraction of sand. High soil pH with high calcium carbonate resulted low availability of Zn in soil solution. The calcium carbonate can influence zinc reduction in the roots during Zn uptake which associated with Zn deficiency in plants (Graham and Rengel,1993; Alloway,2008; Malakouti,2008). 1n the present study the results strongly suggest that in calcareous high pH soil plants suffer from Zn deficiency, and also cleared that corn plants grown in such soil containing less than (1.0 mg kg^{-1}) DTPA- extractable Zn can significantly respond to Zn application.

Screening for Zn efficiency:

In the field experiments the results of assessing Zn relative efficiency can be variable because the severity of the nutrient deficiency varies between sites and seasons. Therefore, our pot assays, which conducted under controlled conditions, allow the relative efficiencies of varieties to be assessed, but these are generally base on seedling growth rather than grain yield. Similar works were done by many researchers (Longnecker et al., 1991).

Zinc efficiency, defined as the ability of a plant to grow and yield well in Zn-deficient soils (Graham and Rengel, 1993). The results showed that corn varieties were different in their Zn efficiency ratio based on leaf area, shoot dry weight, root dry weight, plant height and root depth.

Leaf area and shoot dry matter production:

The first characteristics reaction of plant to micronutrient deficiency is the reduction in shoot growth and leaf area (Cakmak et al., 1998). Similar results in the present study with leaf area were found with Zn deficient in corn plants. Zn efficiency based on leaf area (Table 2) was calculated as the ratio of leaf area at suboptimal Zn (Zn was applied at 0.0 mg Zn Kg^{-1} soil) to leaf area at optimal Zn (Zn was applied at 8.0 mg Zn Kg^{-1} soil). The corn varieties Voaipor and Bakistani/1 had higher Zn efficiency as compared to that of the rest 8 corn varieties. The decrease in leaf area due to Zn deficiency were 0.0% in Voaipor variety, while with the other corn varieties the reduction in leaf area was ranged from 53.9% to 21.8% .

The effect of Zn deficiency on shoot dry matter production (Table 2) was similar to that on leaf area. The decrease in shoot dry matter production due to Zn deficiency were only 5.2% in Voaipor variety and ranged from 60.5% to 12.8% in the other varieties. Increases in leaf area and shoot dry weight with Zn application were related to the function of Zn which is an essential plant nutrients. It is a constituent of enzymes and is involved with the synthesis of indole acetic acid (Fox and Guerinot 1998). Studies on cereal crops showed similar results were an increase in plant growth with the application of zinc fertilizer (Mengel and Kirkby , 2001). . Zinc efficiency of corn varieties based on shoot dry matter production are shown in (Table 2). Voaipor and Acoss varieties had the highest Zn efficiency followed by Bakistani/1,while the Rabiae variety had the lowest Zn efficiency.

Tables (2): Zinc responses and Zn efficiencies of corn varieties based on leaf area, root depth, shoot dry weight, root dry weight and plant height.

Varieties	Leaf area (cm^2)			Root depth (cm)			Shoot dry weight (gm)			Root dry weight (gm)			Plant height (cm)		
	-Zn	+Zn	%*	-Zn	+Zn	%*	-Zn	+Zn	%*	-Zn	+Zn	%*	-Zn	+Zn	%*
Rabiae	510.8	784.0	65.1	65.8	59.3	110.9	6.8	17.2	39.5	7.1	8.3	85.5	49.7	73.8	67.3
Saffia	379.3	750.0	50.5	79.0	71.3	110.7	8.2	18.2	45.0	7.6	7.1	107.0	53.9	70.5	76.4
Bohuth106	463.6	827.3	56.0	73.8	68.8	107.2	10.7	17.2	62.2	8.2	9.3	88.1	56.6	65.8	86.0
Kimbar707	391.6	721.5	54.2	70.7	66.9	105.6	9.6	17.7	54.2	6.4	10.0	64.0	53.3	67.2	79.3
Bakistani 1	649.6	841.5	77.2	78.0	60.9	128.0	12.2	16.9	72.1	12.9	9.5	135.7	64.3	66.0	97.4
Kimbar2	389.6	718.5	54.2	75.8	74.7	101.4	9.2	18.5	49.7	7.2	10.2	70.5	55.7	67.5	82.5
Bakistani 2	422.6	915.8	46.1	70.6	65.0	108.6	13.4	21.3	62.9	14.0	10.4	134.6	57.7	68.7	83.9
Acoss	619.0	891.8	69.4	77.1	71.6	107.6	15.1	17.3	87.2	8.1	15.1	53.6	63.3	72.6	87.1
Dolho	710.0	994.3	71.4	77.5	66.5	116.5	12.1	17.8	67.9	8.4	15.9	52.8	66.8	69.5	96.1
Voaipor	646.3	600.0	107.7	67.3	59.9	112.3	12.9	13.6	94.8	8.3	10.5	79.0	61.3	68.8	89.0
LSD 5%															
Zinc.level.	78.0			4.64			2.709			1.441			1.482		
Variety.	174.5			9.04			6.058			3.222			3.248		
Var.xZ.L.	246.8			12.79			8.567			4.557			4.593		

*%= Efficiency = **-Zn** (0 mg Zn Kg^{-1} soil) / +Zn(8.0 mg Zn Kg^{-1}soil) x 100

Root dry matter and other seedling growth parameters:

Zinc deficiency affect the root dry matter production, plant height and root depth of corn varieties (Table 2) . The decrease in root dry matter production due to Zn deficiency was only 0.0% in Bakistani/1, Bakistani/2 and Saffia varieties and ranged from 47.2% to 11.9% in the other varieties . The lowest reduction percentages in plant height and root depth under Zn deficiency were 2.6% and 0.0% respectively in Bakistani/1 variety . While with other varieties the reduction in the above three parameters were ranged from 0.0 – 47.2 %,2.6 -32.7% and 0.0 % in root dry matter, plant height and root depth respectively.

Nutrients contents in root and shoot:

As expected, Zn supply increased Zn content in roots and shoots of corn plants (Table 3). Root –Zn contents were ranged from 0.0 – 99.0 % higher (Table 3) and shoot contents were 25.6 -256.5 % higher (Table 3) in the $Zn_{8.0}$ treatments compared to $Zn_{0.0}$ treatments with all the corn varieties. Zinc was supplied directly to the soil as $ZnSO_4.7H_2O$ to set up different Zn levels. The content in roots and shoots of corn plants seemed to reflect total supply of zinc and variety efficiency more than any other factor (Chany et al., 1982; Al-Ali, 1996; Li et al.,2007 ;Cui et al.,2007).

Zinc supply generally increased P and K contents in both roots and shoots of corn plants (Tables 4 and 5). Root P contents were 0.0 -139.3 % higher and shoot contents were 7.29 – 275.2% higher (Table 4) in the $Zn_{8.0}$ treatments as compared to $Zn_{0.0}$ treatments. The same relationship between Zn application rates and K content in both roots and shoots of corn varieties was found. Increases in P and K content in both roots and shoots of corn plants with Zn application were related to the an increase in plant growth with the application of zinc fertilizer (Table 5).Zinc is an essential plant nutrients (Fox and Guerinot, 1998;Piavoke,2003). Studies on cereal crops showed similar results were an increase in plant growth and nutrients uptake with the application of zinc fertilizer (Mengel and Kirkby, 2001). The relative proportion of Zn transpoted to shoot in corn varieties was varied. This result was consistence with the finding of White et al.,(1981) with cereal crops, They stated that cereal species differ in their ability to load nutrients into their shoots.

Table (3): Effect of soil Zn application on Zn concentration (mg /kg) and content (mg/pot) in shoots and roots of 10 corn varieties.

Variety	Concentration				Content			
	Shoot		Root		Shoot		Root	
	- Zn	+ Zn	- Zn	+ Zn	- Zn	+ Zn	- Zn	+ Zn
Rabiae	53.3	53.4	82.0	86.6	0.362	0.918	0.582	0.718
Saffia	41.1	69.9	72.8	85.4	0.337	1.272	0.553	0.606
Bohuth / 106	50.9	75.8	66.4	95.9	0.544	1.303	0.544	0.891
Kimbar / 707	53.9	58.4	81.1	86.4	0.517	1.033	0.519	0.864
Bakistan / 1	58.5	63.9	80.7	84.9	0.713	1.079	1.041	0.806
Kimbar / 2	57.5	59.8	77.5	74.6	0.529	1.106	0.558	0.760
Bakistan / 2	55.0	68.0	79.3	81.6	0.737	1.448	1.110	0.848
Th 91A 1509 # A Coss – 8848	42.7	70.8	81.6	77.9	0.644	1.224	0.660	1.176
Th 96B 6175 Doiho - 9445	54.3	57.4	83.4	78.3	0.657	1.021	0.700	1.244
Th 96B 6175 # Voaipor 9433	49.8	61.5	83.5	82.7	0.642	0.836	0.693	0.868
L.S.D 5%								
Zinc level	5.21		2.679		0.1117		0.1156	
Variety	11.64		5.991		0.2498		0.2586	
Variety x Zinc level	16.47		8.473		0.3533		0.3657	

Table (4): Effect of soil Zn application on P concentration(%) and content (mg/pot) in shoots and roots of 10 Corn varieties.

Variety	Concentration				Content			
	Shoot		Root		Shoot		Root	
	- Zn	+ Zn	- Zn	+ Zn	- Zn	+ Zn	- Zn	+ Zn
Rabiae	0.107	0.159	0.072	0.092	7.276	27.34	5.112	7.636
Saffia	0.104	0.154	0.081	0.094	8.528	28.02	6.156	6.674
Bohuth / 106	0.136	0.163	0.072	0.101	14.55	28.03	5.904	9.393
Kimbar / 707	0.164	0.253	0.124	0.110	15.74	44.78	7.936	11.00
Bakistan / 1	0.208	0.204	0.112	0.103	25.37	34.47	14.44	9.785
Kimbar / 2	0.101	0.264	0.096	0.088	9.292	48.84	6.912	8.976
Bakistan / 2	0.168	0.250	0.103	0.106	22.51	53.25	14.42	11.02
Th 91A 1509 # A Coss – 8848	0.137	0.154	0.086	0.098	20.68	26.64	6.966	14.79
Th 96B 6175 Doiho - 9445	0.187	0.138	0.104	0.134	22.62	24.56	8.736	21.30
Th 96B 6175 # Voaipor 9433	0.112	0.269	0.086	0.091	14.44	36.58	7.138	9.555
L.S.D 5%								
Zinc level	0.0306		0.0100		5.18		1.854	
Variety	0.0684		0.0224		11.59		4.145	
Variety x Zinc level	0.0967		0.0317		16.39		5.863	

Table (5): Effect of soil Zn application on K concentration(%) and content (gm/pot) in shoots and roots of 10 corn varietes.

Variety	Concentration				Content			
	Shoot		Root		Shoot		Root	
	- Zn	+ Zn	- Zn	+ Zn	- Zn	+ Zn	- Zn	+ Zn
Rabiae	3.63	3.96	0.75	0.87	0.246	0.681	0.053	0.072
Saffia	3.70	3.80	0.87	0.96	0.303	0.691	0.066	0.068
Bohuth / 106	3.33	3.70	0.90	0.91	0.356	0.636	0.073	0.084
Kimbar / 707	3.40	3.56	0.93	0.46	0.326	0.630	0.059	0.046
Bakistan / 1	3.20	3.56	0.91	0.90	0.390	0.601	0.117	0.085
Kimbar / 2	3.20	3.66	0.82	0.96	0.294	0.677	0.059	0.097
Bakistan / 2	3.30	3.60	0.79	0.89	0.442	0.766	0.110	0.092
Th 91A 1509 # A Coss – 8848	3.63	4.33	0.81	1.08	0.548	0.749	0.065	0.163
Th 96B 6175 Doiho - 9445	3.10	3.60	0.84	0.84	0.375	0.640	0.070	0.133
Th 96B 6175 # Voaipor 9433	2.96	3.66	0.98	1.02	0.381	0.497	0.081	0.107
L.S.D 5%								
Zinc level	0.1725		0.0593		0.0629		0.01562	
Variety	0.3858		0.1326		0.1407		0.03493	
Variety x Zinc level	0.5456		0.1875		0.1990		0.04940	

Variety variation in efficiency:

Generally speaking Bakistani/1 variety showed better Zn efficiency among the ten varieties and it was associated and reflected by higher root dry weight, plant height and root depth efficiencies (ranking first).Bakistani/1 variety also had better leaf area (ranking second) and shoot dry matter production (ranking third) among the ten varieties. The high Zn efficiency of Bakistani/1 may be related to its efficiency to release Zn mobilizing phytosiderophorse from roots to the rhizosphere. Corn is characterized as a strategy II plant, and responds to Zn-deficiency by synthesizing and releasing phytosiderophores which are able to form very stable complexes with Zn in the soil and increase Zn absorption and translocation from root to shoot (Zhang et al., 1991; Von Wiren et al., 1996).

In conclusion our results strongly suggest that the improvement of Zn nutritional status of corn grown in calcareous, Zn- deficient soil in dry land farming region can be met by growing Zn-efficient variety.

To our knowledge this is the first study and report of a large project in IRAQ dealing with screening for micronutrients efficient and inefficient varieties of cereals and its adaptive strategies in calcareous soil.

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كفاءة نبات الذرة الصفراء للنمو في ترب كلسية تعاني من نقص الخارصين

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الخلاصة

أجريت تجربة فى البيت الزجاجى لغربلة عشرة اصناف لنبات الذرة الصفراء من حيث كفائتها للنمو في تربة تعانى من نقص عنصر الخارصين وتمتاز بدرجة تفاعل ومحتوى من كاربونات الكالسيوم عال وذات محتوى واطئ من المادة العضوية .نقص الخارصين بشكل عام انتج نباتات ذات مساحة ورقية،ارتفاع النبات،تعمق الجذور منخفضة، فضلا عن انخفاض في حاصل المادة الجافة لكل من الجذور والأجزاء العليا . الصنف باكستانى/ ا عطى افضل كفاءة تحت تأثير نقص الخارصين اعتمادا على الاوزان الجافة للجذور، ارتفاع النبات وتعمق الجذور (كان تسلسله الاول) وكان ايضا من بين الاصناف الافضل كفاءة في المساحة الورقية (كان تسلسله الثاني) وكان تسلسله الثالث بين الاصناف اعتمادا على الاوزان الجافة للأجزاء العليا. اضافة الخارصين ادى الى زيادة محتوى الجذور والأجزاء العليا من الخارصين.

الكلمات المفتاحية:تربة كلسية، نقص، كفوء، غربلة