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Effects of Bicarbonate and Iron-deprivation on Growth of Different Maize Varieties

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Abstract: The effects of HCO_3^- on shoot and root dry matter content, total and HCl-extractable iron uptake and leaves visual chlorosis degrees of different maize cultivars were examined. Thirteen different hybrid maize (*Zea mays* L. cv.) varieties were grown in perlite containing plastic pots and irrigated with five different nutrient solutions composed of basic nutrient solution with 20 μM FeEDTA (control), iron-free nutrient solution (direct deficiency) and complete basic nutrient solutions with added 7.5; 15 and 30 mM HCO_3^- (indirect bicarbonate induced iron deficiency). Application of 20 μM Fe-EDTA increased both shoots and root dry weights of maize varieties in general also 1N HCl-extractable iron and total iron amounts found high in shoots and roots. Slight growth reduction and dry weight loses were determined but total and 1N HCl-extractable iron concentration and their amounts per shoots and roots were severely effected with the increasing amounts of HCO_3^-. High leaf chlorosis score and low root and shoot dry weight values were found in all maize varieties. According to visual deficiency scores, dry weight, total and 1N HCl-extractable iron amounts; Kendo and C-955 were selected as the highest tolerant and Isİdoro MF as the least tolerant maize varieties.

Key words: Bicarbonate · HCl-extractable iron · iron-deprivation · iron chlorosis · maize varieties

INTRODUCTION

Iron is an essential element for plant growth. Although most soils contain adequate total iron, amounts that are available to plants might be inadequate dependent on various soil factors and plant genotypes. Bicarbonate is considered a determinant factor inducing iron deficiency on calcareous soils [1-10] also in solution culture [7, 11]. Elevated HCO_3^- ion concentration makes iron insoluble, inhibits its uptake by roots and translocation into shoots and leaves [12-14]. Nutrient solutions containing bicarbonate have been used in screening different species for tolerance to Fe chlorosis [2, 9, 14-17]. Among strategy II species, maize is known as one of the least efficient species to take up iron [5, 18, 19]. Tolerance of the varieties to iron-deprivation may differ in a wide range with in the genotypes, while some varieties respond remarkably, the others response might be poor. Studies on selecting the iron deficiency tolerant genotypes may represent an approach to iron deficiency problem and prevent some plant injuries, high application cost and short period effect of soil and foliar applications.

The objective of this greenhouse study was to characterize 13 maize cultivars for their resistance to iron-deprivation by using a common nutrient solution approach with supply of an increasing concentration of bicarbonate with a simultaneous supply of the synthetic iron chelate FeEDTA, measuring dry weight, total and Hcl-extractable iron concentrations and their amounts per shoots and roots.

MATERIALS AND METHODS

The experiment was performed in a greenhouse condition. Thirteen different hybrid maize varieties (*Zea mays* L. cv.,) MF 714 Granada, IsİdoroMF, Tex MF, Kendo MF, Sansia (Agromar seed company), C-955 (Dekalp-Monsanto seed comp.), Premier (G-626) (Güneş seed comp.), Progen 1550 (Özbuğday seed comp.), Darva (Advanta seed comp.), H-2547 (Beta seed comp.), Konsur (Golden west- Hazera seed comp.), Bursa Beyazi and Otello (Ar seed comp.) were investigated. Seeds were grown in perlite containing plastic pots of 2.5 L volume using bottom reservoir technique. To build up reservoir at the bottom of the pots, we put plastic bags in the pots and perfored 4 cm above the bottom and filled up with 2.0 L. of perlite. Six maize seeds were planted per pot, thinned to four after the emergence and daily irrigated

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Table 1: pH and some nutrient element concentrations of the solutions

Number	pH	EC (µS cm^{-1})	Na (mg kg^{-1})	K (mg kg^{-1})	Ca (mg kg^{-1})	Mg (mg kg^{-1})	Fe (mg kg^{-1})
S1	6.86	966	6.7	80.8	111.5	34.44	0.04
S2	6.85	970	6.8	83.5	110.0	34.03	0.54
S3	7.38	1463	171.7	88.3	107.6	32.80	0.53
S4	7.65	1920	274.6	89.6	105.1	32.39	0.49
S5	7.88	2840	648.6	97.8	104.8	31.98	0.48
Tap water	7.43	311	6.2	1.2	32.2	20.20	0.01

with five different nutrient solutions (S1: Basic Nutrient Solution (BNS) with iron; S2: BNS without iron; S3: BNS with iron and 7.5 mM HCO_3^-, S4: BNS with iron and 15mM HCO_3^-, S5: BNS with iron and 30mM HCO_3^-). Basic nutrient solution (BNS) was composed of $Ca(NO_3)_2$ 2 mM; K_2SO_4 0.75 mM; $MgSO_4$ 0.65 mM; KH_2PO_4 0.5 mM; KCl 25 µM; H_3BO_3 10 µM; $MnSO_4$ 1 µM; $CuSO_4$ 0.5 µM; $ZnSO_4$ 0.5 µM; $(NH_4)_6Mo_7O_{24}$ 0.05 µM. Sodium bicarbonate ($NaHCO_3$) was added to the basic nutrient solution to obtain 7.5; 15 and 30 mM bicarbonate levels. 10 µM FeEDTA was used for iron supply. Two weeks later the concentration of iron was increased to 20 µM. pH of the second nutrient solution was adjusted to 4.5 with HNO_3 and the solutions were renewed every four days. pH and some nutrient element concentrations of the solutions were analyzed and shown in Table 1.

Maize plants kept 48 days, which was long enough for the appearance of effects of the treatments. Aerial parts of the plants were harvested on day 48. At harvest, chlorotic status of the young fully expanded leaves was determined using visual appreciation of chlorosis symptoms. Ratings for the degree of iron deficiency/tolerance were made adopting 0-5 scale: 0 (No iron deficiency/high tolerant); 5 (Severe iron deficiency). Intermediate values of 1, 2, 3 and 4 indicated 30, 45, 60 and 75 % intervenial chlorosis, respectively [20]. Plant materials were washed with tap water and finally twice with deionized water, dried in a forced air oven at 70°C for 72 hours; dry weights were determined and ground respectively. The ground plant samples were wet digested using a HNO_3-$HClO_4$ mixture at volume ratios of 4:1 [21]; total iron was determined by atomic absorption spectrophotometry (Philips PU 9200x, Pye Unicam Ltd. GB); 1N Hcl-extractable iron was determined on dry plant parts by atomic absorption spectrophotometry [22].

Statistical analysis: A complete randomized design was used with three replications. The results were subjected to statistical analysis and the mean values were compared using LSD (Least Significant Differences) multiple range test with the aid of computer program Tarist [23].

RESULTS AND DISCUSSION

Visual deficiency symptoms: A few days after emergence, in iron free plots (direct deficiency conditions) all of the thirteen maize varieties exhibited severe iron deficiency symptoms. All varieties had yellow leaf, light green veins and performed severe growth inhibition and gave high leaf chlorosis scores (4.00-5.00) (Table 2). Because of showing the most severe deficiency symptoms and necrosis; Isİdoro MF had the highest chlorosis score (5.00). Kendo MF, H-2547 and Bursa Beyazİ were the varieties, which have the least chlorosis score of direct deficiency (4.00). Chlorosis was developed slightly on plants grown in 7.5 and 15 mM HCO_3^- containing nutrient solutions. Although the varieties Kendo MF, Sansia, C-955 and Progen 1550 have green leaf colour as shown in the control plots, visual Fe deficiency symptoms slightly appeared on others. Sansia and Progen 1550 were the least effected varieties of 15 mM HCO_3^- application (1.67). Shi *et al.* [7] and Cinelli [13] reported that the treatment less than 10 mM $NaHCO_3$ did not induce severe clorosis and the results are in agreement with the findings of other researchers [14, 24]. Deficiency symptoms became severe by the application of 30 mM HCO_3^- in all maize varieties and gave almost similar visual effects of direct deficient plants (4.00-5.00).

Dry weight values: Application of 20 µM Fe (Fe-EDTA) increased both shoot and root dry weights of maize varieties in control pots (Table 3). On the other hand the root and shoot dry weight values of the varieties grown in 7.5-15 mM HCO_3^- containing nutrient solutions were found similar or a little higher than the control, but a sharp decrease occurred in 30 mM bicarbonate application. Roots and shoots of the plants grown in iron free nutrient solution (direct deficiency conditions) and also in the 30 mM HCO_3^- (maximum dose of indirect deficiency) were severely affected and gave the lowest dry weight values (5.19 and 5.81 g pot^{-1}). Decreases on dry weight amounts of roots and shoots have been reported by application of 20 mM HCO_3^- to peach rootstock [2], to barley, sorghum

Table 2: Visual deficiency scores on shoots of various maize varieties grown in different nutrient solutions

	Shoots					
Varieties	$-HCO_3^-$ +Fe (Control)	$-HCO_3^-$ -Fe	7.5 mM HCO_3^- +Fe	15 mM HCO_3^- +Fe	30 mM HCO_3^- +Fe	Mean
MF 714 Granada	1.33	4.67	1.50	2.00	4.67	2.93
IsİdoroMF	1.67	5.00	2.00	2.00	5.00	3.13
Tex MF	1.00	4.67	1.67	2.00	4.33	2.86
Kendo MF	1.00	4.00	1.00	2.00	4.33	2.83
Sansia	1.00	4.33	1.33	1.67	4.33	2.77
C 955	1.00	4.33	1.00	2.00	4.33	2.77
Premier (G-626)	1.50	4.33	2.00	2.33	4.33	3.00
Progen 1550	1.00	4.67	1.33	1.67	4.00	2.64
Darva	1.00	4.33	1.67	2.67	4.33	2.93
H 2547	1.00	4.00	2.00	2.00	4.33	2.79
Konsur	1.33	4.67	1.67	2.00	4.33	2.80
B.Beyazİ	1.33	4.00	1.67	2.00	5.00	2.80
Otello	1.33	4.33	2.00	2.00	4.67	2.87
Mean	1.24d	4.41a	1.64c	2.03b	4.46a	

Varieties: ns, Solutions: **, VxS: ns, $LSD_{0.01}$: 0.328, ** Significant at P<0.01 level, ns: not significant

Table 3: Dry weight values on shoots and roots of various maize varieties grown in different nutrient solutions (g pot^{-1})

	Shoots						
Varieties	$-HCO_3^-$ +Fe (Control)	$-HCO_3^-$ -Fe	7.5mM HCO_3^- +Fe	15mM HCO_3^- +Fe	30mM HCO_3^- +Fe	Mean	
MF 714 Granada	13.04	3.72	16.69	14.28	3.48	10.24	B-E
IsıdoroMF	11.93	1.26	13.55	13.35	1.72	8.36	F
Tex MF	13.62	5.65	12.98	14.87	5.02	10.43	B-D
Kendo MF	16.99	7.30	17.08	14.28	5.78	12.29	AB
Sansia	17.01	4.67	18.10	16.35	6.93	12.61	A
C 955	15.07	4.95	15.28	12.89	6.08	10.85	A-D
Premier (G-626)	13.11	7.21	13.57	13.51	8.95	11.27	A-C
Progen 1550	15.72	5.28	16.15	15.05	8.65	12.17	AB
Darva	14.73	6.38	14.91	12.00	7.48	11.10	A-C
H 2547	13.82	5.49	14.69	14.06	8.13	11.24	A-C
Konsur	8.55	4.41	13.43	11.72	6.13	8.85	DE
B.Beyazı	14.00	6.07	14.49	11.43	2.81	9.76	C-E
Otello	13.90	5.13	13.06	13.09	4.35	9.91	C-E
Mean	13.96ab	5.19c	14.92a	13.61b	5.81c		

Varieties: **, Solutions:**, VxS: ns, $LSD_{0.01}$: 2.058 $LSD_{0.01}$: 1.276

	Roots											
	$-HCO_3^-$ +Fe (Control)		$-HCO_3^-$ -Fe		7.5 mM HCO_3^- +Fe		15 mM HCO_3^- +Fe		30 mM HCO_3^- +Fe		Mean	
MF 714 Granada	5.83b	D-F	1.72c	CD	9.37a	A	7.54ab	AB	2.53c	AB	5.40	CD
IsıdoroMF	5.00a	EF	0.69b	D	6.36a	B	6.24a	B	1.15b	B	3.89	E
Tex MF	6.33a	D-F	2.93b	A-D	7.44a	AB	7.32a	AB	2.48b	AB	5.30	CD
Kendo MF	11.02a	A	4.79cd	D	9.6ab	A	7.18bc	AB	3.05ab	D	7.13	A
Sansia	9.08a	A-C	2.52b	A-D	9.13a	A	7.65a	AB	3.12b	AB	6.30	A-C
C 955	10.64a	AB	2.48b	A-D	9.63a	A	9.20a	A	3.37b	AB	7.07	A
Premier (G-626)	6.51a-c	C-F	4.52bc	AB	8.54a	AB	6.94ab	AB	3.82c	AB	6.07	A-D
Progen 1550	6.80a	C-E	2.06b	B-D	7.94a	AB	7.11a	AB	3.49b	AB	5.48	CD
Darva	8.29a	B-D	3.77b	A-C	8.99a	AB	8.05a	AB	4.51b	A	6.72	AB
H 2547	6.42ab	C-F	2.41c	A-D	8.15a	AB	7.83a	AB	3.83bc	AB	5.73	B-D
Konsur	4.02b	F	2.12b	A-D	7.49a	AB	7.00a	AB	3.72b	AB	4.87	DE
B.beyazı	7.75a	CD	2.74b	A-D	7.37a	AB	6.22a	B	1.61b	B	5.14	CD
Otello	9.08a	A-C	2.53b	A-D	8.16a	AB	7.19a	AB	2.95b	AB	5.98	A-D
Mean	7.44b		2.71c		8.32a		7.34b		3.05c			

Varieties: **, Solutions:**, VxS: **, $LSD_{0.01}$: 1.210 $LSD_{0.01}$: 0.750 $LSD_{0.01}$: 2.705, ** Significant at P<0.01 level, Means followed by the same letter are not significantly different. Capital letters for each column, small letters for each row and maize [4] and to Kiwi (*Actinidia deliciosa cv.* Hayward) [25] in recent researches. In general means, the highest shoot dry weight values were determined from Sansia (12.61 g pot^{-1}) and highest root dry weights were determined from Kendo MF and C 955 (7.13 and 7.07 g pot^{-1}) (Table 3).

Iron concentrations: According to the mean values total iron concentrations of shoots and roots of the maize varieties found highest in 20 μM Fe containing nutrient solution (control) (29.4 and 156.9 mg kg^{-1}) and tend to decrease by the effect of HCO_3^- applications under the indirect deficiency conditions (Table 4). Degradation on total iron amounts were slight in 7.5 mM HCO_3^- level but became severe in 15 mM HCO_3^- level. Shi *et al.* [7] were determined that the total amount of iron taken up by the plants decreased as the HCO_3^- level was increased and higher levels of bicarbonate (>10 mM) has been reported by many researchers to inhibit iron uptake and translocation in many crops [10, 14, 26, 27]. Although the total iron concentrations of roots decreased with the increasing HCO_3^- levels, amounts were found higher than

Table 4: Total Fe concentrations on shoots and roots of various maize varieties grown in different nutrient solutions (mg kg^{-1} DW)

	Shoots					
Varieties	$-HCO_3^-$ +Fe (Control)	$-HCO_3^-$ -Fe	7.5mM HCO_3^- +Fe	15mM HCO_3^- +Fe	30mM HCO_3^- +Fe	Mean
MF 714 Granada	26.67a A-C	29.33a A	25.00a A-C	12.67b A	14.33b B	21.60 B-D
IsıdoroMF	25.33a BC	23.67ab A	20.33ab B-D	14.67b A	18.33ab AB	20.47 CD
Tex MF	28.33a A-C	23.67ab A	22.67ab B-D	14.33b A	18.00b AB	21.40 B-D
Kendo MF	29.67a A-C	25.67a A	24.33a A-C	13.67b A	12.33b B	21.13 B-D
Sansia	22.67ab C	26.67a A	21.67ab B-D	14.00bc A	11.67c B	19.33 D
C 955	29.33a A-C	27.00a A	29.67a AB	20.33a A	24.00a A	26.07 A
Premier (G-626)	35.67a A	23.33b A	33.00a A	16.67b A	17.00b AB	25.13 AB
Progen 1550	28.67a A-C	27.67a A	21.33ab B-D	19.00c A	25.00ab A	24.33 A-C
Darva	25.33a BC	26.67a A	18.67a CD	17.33a A	18.67a AB	21.33 B-D
H 2547	33.67a AB	24.33a A	22.33b B-D	16.33b A	19.33b AB	23.20 A-D
Konsur	33.33a AB	28.33a A	19.00bc CD	18.67c A	24.33abc A	24.73 AB
B.Beyazı	34.00a AB	26.67ab A	14.67c D	17.67bc A	25.67ab A	23.73 A-C
Otello	29.33a A-C	27.00a A	21.33ab B-D	14.00b A	20.00ab AB	22.33 A-D
Mean	29.39a	26.15b	22.62c	16.1e	19.13d	

Varieties: **, Solutions:**, VxS: **, $LSD_{0.01}$: 4.202 $LSD_{0.01}$:2.606 $LSD_{0.01}$: 9.395

	Roots					
	$-HCO_3^-$ +Fe (Control)	$-HCO_3^-$ -Fe	7.5 mM HCO_3^- +Fe	15 mM HCO_3^- +Fe	30 mM HCO_3^- +Fe	Mean
MF 714 Granada	109.67a D-F	49.33a B	39.33a C	38.67a A	33.67a A	54.13 D
IsıdoroMF	177.33a A-E	86.67ab AB	53.33b BC	48.67b A	48.33b A	82.87 B-D
Tex MF	211.67a A-D	94.33b AB	117.33ab BC	49.33b A	73.67b A	109.27 A-C
Kendo MF	282.33a A	110.33b AB	234.00a A	41.00b A	34.00b A	140.33 A
Sansia	250.33a AB	128.67b AB	41.00b C	51.67b A	55.00b A	105.33 A-C
C 955	152.00a B-F	120.00ab AB	40.67b C	85.00ab A	71.33a A	93.80 A-D
Premier (G-626)	233.00a A-C	161.67a B	98.00bc BC	40.00c A	40.00c A	114.53 A-C
Progen 1550	96.33a EF	117.33a AB	77.33a BC	90.00a A	28.00a A	81.80 B-D
Darva	194.33a A-E	142.33ab AB	152.67ab AB	79.33b A	46.00b A	122.93 AB
H 2547	65.00a F	95.67a AB	69.67a BC	77.67a A	56.00a A	72.80 CD
Konsur	67.30a F	111.00a AB	64.00a BC	86.00a A	57.67a A	77.20 B-D
B.Beyazı	139.00a C-F	128.67a AB	113.67a BC	94.67a A	56.33a A	106.47 A-C
Otello	61.33a F	78.67a AB	123.33a BC	69.00a A	34.00a A	73.27 CD
Mean	156.9a	109.59b	94.18bc	65.46cd	48.77d	

Varieties: **, Solutions:**, VxS: **, $LSD_{0.01}$: 48.284 $LSD_{0.01}$: 29.944 $LSD_{0.01}$: 107.965, ** Significant at P<0.01 level, Means followed by the same letter are not significantly different. Capital letters for each column, small letters for each row

Table 5: Correlation coefficients of selected parameters on shoot and roots

	Shoot					Root			
	Dry Weight	Chlorosis Degree	Total Fe Concentration	1N Hcl-extractable Fe Concentration	Total Fe Content	Dry Weight	Total Fe Concentration	1N Hcl-extractable Fe Concentration	Total Fe Content
Chlorosis degree	-0.893**	-							
Total Fe concentration	-0.054 ns	-0.115 ns	0.251**						
1N Hcl-extractable Fe concentration	0.463**	-0.698**	0.391**	-0.008 ns	0.139*				
Total Fe content	0.793**	-0.810**	0.521**	0.627**	0.597**	0.878**	0.193**		
1N Hcl-extractable Fe content	0.939**	-0.945**	0.109ns	0.720**	0.853**	0.914**	0.369**	0.301**	0.693**

**Significant at P<0.01, *Significant at P<0.05 level, ns: not significant

shoots. Cinelli [13] found similar results and suggested that greater accumulation of the element occurs in the root system. Zribi and Gharsalli [28] in pea, Kosegarten *et al.* [29] in sunflower, found root iron concentrations much higher than in leaves and as shown by Mengel [6]. In general means, second high total iron amounts of roots and shoots were found in iron free nutrient solution (direct deficiency) (109.6 and 26.2 $mgkg^{-1}$) and also root and shoot total iron concentrations of some varieties were found similar or higher than control and particularly this situation shown between doses of indirect deficiency conditions. Because of the severe inhibited growth of plants under direct and indirect deficiency conditions, the concentration of total iron perceived higher than the usual. Chlorotic leaves including as much or over total iron than green healthy ones, has been called as "the chlorosis paradox" [30]. This phenomenon is explained as the consequence of an absence of iron dilution in young chlorotic leaves due to an inhibited leaf expansion growth [3, 24, 32]. Because of this phenomenon, total iron does not always give a good indication of the iron status of the plant [13, 33-35]. Oserkowsky [36] named that the fraction of iron as "active iron" which could be extracted by 1N HCl from fresh leaf material gave a better indication of the iron status. Various authors conclude that the concentration of 1N HCl-extractable iron in fresh/dry leaves is a better nutritional iron indicator than total iron because of a positive correlation with chlorophyll concentration [33-35, 37-40]. In agreement with these findings, no significant correlation was found between total iron concentrations and chlorosis degree (r = -0.115ns), also dry weight results and 1N Hcl-extractable iron amounts respectively (r = -0.054ns, r = -0.109ns) (Table 5).

1 N HCl-extractable iron concentrations of shoots and roots were found highest in iron applied plants (control) and decreased with bicarbonate addition. The lowest amounts of shoots were taken from 30 mM HCO_3^- applied indirect deficiency conditions and from direct deficiency conditions (Table 6). In agreement with previous researches [38, 40-42] the amount of 1 N HCl-extractable iron tended to decrease with the increase in the degree of visual deficiency symptoms and significant correlations were found between chlorosis degree (r = -0.698**) and also dry weight (r = 0.463**). C-955 has the highest, Sansia and Darva have the least amounts among the other varieties according to the general means taken from shoots. In contrast to the much higher amounts of total iron in roots, 1 N HCl-extractable iron concentrations of the roots were found a little higher than the amounts from shoots but not as high as the total iron amounts. The roots acted as a reservoir but its mobilization and translocation to shoots could not be done due to low Fe III reductase activity at a high pH induced by bicarbonate [43, 44]. Mengel and Geurtzen [45] reported that apoplastic iron of maize roots could be mobilized and translocated to the shoots if the pH of the root medium was lowered and this is corroborated in other researches [6, 29]. On the other hand von Wiren *et al.* [46] and Römheld and Marschner [47] reported that in the graminaceous plants an inducible Fe^{+2} transport system was either absent or less pronounced, as no reduction step was required for Fe^{+3} phytosiderophore uptake in Strategy II plants. The highest 1N HCl-extractable iron concentration of the roots was found in control and the lowest concentration was found in direct deficiency conditions. Amounts on 30 mM HCO_3^- application was found higher than other bicarbonate applications and seemed a similar situation mentioned in total iron amounts of shoots.

Iron amounts per shoot and roots: The highest total iron and 1N HCl-extractable iron amounts per shoots and roots of the plants were also found in control plots and tend to

Table 6: 1N HCl extractable Fe concentrations on shoots and roots of various maize varieties grown in different nutrient solutions (mg kg^{-1} DW)

	Shoots					
Varieties	$-HCO_3^-$ +Fe (Control)	$-HCO_3^-$ -Fe	7.5 mM HCO_3^- +Fe	15 mM HCO_3^- +Fe	30 mM HCO_3^- +Fe	Mean
MF 714 Granada	17.67a A-D	13.13b A	14.87ab AB	13.47b A-D	12.47b A-C	14.32 AB
IsıdoroMF	15.87a B-D	12.13b A	13.27ab AB	12.60b B-D	12.40b A-C	13.25 B-D
Tex MF	18.13a AB	11.47c A	14.73b AB	12.40bc CD	10.87c A-C	13.52 A-D
Kendo MF	20.07a A	13.00b A	14.93b AB	13.07bc A-D	10.60c A-C	14.33 AB
Sansia	15.00a CD	12.07a A	13.33a AB	12.33ab CD	9.47b C	12.44 D
C 955	19.60a A	11.00c A	15.73b A	15.20b A-C	11.93c A-C	14.69 A
Premier (G-626)	17.87a A-C	11.93b A	12.93b AB	12.13b D	10.67b A-C	13.11 B-D
Progen 1550	16.40a B-D	11.27b A	13.33b AB	14.27ab A-D	12.60b AB	13.57 A-D
Darva	15.47a B-D	10.87b A	12.00b B	12.53ab CD	11.27b A-C	12.43 D
H 2547	18.33a AB	11.20b A	12.27b B	12.20b CD	12.40b A-C	13.28 B-D
Konsur	15.07a CD	11.47b A	14.53a AB	15.60a AB	13.53ab A	14.04 A-C
B.Beyazı	16.20a B-D	12.80b A	13.27ab AB	15.93a A	12.33b A-C	14.11 A-C
Otello	14.73a D	13.00ab A	13.33a AB	13.13ab A-D	10.20b BC	12.88 CD
Mean	16.95a	11.95c	13.73b	13.45b	11.60c	

Varieties: **, Solutions: **, VxS: **, $LSD_{0.01}$: 1.354 $LSD_{0.01}$: 0.840 $LSD_{0.01}$: 3.029

	Roots					
Varieties	$-HCO_3^-$ +Fe (Control)	$-HCO_3^-$ -Fe	7.5 mM HCO_3^- +Fe	15 mM HCO_3^- +Fe	30 mM HCO_3^- +Fe	Mean
MF 714 Granada	15.60a AB	13.20a B	14.67a A	14.33a A	16.40a B-D	14.84 CD
IsıdoroMF	20.20b B-D	27.40a A	12.00b A	15.00b A	19.93b AB	18.91 A
Tex MF	19.20ab AB	14.00c B	16.07bc A	15.47bc A	21.53a A	17.25 AB
Kendo MF	23.00a A	12.07b B	13.53b A	15.27b A	15.80b B-D	15.93 BC
Sansia	18.53a AB	11.93b B	12.80b A	16.67ab A	14.67ab CD	14.92 CD
C 955	16.60a B-D	10.07b B	15.33a A	13.67ab A	16.67a B-D	14.47 C-E
Premier (G-626)	17.87a BC	10.53b B	11.87b A	13.93ab A	14.33ab CD	13.71 DE
Progen 1550	17.80a BC	10.13c B	12.47bc A	16.87ab A	17.33a A-D	14.92 CD
Darva	15.87a B-D	9.67b B	14.40ab A	13.20ab A	16.87a A-D	14.00 C-E
H 2547	13.07ab CD	9.60b B	13.00ab A	15.40a A	17.47a A-D	13.71 DE
Konsur	16.60a B-D	9.53b B	14.27ab A	14.27ab A	16.13a B-D	14.16 C-E
B.Beyazı	15.47ab B-D	11.20b B	14.87ab A	14.47ab A	17.93a A-C	14.79 CD
Otello	12.73a D	10.40a B	13.73a A	12.93a A	12.73a D	12.51 F
Mean	17.12a	12.29c	13.77b	14.73b	16.75a	

Varieties: **, Solutions: **, VxS: **, $LSD_{0.01}$: 2.167 $LSD_{0.01}$: 1.344 $LSD_{0.01}$: 4.846, ** Significant at P<0.01 level, Means followed by the same letter are not significantly different. Capital letters for each column, small letters for each row

decrease with the increasing amounts of bicarbonate (Table 7). Total and 1N Hcl-extractable iron amounts of shoots gave high correlations with dry weight (r = 0.793**, r = 0.939**) and chlorosis degree (r = -0.810**, r = -0.945**) respectively (Table 5). The least amounts of total and 1N HCl-extractable iron were detected in 30 mM HCO_3^- level of indirect deficiency and direct deficiency conditions (Table 7 and 8). According to the total iron amounts of shoots, Isİdoro MF has the least (0.17 mg pot^{-1}) and Premier (G-626), Progen and C-955 have the highest (0.29 mg pot^{-1}) amounts. The l east amounts of 1N Hcl-extractable iron determined from Isİdoro MF (0.12 mg pot^{-1}) and the highest one from Kendo (0.19 mg pot^{-1}) (Table 8). In roots, Kendo has also the highest total and 1N Hcl-extractable iron amounts (1.27 and 0.12 mg pot^{-1}).

Table 7 : Total Fe amounts per shoot and root of various maize varieties grown in different nutrient solutions (mg pot^{-1})

	Shoots					
Varieties	$-HCO_3^-$ +Fe (Control)	$-HCO_3^-$ -Fe	7.5 mM HCO_3^- +Fe	15 mM HCO_3^- +Fe	30 mM HCO_3^- +Fe	Mean
MF 714 Granada	0.35	0.11	0.41	0.18	0.05	0.22 C-E
IsıdoroMF	0.30	0.03	0.27	0.20	0.03	0.17 E
Tex MF	0.39	0.13	0.30	0.21	0.08	0.22 B-E
Kendo MF	0.50	0.17	0.42	0.20	0.07	0.27 A-C
Sansia	0.38	0.13	0.38	0.23	0.08	0.24 A-D
C 955	0.45	0.13	0.45	0.26	0.15	0.29 AB
Premier (G-626)	0.47	0.17	0.45	0.22	0.15	0.29 A
Progen 1550	0.46	0.15	0.35	0.29	0.21	0.29 A
Darva	0.37	0.17	0.28	0.21	0.14	0.23 A-D
H 2547	0.47	0.13	0.33	0.23	0.15	0.26 A-D
Konsur	0.28	0.13	0.26	0.22	0.15	0.21 DE
B.Beyazı	0.47	0.16	0.21	0.20	0.07	0.22 B-E
Otello	0.40	0.14	0.29	0.18	0.08	0.22 C-E
Mean	0.41a	0.14d	0.34b	0.22c	0.11d	

Varieties: **, Solutions:**, VxS: ns, $LSD_{0.01}$: 0.066 $LSD_{0.01}$: 0.041

	Roots					
Varieties	$-HCO_3^-$ + Fe (Control)	$-HCO_3^-$ -Fe	7.5mM HCO_3^- +Fe	15mM HCO_3^- +Fe	30mM HCO_3^- +Fe	Mean
MF 714 Granada	0.64a D-F	0.07a A	0.37a BC	0.28a A	0.09a A	0.29 C
IsıdoroMF	0.91a C-F	0.07a A	0.34a C	0.30a A	0.06a A	0.34 C
Tex MF	1.34a B-E	0.25b A	1.03ab BC	0.37ab A	0.20b A	0.64 BC
Kendo MF	3.08a A	0.57b A	2.28a A	0.30b A	0.10b A	1.27 A
Sansia	2.22a AB	0.32b A	0.38b BC	0.40b A	0.16b A	0.69 BC
C 955	1.60a B-D	0.29b A	0.39b BC	0.81ab A	0.26b A	0.67 BC
Premier (G-626)	1.58a B-D	0.70ab A	0.84ab BC	0.26b A	0.15b A	0.71 BC
Progen 1550	0.66a D-F	0.22a A	0.60a BC	0.61a A	0.10a A	0.44 C
Darva	1.88a BC	0.56bc A	1.36ab AB	0.63bc A	0.21c A	0.93 AB
H 2547	0.43a EF	0.24a A	0.57a BC	0.61a A	0.23a A	0.41 C
Konsur	0.26a F	0.23a A	0.48a BC	0.59a A	0.21a A	0.36 C
B.Beyazı	1.10a C-F	0.34ab A	0.84ab BC	0.57ab A	0.09b A	0.59 BC
Otello	0.56a EF	0.19a A	0.96a BC	0.49a A	0.10a A	0.46 C
Mean	1.25a	0.31cd	0.80b	0.48c	0.15d	

Varieties: **, Solutions: **, VxS: **, $LSD_{0.01}$: 0.449 $LSD_{0.01}$: 0.279 $LSD_{0.01}$: 1.004, ** Significant at $P<0.01$ level, Means followed by the same letter are not significantly different. Capital letters for each column, small letters for each row

CONCLUSION

7.5 and 15 mM doses of HCO_3^- did not induce severe visual deficiency symptoms, growth reduction or dry weight loses but total and 1N HCl-extractable iron concentration and their amounts per shoots and roots were severely effected with bicarbonate. The varieties grown in direct and 30 mM HCO_3^- dose of indirect deficiency conditions were the most affected ones. Application of bicarbonate affected the total iron amounts much more than 1N HCl-extractable iron amounts of both shoot and roots. No significant correlation was obtained between total iron concentrations and chlorosis degree, dry weight and 1N HCl-extractable iron amounts per shoots and roots. However, significant correlations were found between 1N Hcl-extractable iron and chlorosis

Table 8: 1N HCl-extractable Fe amounts per shoot and root of various maize varieties grown in different nutrient solutions (mg pot^{-1})

Varieties	Shoots -HCO_3^- +Fe (Control)	-HCO_3^- -Fe	7.5 mM HCO_3^- +Fe	15 mM HCO_3^- +Fe	30 mM HCO_3^- +Fe	Mean
MF 714 Granada	0.23a BC	0.05b AB	0.25a AB	0.19a A	0.05b A-C	0.15 B-D
IsıdoroMF	0.19a CD	0.02b B	0.18a CD	0.17a A	0.02b C	0.12 E
Tex MF	0.24a BC	0.07b AB	0.19a B-D	0.19a A	0.05b A-C	0.15 B-D
Kendo MF	0.34a A	0.09d A	0.26b A	0.19c A	0.06d A-C	0.19 A
Sansia	0.25a BC	0.06b AB	0.24a A-D	0.20a A	0.06b A-C	0.16 A-C
C 955	0.30a AB	0.05c AB	0.24ab A-C	0.20b A	0.07c A-C	0.17 AB
Premier (G-626)	0.23a BC	0.09c A	0.17a D	0.16ab A	0.10bc A-B	0.15 B-D
Progen 1550	0.25a BC	0.06b AB	0.21a A-D	0.22a A	0.11b A	0.17 A-C
Darva	0.23a C	0.07c AB	0.18ab CD	0.15b A	0.08c A-C	0.14 C-E
H 2547	0.25a BC	0.06d AB	0.18b CD	0.17bc A	0.10cd AB	0.15 B-D
Konsur	0.14a bD	0.05c AB	0.20a A-D	0.18a A	0.08b A-C	0.13 DE
B.Beyazı	0.22a C	0.08b AB	0.19a A-D	0.18a A	0.04b BC	0.14 BE
Otello	0.20a CD	0.07b AB	0.18a CD	0.17a A	0.04b A-C	0.13 DE
Mean	0.24a	0.06d	0.21b	0.18c	0.07d	

Varieties: **, Solutions: **, VxS: **, $LSD_{0.01}$: 0.030 $LSD_{0.01}$: 0.019 $LSD_{0.01}$: 0.067

Varieties	Roots -HCO_3^- +Fe (Control)	-HCO_3^- -Fe	7.5 mM HCO_3^- +Fe	15 mM HCO_3^- +Fe	30 mM HCO_3^- +Fe	Mean
MF 714 Granada	0.09a C-E	0.02b A	0.14a A	0.11a A	0.04b AB	0.08 C-F
IsıdoroMF	0.10a C-E	0.02b A	0.08a B	0.09a A	0.02b B	0.06 F
Tex MF	0.12a CD	0.04b A	0.12a AB	0.11a A	0.05b AB	0.09 B-E
Kendo MF	0.25a A	0.06c A	0.13b A	0.11b A	0.05c AB	0.12 A
Sansia	0.17a B	0.03c A	0.12b AB	0.13ab A	0.05c AB	0.10 BC
C 955	0.17a B	0.03c A	0.15ab A	0.12b A	0.06c AB	0.11 AB
Premier (G-626)	0.11a CD	0.05b A	0.10a AB	0.09ab A	0.05b AB	0.08 C-F
Progen 1550	0.12a CD	0.02c A	0.10ab AB	0.12a A	0.06bc AB	0.08 C-E
Darva	0.13a BC	0.03c A	0.13a A	0.11ab A	0.07bc A	0.10 B-D
H 2547	0.08ab DE	0.03c A	0.10ab AB	0.12a A	0.07bc AB	0.08 C-F
Konsur	0.06ab E	0.02b A	0.11a AB	0.10a A	0.06ab AB	0.07 D-F
B.Beyazı	0.12a CD	0.03b A	0.11a AB	0.09a A	0.03b AB	0.08 D-F
Otello	0.11a CD	0.03b A	0.11a AB	0.09a A	0.04b AB	0.08 D-F
Mean	0.13a	0.03d	0.12ab	0.11b	0.05c	

Varieties: **, Solutions: ** VxS: **, $LSD_{0.01}$: 0.021 $LSD_{0.01}$: 0.013 $LSD_{0.01}$: 0.048, ** Significant at $P<0.01$ level, Means followed by the same letter are not significantly different. Capital letters for each column, small letters for each row

degree and dry weight. Total and 1N HCl-extractable iron amounts of shoots gave high correlations with dry weight and chlorosis degree. Total and 1N Hcl-extractable iron amounts p er shoots and roots might be useful parameters evaluating the nutrition status of the plants instead of the concentrations because of the chlorosis paradox. According to visual deficiency scores, the dry weight, total and 1N Hcl-extractable iron amounts Kendo and C-955 were indicated as the highly tolerant and Isİdoro MF as the least tolerant maize varieties.

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