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EFFICIENT BORON UPTAKE AND USE BY SUNFLOWER GENOTYPES GROWN IN NUTRIENT SOLUTION AND SOIL

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SUMMARY

The use of sunflower genotypes more efficient in B uptake and use or more tolerant to low B soils, can be an important practice for tropical soils, where soil acidity and B deficiency limit grain yield. The objective of this paper was to define criteria and parameters to evaluate boron efficient sunflower genotypes in nutrient solutions and soil. Three experiments were done, one in field and two in greenhouse conditions, all arranged in randomized complete blocks with four replications. In field, different degrees of boron deficiency were observed in 6 sunflower genotypes (notes attributed from 1 to 5) and high correlation coefficients were obtained between the notes and total B content in the plants. The visual symptoms were characterized by smaller and deformed heads with hollow seeds, and head clipping. In nutrient solution, 5 genotypes were grown in increasing B concentrations during 28 days, in order to define the level that best could differentiate sunflower genotypes. In another experiment, 16 genotypes were grown for the same period, in nutrient solution with 0.05 and 0.10 ppmB (previously selected B concentrations) when the following variables were evaluated: plant heights, dry matter yields, B concentrations, B contents and degrees of B deficiency (notes attributed from 0 to 6). Large variations in B concentrations and B contents in the leaves were observed, highly correlated with the notes attributed to B deficiency symptoms. The results indicated there is a potential for genetic improvement of sunflower genotypes for B uptake and use and that the nutrient solution technique can be used as a support for breeding programs.

INTRODUCTION

Soil acidity and boron deficiency has limited sunflower yield in tropical soil conditions, as has been demonstrated by Blamey (1976), Blamey et alii (1978) and Quaggio et alii (1985). These results indicated that sunflower requires pH around 6.5 for maximum yield. However, boron is less available to plant in soils with high pH values (Evans & Sparks, 1983), and in these conditions the occurrence of boron deficiency symptoms could be more frequent. There is not a good soil testing method to prevent boron deficiency because climatic variations interferes on boron availability.

The use of genotypes less sensible to B deficiency or more efficient in B uptake and use could be a practical alternative.

It is recognized that cultivars within a species may differ in response to nutrient levels in the soil. These differences have been attributed to: a) differences in tissue nutrient requirements and b) differences in the ability of plants to absorb nutrients from the soil.

Information about the variation in the ability to absorbing nutrients among sunflower cultivars are not consistent. Robinson

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(1970) and Blamey et alii (1982) did not found differences, among cultivars, in the nutrient concentration in sunflower tissues. Otherwise, Foy et alii (1974) found differences between sunflower genotypes in their responses to Al toxicity and Blamey et alii(1984) found differences in the nutrient concentration in the leaves of different genotypes.

Blamey & Chapman (1980) concluded that differences in response to B fertilization was due to differences in B uptake an not in tissue requirement for B.

The potential for breeding sunflower cultivars specially adapted to low available nutrient in soils has been recognized. Blamey et alii (1984) found that nutrient uptake efficiency is simple inherited and seems to be not associated to yield; they found, also, that the incidence of B deficiency symptoms generally reflected the B status of the plants.

The objective of this paper was to define criteria and parameters to evaluate boron efficiency sunflower genotypes in nutrient solutions and field.

MATERIAL AND METHODS

Experiment 1 - Characterization of boron deficiency in the field

Differents degrees of boron deficiency symptoms were observed among sunflower cultivars in a Yield Comparative Trial set up at the Experimental Station of Campinas, Agronomic Institute of the São Paulo State.Treatments were arranged in a randomized complete block design with four replications. An evaluation of the degree of boron deficiency symptoms were made in each plot, attributing notes according to the severity of the symptoms. The notes ranged from 1 (absence of symptoms) to 5(severe head deformation, hollow seeds, head clipping. The genotypes were classified according to the average degree of symptoms, in sensible, moderately sensible, and tolerant to boron deficiency.Seven genotypes were selected according to their classification and plants were harvested for the determination of B concentration in plant tissues and its possible relations with the degree of symptoms observed.

Five plants per plot were harvested at the seed maturation stage, and the following variables were determined: dry matter of leaves, stems, pecioles, heads and seeds; grain yield; head diameters and plant heights. Plant parts were ground and analysed for B content by the method of Azometria H (Bataglia et alii, 1983).

Experiment 2 - Determination of the best boron concentration in nutrient solution for differentiation of sunflower genotypes

A greenhouse essay was conducted with the genotypes Conti - 112, Indussen 380-A, Issanka, DK-180 and IAC-Anhandy, cultivated in nutrient solution with six different B concentration. The experiment was arranged in a randomized complete block design with four replications. The sunflower seeds were germinated in paper towels and seven day-old seedlings were transplanted into 2.8liter plots with nutrient solution of the following composition (mg/l): Ca 151; K 141; Mg 17; N-NO_3 137; N-NO_4 20; Cl 33; S 54; P 80; Fe 4.8; Mn 0.5; Zn 0.13; Cu 0.04 and Mo 0.08. These nutrients were given as the following salts: $Ca(NO_3) . 4H_2O)$; KNO_3; K_2SO_4; KC_1; NH_4NO_3; $MgSO_4 . 7H_2O$; K_2PO_4; $MnCl_2 . 4H_2O$; $ZnSO_4 . 7H_2O$; $CuSO_4 . 5H_2O$ and Na_2MoO_4. The iron was utilized as Fe-EDTA and $FeSO_4 . 7H_2O$.

The B levels, as H_3BO_3, were; 0;0.05; 0.10;0.20;0.40 and 0.80 mgB/l. The pH was initially adjusted to 5.0 and monitored each other day untill the end of the experiment. The temperature and relative

humidity registered during the period were within the range considered adequate for sunflower growth. After twenty-nine days in nutrient solution the visual symptoms of B deficiency were evaluated in each pot. The plants were harvested, rinsed in destilled water, and separated in leaves, stems, and roots.
The samples were dryed in a forced air oven, at 70°C, in order to determine the dry matter weights. After that, they were ground and analysed for B as described in Bataglia et alii (1983).

Experiment 3 - Screening of sunflower genotypes for boron efficiency

Sixteen sunflower genotypes were grown in nutrient solution in a greenhouse, at the Experimental Station of Campinas, in 1986, arranged in a randomized complete block design with four replications. The following genotypes were utilized: 1- Uruguai; 2- H_2P_5; 3- VNIIMK; 4- Elia; 5- HEMf 085-056; 6- H_2P_7; 7- Rodeo; 8- HE 085-062; 9- Contisol 621; 10- IAC-Anhandy; 11- Contisol 711; 12- Luciole; 13- Arrowhead; 14- H_2P_8; 15- H_2P_6; 16- Primasol.
The growth system and the nutrient solution composition were the same described for the experiment 2.The previously selected B level were 0.05 and 0.10 mgB. Another free boron treatment, with two replications, was set up in order to confirm the purity of the reagents used in the nutrient solution composition.

RESULTS

Experiment 1

There were differences in all genotypes for the variables analysed (Table 1). The hybrids Conti-233 and Contisol showed the highest yield production, head diameter, B content in the aerial part of the plant, and the lowest level of B deficiency symptoms (Table 2). So, these hybrids had the highest capacity to absorb and translocate the boron.
The results led to the conclusion that the visual symptoms observed were related to boron deficiency because the notes attributed to the different degrees of visual symptoms, in the field, were highly correlated to B content in the whole plant (r= 0.88). Moreover grain yield was highly correlated with notes of defficient degrees (r= 0.97) and also with boron content in the whole plant (r= 0.98). Head diameter was also correlated with total boron uptake (r= 0.75).

Table 1 - Grain yield, head diameter and plant height of 6 sunflower cultivars from a Yield Comparative Trial, 1983/84 (average of 4 replications).

Cultivars	Grain yield	Head diameter	Plant height	Degree of B deficiency[1]
	kg/ha	cm	cm	
Contisol	1320	14.1	189	2.3
Conti-112	1099	12.5	189	4.0
Conti-233	1493	16.6	153	1.6
Conti-422	1183	14.7	199	2.8
Sunbred-254	1064	13.7	195	3.5
Conti-812	1078	13.4	169	3.3

[1] Notes attributed to visual symptoms of B deficiency,characterized by head deformation and amount of empty seeds (from 1.0 to 5.0); 1.0- normal heads; 2.0- few empty central seeds, no head deformation; 3.0- empty central seeds and light head deformation; 4.0- smaller and more deformed heads; 5.0- severely deformed heads.

Table 2 - B concentration and B content in dry matter of six sunflower genotypes from the Yield Comparative Trial, 1983/84 (average of 4 replications).

Genotypes	Leaves	Petioles	Stems	Heads	Seeds	Shoot
	B concentration (ppm)					
Contisol	78	91	52	56	39	---
Conti-112	73	61	49	47	38	---
Conti-233	78	61	41	67	39	---
Conti-422	70	66	37	63	45	---
Sunbred-254	79	65	35	44	32	---
Conti-812	80	66	28	48	36	---
	B content (µg/plant)					
Contisol	5431	1240	6831	3200	2427	19129
Conti-112	3346	663	4721	2140	3245	14106
Conti-233	6243	1355	5421	3607	4592	21208
Conti-422	3240	707	3996	3761	3412	15116
Sunbred-254	3672	585	3443	1850	1889	11459
Conti-812	4685	793	3079	1899	2273	12727

The symptoms of B deficiency observed in field, i.e., smaller and deformed heads, with hollow seeds, and head clipping agree with those described in the literature (Blamey, 1976).

Experiment 2

The total dry matter yields and B contents in the plants varied largely among genotypes and were related to each other for all B levels in the nutrient solution (Table 3). Indussen 380-A and DK-180 had the lowest and Issanka the highest dry matter yields and B contents for all B levels. Among the five genotypes, Issanka was the best in B uptake and use efficiency. IAC-Anhandy produced high dry matter with 0.05 and 0.10 mgB/liter and above these levels showed growth depression; this indicated it high B uptake and use efficiency in low B levels. However, B contents increased only slightly with B levels, indicating that IAC-Anhandy is a non-responsive and non-tolerant genotype to high B levels. Conti-112 was an intermediary genotype in dry matter yield and B contents, but responsive up to 0.80 mgB/liter (Table 3). All genotypes presented severe boron deficiency symptoms in the absence of B (0 mgB/liter): seedlings did not develop, terminal buds died, roots stopped growing and developped dark tips; finally seedlings died after 8-10 days. The objective of this experiment was to define the best level for differentiation of sunflower genotypes. The results indicated that the levels of 0.05 and 0.10 mgB/liter of nutrient solution are adequate for screening purposes. Additional information obtained from a field experiment confirmed the selected levels for subsequent nutrient solution experiments: notes were attributed to different degrees of B deficiency symptoms for these same genotypes grown in the field; a correlation analysis between notes and each of the variables measured in nutrient solution showed high correlation coefficients for both leves (B contents, r 0.05 = -0.83 and r 0.10 = -0.77; dry matter yields, r 0.05 = -0.92 and r 0.10 = -0.80) (Table 3).

Table 3 - Dry matter yield and boron content of 5 sunflower genotypes grown in nutrient solution with 6 levels of B. Correlation coefficients (r) of these variables with notes attributed to visual symptoms of B deficiency in the same genotypes grown in the field.

Genotype	Boron concentration in nutrient solution						Degree of B deficiency in field (1) (notes)
	0	0.05	0.10	0.20	0.40	0.80	
			Total B content (µg/2 plants)				
Indussen 380-A	63	126	152	182	186	181	4.5
Conti-112	68	177	180	223	297	342	3.8
DK-180	58	166	169	238	221	257	3.0
Issanka	87	258	260	292	272	361	2.6
IAC-Anhandy	99	225	225	226	241	267	2.0
Correlation coeficients (r) (2)	-0.77	-0.83	-0.77	-0.64	-0.29	-0.42	
			Total dry matter (g/2 plants)				
Indussen 380-A	1.08	1.99	2.50	3.23	2.88	1.88	
Conti-112	1.64	3.21	3.32	3.68	4.57	5.23	
DK-180	0.54	3.58	2.96	2.66	2.99	2.92	
Issanka	1.61	6.41	6.22	5.61	5.60	6.07	
IAC-Anhandy	1.04	6.30	5.43	3.25	3.32	3.81	
Correlation coeficients (r) (2)	0.10	-0.92	-0.80	-0.29	-0.23	-0.42	

(1) Notes attributed to B deficiency symptoms for the genotypes grown in the field.
(2) Correlation coefficients (r) obtained between notes and total B content, and notes and total dry matter.

Experiment 3

The sixteen genotypes studied presented variation in the degree of visual B deficiency symptoms, and a scale of notes from 0 to 6 was stablished according to their severity (Table 4).
These symptoms, observed in 28 day-old plants grown in nutrient solution, can be described as follows: a) Tops - shortened internodes in direction of the apical part of the plant; smaller and shrinkled leaves with characteristic brownish; leaf shrinkling and brownish were more evident in the more severely B deficient

plants; the brown tissue areas tended to dry and die; b) Roots-darker,thinner and extensively sub divided roots, with black tips, evidencing tissue death.The variation in plant heights showed high significant correlation coefficients with the notes attributed to B deficiency symptoms (r= 0.76). The total dry matter yield (leaf + stem + root) also varied among genotypes but were not significantly correlated with the degree of B deficiency (Table 4). Neverthless, the dry matter distribution in the plant was affected by B deficiency and varied among genotypes.It was observed a decreasing proportion of stems and roots in relation to leaves, as B deficiency symptoms increased. In this way, the calculated ratios leaf/total dry matter yields decreased as B levels increased in the solution, and were significantly correlated with the notes (r = 0.45). The mean values for stem and root dry matter yields were significantly higher for the level of 0.10 mgB/liter, while leaf dry matter did not vary.Significant variations among genotypes and among B levels were observed for B concentration in the leaves and stems. By the other hand, B contents varied significantly in stems and roots, but not in the leaves. These data indicated that B transport and distribution in the plant may play an important role in more efficient plants. B concentrations and contents in the leaves were significantly correlated with the notes attributed to the symptoms (r= 0.76 and r= 0.71, respectively) (Table 5). The data suggests that genotypes may be evaluated by B concentrations in leaves and by the degree of B deficiency symptoms.In the field, the third leaf downwards is usually collected for chemical analysis,and B deficiency symptoms are more evident in the sunflower heads. In the nutrient solution,all leaves of 35 day-old plants were sampled together for B determination, and B deficiency symptoms were evaluated on the aerial part(leaves, apix, inter-nodes).

Table 4 - Degree of B deficiency, plant height and total dry matter of 16 sunflower genotypes grown in nutrient solution during 28 days with two levels of B (average of four replications).

Genotypes	Degree of B deficiency (1)		Plant height (2)		Total dry matter (g/2 plants) (2)		
	Level 1	Level 2	Level 1	Level 2	Level 1	Level 2	Means
Luciole	4.8	4.0	34.8	39.5	13.04	18.53	15.78 A
Arrowhead	4.8	3.8	34.3	42.0	11.97	16.73	14.35 A-D
H_2P_5	4.8	3.1	34.1	40.8	13.71	15.62	14.66 A-C
H_2P_6	4.6	2.8	35.0	41.1	13.67	16.88	15.27 A-B
HEMI 085-56	4.4	2.6	36.2	41.8	12.63	15.30	13.97 A-D
VNIIMK	5.4	2.6	34.9	43.1	13.48	16.30	14.89 A-D
H_2P_8	4.4	2.5	30.3	38.8	12.93	14.87	13.90 A-D
IAC-Anhandy	4.4	2.4	37.3	47.1	13.82	14.66	14.24 A-D
Elia	4.0	2.3	38.1	41.8	10.35	12.79	11.57 E
Rodeo	5.0	2.1	32.4	40.6	12.32	14.68	13.50 B-E
Conti 711	4.1	2.1	31.6	45.9	13.45	15.25	14.35 A-D
H_2P_7	5.0	2.0	33.5	43.8	11.34	12.96	12.15 D-E
Conti 621	4.4	1.9	39.3	46.5	11.20	13.69	12.44 C-E
Primasol	5.1	1.9	30.4	47.0	12.58	16.22	14.40 A-D
HE 085-062	4.9	1.6	32.9	41.4	12.60	14.26	13.43 B-E
Uruguai	4.9	1.5	31.0	42.9	13.12	11.86	12.49 C-E
Means	4.7	2.4	34.1 B	42.6 A	12.64 B	15.04 A	
Correlation coefficients (r) (3)			- 0.76		n.s		

(1) Notes attibuted to the degrees of B deficiency symptoms in the leaves: 0= none; 6= severe.
(2) F significant (0.01) for differences among B levels and among genotypes.
(3) Coefficient correlations (r) between notes and the other variables (plant height and dry matter).

Table 5 - B concentrations and B contents in the dry matter of plant parts of 16 sunflower genotypes grown in nutrient solution during 28 days, with two levels of boron (average of four replications).

Genotype	B concentration (1)						B content					
	Leaves		Stems		Roots		Leaf B		total B (2)		leaf B/total B	
	Level 1	Level 2	Level 1	Level 2	Level 1	Level 2	Level 1	Level 2	Level 1	Level 2	Level 1	Level 2
	ppm						µg/2 plants					
Luciole	18.5	26.0	16.0	16.5	16.8	18.0	118	204	226	389	0.52	0.53
Arrowhead	23.8	25.8	13.5	14.3	17.3	18.3	126	191	215	336	0.58	0.57
H_2P_5	16.8	30.8	12.3	16.3	17.3	16.8	108	208	234	328	0.52	0.59
H_2P_6	17.8	28.3	12.5	15.0	19.3	20.3	127	199	226	365	0.56	0.55
HEMI 085-56	17.0	29.3	15.5	18.8	20.5	24.5	110	193	214	360	0.51	0.54
VNIIMK	18.0	27.0	14.5	14.3	15.5	19.3	117	180	220	344	0.53	0.52
H_2P_8	20.3	29.3	14.5	18.0	19.8	19.3	132	194	236	372	0.55	0.56
IAC-Anhandy	19.3	32.5	16.3	18.0	23.3	21.8	126	197	262	355	0.48	0.55
Elia	22.8	31.3	17.0	21.5	19.0	26.8	114	185	207	343	0.55	0.54
Rodeo	18.5	28.5	16.8	16.3	22.8	21.8	111	181	231	340	0.49	0.54
Conti 711	18.8	31.0	12.0	16.0	20.5	17.3	113	201	224	346	0.50	0.58
H_2P_7	20.6	34.5	13.0	16.5	24.5	19.5	119	180	210	398	0.57	0.60
Conti 621	20.0	30.5	15.0	16.3	21.0	19.5	104	180	206	343	0.51	0.57
Primasol	17.3	29.0	13.0	16.3	22.0	17.3	121	204	210	353	0.58	0.58
HE 085-062	19.0	30.0	14.5	17.0	20.0	18.3	132	198	227	330	0.58	0.60
Uruguai	19.3	44.0	14.0	19.8	18.0	27.8	118	226	226	367	0.52	0.62
Means (1)	19.2 B	30.4 A	14.3 B	17.2 A	19.8 B	20.0 A	118 B	195 A	223 B	348 A	0.53 B	0.56 A
Correl.coef (r) (3)	- 0.76		- 0.45		- 0.15		- 0.71		- 0.65		- 0.36	
Correl.coef (r) (4)	n.s.		n.s.		- 0.27		0.57		0.67			
Correl.coef (r) (5)	0.65		0.39		0.05		0.63		0.60			

(1) Test F significant (0.01) for differences among B levels and among genotypes. Means followed by the same letters do not differ by Duncan's test (0.05).
(2) Total B = leaf B + stem B + root B (non significant F for genotypes).
(3) Correlation coefficient (r) between degree of B deficiency and the other variables.
(4) Correlation coefficient (r) between total dry matter and the other variables.
(5) Correlation coefficient (r) between plant heights and the other variables.

Although differences were small among the sixteen genotypes studied at least one fourth could be selected for subsequent genetic improvement, based on the lowest degrees of deficiency and, or on the highest B concentrations on the leaves. Additional information on the selected genotypes should be get in the field, to know their response potential to B levels and also the genetic heritability of this characteristic.

Another important discussion point is arisen from the fact that variety competition trials usually are not B fertilized. In this situation, some of the genotypes with different abilities on B uptake and use may have their yields lowered due to a non-detected B deficiency. In such experiments, adequate B fertilization assumes an important role.

CONCLUSIONS

The results permit to conclude that:

The nutrient solution technique, using the B levels of 0.05 and 0,10 mgB/liter, may be of great help on the screening for more efficient sunflower genotypes in B uptake and use.

B concentrations in the leaves and the visual symptoms of B deficiency are sufficient to differentiate genotypes in the field and in the nutrient solution. The selection of more efficient genotypes in the uptake and use of B seems, feasible, however, additional information on genetic variability and heretability are necessary.

On variety competition experiments an adequate B fertilization assumes an important role.

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