Selection of sunflower cultivars for boron efficiency using nutrient solution

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ABSTRACT

Boron deficiency is common in Brazilian soils specially under Savanna conditions. Sunflower crop is very demanding as to boron supply, showing low tolerance to its deficiency. This research was done to screen sunflower cultivars for high boron utilization efficiency based on relative plant reaction in complete (0.15 mg B L^{-1}) and deficient (0.00625 mg B L^{-1}) nutrient solution. Twenty-two cultivars were evaluated in three independent assays, according to a randomized complete block design with six replicates. Root growth, plant height, leaf length, fresh root weight, fresh canopy weight, and symptoms of boron deficiency were evaluated. A criteria of efficiency and responsiveness was established. The selection procedure was efficient for root and canopy fresh weights, plant height and root growth, and allowed the selection of superior sunflower genotypes such as the AS 238 and AS 243 cultivars.

KEY WORDS: *Helianthus annuus*, nutrient solution, plant nutrition, micronutrient.

INTRODUCTION

Boron (B) is an essential micronutrient for plant development. Boron deficiency happens more often than for any other micronutrient and has been referred to in more than 80 countries and 132 crops during the last 70 years (Shorrocks, 1997). Boron deficiency in Brazil, in addition to copper and zinc deficiency, is common and take place in any soil, more frequently in acidic savanna and quartzite soils (Malavolta et al., 1988).

Sunflower requires a high amount of boron compared to other crops and has been used as a biologic tester for the boron soil supply (Schuster and Stephenson, 1940). Improvements on grain yielding have been obtained worldwide with the addition of boron to different soil types (Blamey et al., 1997).

Elongation inhibition or halt, both in primary and secondary roots, is the first symptom of boron deficiency (Dell and Huang, 1997). Under boron deficiency conditions, the young leaves become hardened, malformed, and necrotic and may develop bronze color (Calle Manzano, 1985), the stem and peduncle become brittle and may break resulting severe yield reduction (Connor and Hall, 1997) with generally small heads being produced, often deformed and, in some cases, ray florets or bracts grow in the middle of the head (Castro et al., 1996).

Differential responses to low boron soil supply among species and among genotypes derived from the same species are evidence of genetic variability in response to the micronutrient availability (Rerkasem and Jamjod, 1997). Selection and improvement can allow us to overcome the problem caused by boron deficiency in sunflower (Blamey et al., 1997). Significant differences were observed among sunflower cultivars concerning uptake ability from soils with low supply and from supplementary boron applied to plants (Blamey et al, 1979). Also, Blamey et al. (1984) observed different germplasm efficiencies in boron uptake and reported that this trait does not influence yield potential. Furlani et al. (1990) also reported on genetic potential for improvement of germplasm boron efficiency in breeding programs and that selection of superior genotypes can be performed in nutrient solution.

The objective of this work was to identify efficient sunflower cultivars for boron utilization and to determine the most appropriate time plants should stay in solution to allow assessment.

MATERIAL AND METHODS

The work was developed in the experimental farm of Embrapa Soybean, Londrina, Paraná, between November and December of 2001. Laboratory structure and part of a glass greenhouse compartment, equipped with airing and nutrient solution system, were used.

The nutrient solution used was prepared as reported by Asad et al. (2001), including distilled and deionized water containing (mg L^{-1}): NH_4NO_3 160; KNO_3 283; $Ca(NO_3)_2.4H_2O$ 189; $MgSO_4.7H_2O$ 123; KH_2PO_4 13.5; K_2HPO_4 17.3; $ZnSO_4.7H_2O$ 0.287; $MnSO_4.H_2O$ 0.169; $CuSO_4.5H_2O$ 0.062; $Na_2MoO_4.2H_2O$ 0.0087; NaCl 0.467; FeEDTA 4.89; and two levels of H_3BO_3: 0.15 and 0.00625.

The receptacles for the nutrient solution were 61 x 41 cm plastic trays with 36-liter capacity. Trays were previously cleaned with common detergent, sterilized with HCl 0.5N and cleaned again with distilled and deionized water.

Three experiments were performed including four, seven and ten days of plant permanence in nutrient solution. Three experiments with 22 sunflower cultivars and two levels of boron were established according to a completely randomized block design. There were two blocks for each boron level, represented by two trays, each with three randomly distributed plants of each cultivar in a total of 12 plants/cultivar evaluated in each experiment. Statistic analysis was performed for each boron level according the model:

$Y_{ijkl} = m + T_i + B_{j(i)} + C_k + TC_{ij} + IRL_{l(k)} + e_{ijkl}$, where:

Y_{ijkl} is the observed value at the i^{th} time, j^{th} block and k^{th} cultivar; m is the general mean; T_i is the effect of time of plants in nutrient condition; $B_{j(i)}$ is the effect of block nested into the time of permanence in solution; C_k is the effect of cultivar; TC_{ij} is the interaction between time in nutrient solution and cultivar; $IRL_{l(k)}$ is the effect of the covariable length of primary root evaluated at the moment of the transference of seedlings to the nutrient solution nested into the cultivar effect; and e_{ijkl} is the error effect.

Seeds were germinated in moistened paper towel in a chamber with controlled temperature (25ºC) and humidity (between 90% and 95%). After 96 hours, 36 seedlings were selected based on their root uniformity and transferred to plastic boxes. Nutrients were applied to the boxes 24 hours before the transference of seedlings to attest the homogeneity of solution. Every day, the pH of solution was adjusted to 5.2 ± 0.1 with HCl 1N or NaOH 2M. The level of solution in the boxes was maintained with the addition of distilled and deionized water (Furlani et al., 1990).

Seedlings were fixed in 60 x 40 x 2 cm polystyrene boards with 66 holes of 1.9 cm diameter and 3 cm apart. The polystyrene cylinders derived from the holes were sliced longitudinally at ¾ of their diameter and used to hold plants in the board. Airing of nutritive solution was continuous. The studied sunflower cultivars were the same assessed by Castiglioni et al. (1997) in the final yield trials established in the cities of Pedra Preta and Rondonópolis, state of MT, and the intermediary yield trial established in Rondonópolis, MT, as part of the official trials for evaluation of sunflower genotypes. These environments permitted the assessment of head fall, the most drastic symptom of boron deficiency. The simple hybrids AS 226, AS 238, AS 243, AS 470, AS 603, C 9301, C 9302, C 9303, C 9402, Contiflor 3, DK 180, GV 37017, M 736, M 737, M 738, M 740, M742, Rumbosol 90 and Rumbosol 91; the triple hybrids Contiflor 7 and M 736; the open pollinated variety Embrapa 122 and the inbred line HA 302 were assessed in this work. Seeds from these cultivars provided by Embrapa Soybean had different sources and can show different age and boron content. The evaluated traits included: initial root length (IRL) of seedlings at the moment of transference to solution, and the final root length (FRL), assessed after the permanence of plants in nutrient solution; plant height (PH), leaf length (LL), fresh root weight (RW), and fresh canopy weight (CW). In addition to RW, another indicator of boron deficiency on roots was root growth (RG), determined as the difference between FRL and IRL. The IRL was used as covariable in the statistic model.

The leaf symptoms, characteristic indicator of boron deficiency (Castro et al., 1996), were graded from 0 (without symptoms) to 5 (severe symptoms) on the first leaf. Pearson correlation was estimated between leaf symptom and the remaining variables. Variables showing high association with leaf symptoms were used to discriminate the efficient sunflower cultivars for boron efficiency.

A method suggested by Pípolo (1998) was adapted to rank the sunflower cultivars based on their mean in low boron supply associated to the response to the boron increment in solution. The boron response (BR) was calculated for each variable as the difference of phenotypic value obtained in the complete boron solution (0.15 mg B L^{-1}) and the value obtained in the deficient solution (0.00625 mg B L^{-1}). For each trait, the cultivar was classified as efficient when its mean was greater than the mean of all cultivars developed with 0.00625 mg B L^{-1}, and inefficient when its mean was smaller than the general mean in the same boron solution; and responsible and non-responsible when the BR was greater and smaller than the group BR mean, respectively.

RESULTS AND DISCUSSION

The physical structure of the solution system used in this work was not adequate to the evaluate seedlings after 10 days of growth, because it was impossible to isolate the roots of individual plots. Thus, data from the third experiment were not analyzed nor included in this report.

The joint analyzes of experiments, developed for each boron level (Table 1), showed significance ($P<0.01$) of the covariable effect IRL on the traits PH in the deficient boron solution and for CW in the complete boron solution. Therefore, corrected means for the covariable or minimum square means by cultivar were obtained using the LSMEANS SAS procedure (SAS, 1987).

The traits RG, PH, LL, RW and CW, in the deficient boron solution, showed a mean reduction of 25.6% after four days – minimum of 11% for PH and maximum of 45% for RG – compared to the complete solution; and a mean reduction of 43.4% after seven days – minimum of 18% for PH and maximum of 65% for CW. In both experiments, with four and seven days of permanence in nutrient solution, PH was proportionally less affected by the boron deficiency. However, since PH showed one of the smallest coefficient of variation in the joint variance analysis it was used as an indicator of the boron deficiency effects.

The main effects time of permanence in solution (TPS) and cultivar were significant ($P<0,01$) for all evaluated traits (Table 1), in both boron solution,

Table 1. Analysis of variance of experiments with sunflower plants assessed after four and seven days (T) of permanence in complete nutrient solution at the levels 0.00625 and 0.15 mg L^{-1} of boron, for the traits root growth (RG), fresh root weight (RW), fresh canopy weight (CW), plant height (PH), leaf length (LL) and deficiency symptom scores.

				MS – Boron 0.00625 mg L^{-1}			
Source of Variation	df	RG (mm^2)	RW ($mg^2.10^{-2}$)	CW ($mg^2.10^{-2}$)	PH (mm^2)	LL (mm^2)	Grade
TIME (T)	1	$10327.10^{2/}$	$604.54^{2/}$	$154842.25^{2/}$	$21061.26^{2/}$	$8974.24^{2/}$	$31.18^{2/}$
BLOCK (B)	2	1218.58	69.13	1626.19	$1004.48^{2/}$	$419.83^{1/}$	1.15
CULTIVAR (C)	21	$5632.51^{2/}$	$1008.83^{2/}$	$15989.59^{2/}$	$3090.21^{2/}$	$799.67^{2/}$	$7.81^{2/}$
T x C	21	1907.34	$111.00^{1/}$	$2096.54^{2/}$	$345.90^{2/}$	$228.57^{1/}$	0.79
IRL (C)[1]	22	1485.22	78.14	1001.54	$276.00^{1/}$	117.42	0.97
ERROR	188	1414.05	66.08	883.65	166.74	136.16	0.84
Mean		71.56	301.80	1223.90	84.55	24.74	1.2
CV%		52.55	26.93	24.29	15.22	47.15	77.67
				MS – Boron 0.15 mg L^{-1}			
Variation source	df	RG (mm^2)	RW ($mg^2.10^{-2}$)	CW ($mg^2.10^{-2}$)	PH (mm^2)	LL (mm^2)	Grade
TIME (T)	1	$538925.82^{2/}$	$65980.46^{2/}$	$851283.75^{2/}$	$64345.48^{2/}$	$52857.10^{2/}$	-
BLOCK (B)	2	265.41	359.42	1238.89	47.6	75.15	-
CULTIVAR (C)	21	$13433.48^{2/}$	$2565.47^{2/}$	$19172.66^{2/}$	$2173.39^{2/}$	$290.20^{2/}$	-
T x C	21	4386.5	317.73	$3153.91^{2/}$	291.92	$60.27^{2/}$	-
IRL (C)[1]	22	1575.21	319.63	$1352.21^{1/}$	152.15	32.11	-
ERROR	185	3576.84	241.29	832.42	247.82	28.38	-
Mean		164.33	529.90	1739.40	98.26	43.14	
CV%		36.39	29.31	16.59	16.02	12.35	-

$^{1/}$ and $^{2/}$: significant at 5% and 1%, respectively by the F test; [1] IRL – Initial root length at the transference of plants to the nutrient solution showing that the number of days of permanence in solution had effect and that there is genetic variability for all the evaluated traits used as indicators of the efficiency of boron use. The interaction TPS x cultivar was significant (P<0,01) for the traits RW, CW, PH and LL, under low boron condition, and for CW and LL, under complete boron condition. This fact indicates the occurrence of a differential response of cultivars to the time of permanence in solution, which is expected for traits with more complex genetic control and low heritability. Cultivar effect was significant (P<0,01) for leaf symptoms scores, showing different cultivar response to boron (Table 1). The assessment at seven days in nutrient solution was better than at four days because it allowed a better perception of the symptoms, increasing the score means (Tables 2 and 3). Considering the intensity of deficiency symptoms jointly with the remaining traits, the result obtained after seven days in solution must be suitable to reach the objectives of this work.

To determine the trait which should be used to discriminate efficient cultivars for boron utilization, it was observed that CW and LL, under low boron condition, showed high correlation with scores at seven days (– 0.70 and – 0.78, respectively). The trait RW showed only an intermediate correlation with scores at seven days (- 0.47), but also correlate well with CW (0.75). Thus, these two traits can be considered as good indicators for the efficiency of boron utilization of sunflower cultivars. The trait LL also showed high correlation with the scores, but it was not included as an efficient indicator since the deficiency symptoms themselves – malformed and hardened leaves – make its evaluation difficult, generating imprecise data.

After four days of permanence in solution (Table 2), cultivars M 738, AS 238 and AS 243 were classified as efficient and responsive to the boron increase for CW and RW; and M 737, AS 603 and Contiflor 7 only for RW. As already discussed for the scores, in spite of the fact that the effects of boron absence were evident after four days in solution, the level of response to boron was smaller than in the second experiment.

In the second experiment, after seven days in solution (Table 3), cultivars AS 238, AS 226 and AS 243 were classified as efficient and responsive for RW and CW; C 9302 and Contiflor 7 only for RW; and M 740, M 738, Rumbosol 91 and Contiflor 3 only for CW. Among the mentioned cultivars in

Table 2. Estimated mean (M) with 0.00625 mg L^{-1} of boron, response to the increase of boron level to 0.15 mg B L^{-1} (BR), and responsiveness (Re) for the traits root growth (RG), fresh root weight (RW), fresh canopy weight (CW), plant height (PH), leaf length (LL) and deficiency symptom scores (Grade), for each cultivar, after four days of permanence in nutrient solution.

	RG (mm)			PH (mm)			LL (mm)			RW (mg.10^{-1})			CW (mg.10^{-1})			
Cultivar	M	BR	Re	M	BR	Re	M	BR	Re	M	BR	Re	M	BR	Re	Grade
M 740	82.33	-4.67	NR	95.89	32.94	NR	27.00	7.00	NR	26.50	-4.33		129.00	40.00	NR	0.17
M 742	63.67	43.00		51.64	39.69		12.00	21.67		18.00	16.17		75.33	82.17		1.50
GV 37017	49.83	-5.67		50.87	31.29		12.50	8.83		16.67	1.67		62.00	31.83		0.58
M 738	99.50	42.70	R	78.94	16.89	NR	30.83	16.33	NR	37.33	5.00	R	124.17	70.67	R	0.00
DK 180	68.40	-42.40	R	90.91	-1.58	NR	12.00	-1.33		21.00	-4.83		70.60	8.07	NR	1.80
M 737	115.17	-6.83	NR	56.66	9.00		16.33	3.33		28.83	2.33	R	83.00	24.50		0.58
Rumbosol 91	56.17	-0.33		115.42	12.91	NR	16.33	17.83		25.67	-0.50		102.67	51.67	NR	0.25
Embrapa 122	61.50	19.00		59.74	18.42		13.33	10.83		19.17	4.17		79.00	36.00		0.80
C 9303	45.17	36.58		48.53	43.80		15.50	-1.33		25.00	7.75		79.00	29.83		1.83
C 9402	54.83	24.67		75.80	25.86	R	12.33	15.33		23.50	2.00		74.00	39.83		1.75
C 9301	53.00	-22.20		41.60	34.80		10.17	14.23		24.00	-2.60		65.50	6.30		2.40
AS 470	56.17	10.17		76.84	19.99	NR	23.00	15.00	R	26.83	4.33		84.17	60.83		0.00
AS 238	91.00	13.67	R	77.47	-3.30	NR	18.17	2.17		42.67	15.17	R	133.17	55.67	R	1.25
M 736	56.83	28.37		73.27	14.57	NR	14.00	12.00		28.33	1.47		80.17	31.67		1.58
AS 226	29.60	7.90		56.79	11.87		41.20	-14.53	NR	41.00	9.00	NR	144.20	77.13	NR	1.40
C 9302	60.40	47.20		62.55	31.28		25.40	19.27	NR	27.60	5.00		98.40	83.77	NR	0.00
Rumbosol 90	48.00	-5.17		83.61	7.72	NR	15.83	14.00		27.00	0.00		89.83	36.83		0.50
AS 243	70.83	20.50	R	54.40	24.77		23.17	22.83	NR	40.50	8.50	R	127.83	75.33	R	0.00
Contiflor 7	80.17	-10.00	R	112.77	17.07	NR	25.67	19.50	NR	42.83	1.00	R	164.17	78.17	NR	0.08
Contiflor 3	54.40	30.60		93.97	37.20	NR	17.33	21.67		23.20	2.63		94.17	59.00		0.75
AS 603	65.25	73.95	R	67.89	16.27		23.60	20.90	NR	37.20	14.60	R	111.00	108.33	NR	0.00
HA 302	64.67	-15.33		75.25	8.41	R	13.17	6.03		28.67	-7.17		85.67	13.67		1.75
Overall Mean	64.86	12.99		72.77	20.45		19.04	11.43		28.70	3.70		98.05	50.06		0.86

the second experiment, AS 238, C 9302, Contiflor 3 and AS 243 also were efficient and responsive for RG. Cultivar HA 302 was classified as inefficient and non-responsive for RG, RW and CW. Cultivar AS 226 classified as efficient and responsive for RW and CW, was inefficient for RG, suggesting the classification of cultivars can be influenced by the trait taken as indicator and give an idea of the complexity of this assessment. The efficiency of some cultivars only for RW or only for CW also shows the same fact.

In spite of the assessment difficulties and the greater responses to boron in the second experiment, the majority of cultivars classified as efficient in the second experiment were the same as the first experiment, mainly for CW. This high repeatability on classification of cultivars along the two experiments is an indicative that the TPS x cultivar interaction observed in the analyses of variance must be of simple type, where the rank of cultivars in each experiment must have been similar. By comparing the results of table 3 with those obtained by Souza (2002), for the same group of cultivars, with the same time of permanence in nutritive solution containing only calcium and boron, the classification for the trait RG, considering the efficiency, showed high agreement in the two experiments. Plants growing in nutritive solution containing only calcium and boron (Souza, 2002) did not show any visual symptoms of boron deficiency, and it was not possible to detect any association between the scores and other traits. Figures 1 and 2 show the development difference among plants after seven days in nutrient solution containing only Ca and B and in a complete nutrient solution.

In both conditions, at four and at seven days in solution, there was a relative agreement between the cultivar classification and the scores attributed to the symptoms, where the cultivars classified as efficient and responsive often showed smaller grades. Thus, the use of scores *per se* can not be discarded for the purpose of classification of sunflower cultivars concerning the efficiency on boron utilization. The use of scores would be more quick and efficient, only once the low boron solution would be necessary for the assessment, but with less repeatability –

Table 3. Estimated mean (M) with 0.00625 mg L^{-1} of boron, response to the increase of boron level to 0.15 mg B L^{-1} (BR), and responsiveness (Re) for the traits root growth (RG), fresh root weight (RW), fresh canopy weight (CW), plant height (PH), leaf length (LL) and deficiency symptom scores (Grade), for each cultivar, after seven days of permanence in nutrient solution [1/].

	RG (mm)			PH (mm)			LL (mm)			RW ($mg.10^{-1}$)			CW ($mg.10^{-1}$)			
Cultivar	M	BR	Re	M	BR	Re	M	BR	Re	M	BR	Re	M	BR	Re	Grade
M 740	77.67	76.00		128.83	14.37	NR	34.00	25.20	NR	22.17	45.17		169.00	108.00	R	1.00
M 742	106.67	54.00	NR	91.33	31.17		33.67	16.50	NR	34.17	-1.83	NR	157.50	2.33	NR	1.92
GV 37017	44.17	153.03		82.17	18.33		21.33	25.33		18.33	31.27		93.83	66.33		1.42
M 738	142.20	124.30	NR	95.83	12.50	NR	47.17	19.67	NR	42.33	36.07	NR	194.83	87.97	R	0.50
DK 180	26.00	127.20		89.33	24.87		10.67	52.53		16.17	38.23		78.67	123.53		3.25
M 737	108.33	199.17	R	65.67	20.00		19.67	36.33		31.17	56.50		107.50	107.50		2.33
Rumbosol 91	55.83	61.67		128.33	20.67	NR	34.17	23.63	NR	25.17	42.08		154.33	87.87	R	1.50
Embrapa 122	80.50	99.17	NR	78.17	34.17		24.17	26.00		23.33	28.00		115.00	93.50		1.90
C 9303	81.75	80.42	NR	92.33	26.83		14.17	45.33		32.75	28.75	NR	108.83	78.17		3.67
C 9402	79.50	100.30	NR	101.67	15.33	NR	27.67	27.83		25.50	30.30		113.83	53.17		2.42
C 9301	30.80	175.00		76.40	34.60		24.40	31.40		21.40	39.20		71.80	123.80		2.90
AS 470	66.33	175.67		96.83	14.33	NR	38.00	29.00	R	31.17	58.63		145.00	133.50		0.75
AS 238	104.67	213.33	R	74.17	27.33		20.33	39.67		57.83	55.77	R	188.83	106.83	R	1.08
M 736	85.20	97.13	NR	87.83	28.00		26.00	32.17		29.80	35.37		111.83	75.33		2.08
AS 226	37.50	153.90		68.67	39.93		26.67	35.53		50.00	40.20	R	221.33	104.87	R	1.50
C 9302	107.60	159.90	R	93.83	10.50	NR	44.67	17.00	NR	32.60	38.07	R	182.17	66.23	NR	0.92
Rumbosol 90	42.83	138.17		91.33	23.67		29.83	18.33		27.00	29.25		126.67	75.00		1.08
AS 243	91.33	176.00	R	79.17	21.17		46.00	21.67	NR	49.00	50.83	R	203.17	123.67	R	0.42
Contiflor 7	70.17	184.63		129.83	-6.33	NR	45.17	17.33	NR	43.83	48.17	R	242.33	61.00	NR	0.50
Contiflor 3	85.00	148.50	R	131.17	1.67	NR	39.00	19.33	NR	25.83	35.50		153.17	104.67		0.67
AS 603	139.20	101.63	NR	84.17	20.67		44.50	11.50	NR	51.80	34.70	NR	219.33	44.00	NR	0.50
HA 302	49.33	99.47		83.67	35.83		19.20	25.80		21.50	17.30		99.33	47.17		2.00
Overall mean	77.84	131.75		93.22	21.35		30.47	27.14		32.40	37.16		148.10	85.20		1.56

[1/] Cultivar classes: R = efficient and responsive and NR = efficient and non-responsive. Inefficient cultivars were not classified.

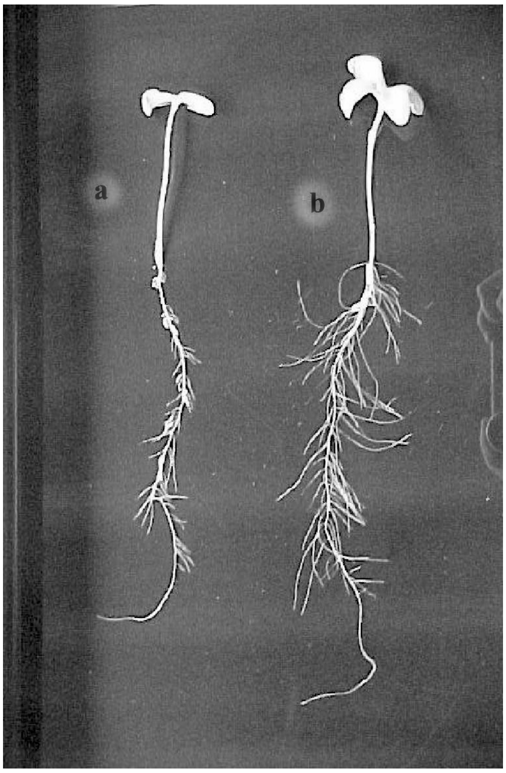

Figure 1. Sunflower plants in nutrient solution containing only calcium and boron: a) 0.00625mg L^{-1} of boron; b) 0.15 mg L^{-1} of boron (Souza, 2002).

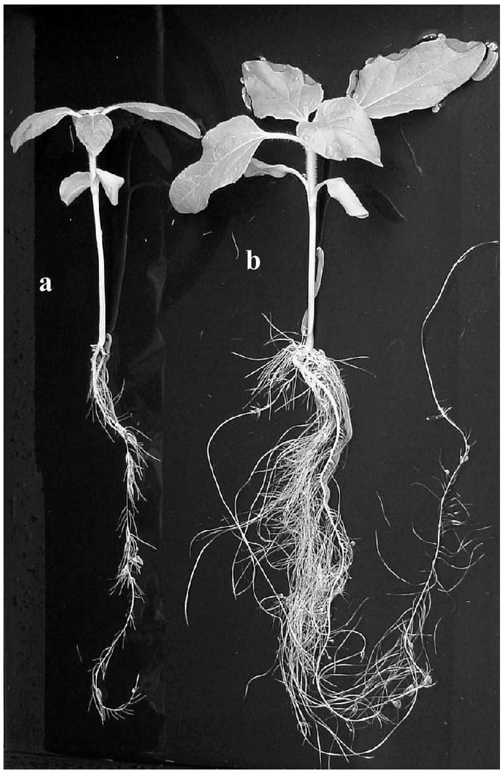

Figure 2. Sunflower plants grown in complete nutrient solution: a) 0.00625 mg L^{-1} of boron; b) 0.15mg L^{-1} of boron.

consequence of the greater variation for the symptoms in the same cultivar – and, therefore, with a greater associated error given by the high coefficient of variation (CV = 77.7%).

The use of mean data obtained from low boron solution and BR, allows the discrimination of sunflower cultivars with high efficiency of boron utilization and gives additional information about the responsiveness of cultivars to the boron increment in nutrient solution, which would be impossible with only one experiment with low boron. Cultivar responsiveness is an important information considering the current agricultural economic conditions, where the objective is high yield with low costs. Presently available technical information still requires use of fertilizers containing boron for non-responsive sunflower cultivars, especially with the possible occurrence of losses as a consequence of boron deficiency. As already observed, all cultivars evaluated until now reacted to boron with higher or lower intensity and, even with the concentrations of this work, the effects of boron absence are highly significant.

CONCLUSIONS

Sunflower cultivars AS 238 and AS 243 were classified as efficient concerning boron utilization and responsive to the increment of boron in the nutrient solution, and cultivar HA 302 was classified as inefficient and non-responsive.

Seven days' permanence in nutrient solution allows the selection of efficient and responsive sunflower genotypes.

The traits root growth, plant height, fresh root weight and fresh canopy weight can be used to select sunflower genotypes for efficiency of boron utilization in nutrient solution.

The leaf length is not a good indicator of the effects of boron deficiency in nutrient solution.

The simple assessment of leaf symptoms can be used for selection, despite its lower reliability in relation to the other traits and the lack of information about the responsiveness of genotypes.

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RESUMO

Seleção de cultivares de girassol para eficiência de boro usando solução nutritiva

A deficiência de boro é comum no Brasil e ocorre com mais freqüência nos Cerrados. A cultura do girassol é exigente em boro e pouco eficiente em seu aproveitamento. Para identificar cultivares de girassol eficientes no aproveitamento de boro e determinar o efeito do tempo de permanência em hidroponia, três experimentos, contendo 22 cultivares e duas concentrações de boro, foram instalados segundo delineamento em blocos completos casualizados, com seis repetições. Após quatro, sete e 10 dias de permanência em hidroponia, foram avaliados o crescimento de raiz, altura de plântula, comprimento do limbo foliar, peso fresco de raiz, peso fresco da parte aérea e notas para os sintomas visuais de deficiência. Com base na eficiência e responsividade para peso fresco da parte aérea, peso fresco de raiz, altura de plântula e crescimento de raiz, foi possível selecionar cultivares de girassol superiores, destacando-se as cultivares AS 238 e AS 243.

REFERENCES

Asad, A.; Bell, R.W. and Dell, B. 2001. A critical comparison of the external and internal boron requirements for contrasting species in boron-buffered solution culture. Plant and Soil. 233:31-45.

Blamey, F.P.C.; Mould, D. and Chapman, J. 1979. Critical boron concentrations in plant tissues of two sunflower cultivars. Agronomy Journal. 71:243-247.

Blamey, F.P.C.; Vermeulen, W.J. and Chapman, J. 1984. Inheritance of boron status in sunflower. Crop Science. 24:43-46.

Blamey, F.P.C.; Zollinger, R.K. and Schneiter, A.A. 1997. Sunflower production and culture. p.595-670. In: Schneiter, A.A. (Ed.). Sunflower technology and production. Agronomy, 35. ASA/CSSA/SSSA, Madison.

Calle Manzano, C.L. 1985. Carencia de boro en girasol. Hojas Divulgadoras, 7. Publicaciones de Extesion Agraria, Madrid.

Castiglioni, V.B.R.; Leite, R.M.V.B. de C.; Borba Filho, A.B.; Arias, C.A.A. and Fernandes, M.O. 1997. Avaliação de genótipos de girassol para a sensibilidade à deficiência de boro, na safra 1996. In: Resumos da Reunião Nacional de Pesquisa de Girassol, 12., Campinas, 1997. Fundação Cargill, Campinas.

Castro, C.; Castiglioni, V.B.R.; Balla, A.; Leite, R.M.V.B. de C.; Karan, D.; Mello, H.C.; Guedes, L.C.A. and Farias, J.R.B. 1996. A cultura do girassol. Circular Técnica, 13. Embrapa-Cnpso, Londrina.

Connor, D.J. and Hall, A. J. 1997. Sunflower physiology. p.113-182. In: Schneiter, A.A. (Ed.). Sunflower technology and production. Agronomy, 35. ASA/CSSA/SSSA, Madison.

Dell, B. and Huang, L. 1997. Physiological response of plants to low boron. Plant and Soil. 193:103-120.

Furlani, A.M.C.; Úngaro, M.R.G. and Quaggio, J.A. 1990. Comportamento diferencial de genótipos de girassol: eficiência na absorção e uso do boro. Revista Brasileira de Ciência do Solo. 14:187-194.

Malavolta, E.; Boaretto, A.E. and Paulino, V.T. 1988. Micronutrientes – uma visão geral. p.1-74. In: Anais do Simpósio sobre Micronutrientes na Agricultura, 1st, Jaboticabal, 1988. Unesp, Jaboticabal.

Pípolo, A.E. 1998. Avaliação de linhagens de soja quanto à tolerância ao alumínio tóxico e eficiência na utilização de fósforo. p.25-29. In: Embrapa. Centro Nacional de Pesquisa de Soja. Resultados de pesquisa da Embrapa Soja 1997. Documentos, 118. Embrapa-Cnpso, Londrina.

Rerkasem, B. and Jamjod, S. 1997. Genotypic variation in plant response to low boron and implications for plant breeding. Plant and Soil. 193:169-180.

SAS Institute Inc. SAS/STAT 1987. Guide for personal computers, Version 6 edition. SAS Institute, Cary.

Schuster, C.E. and Stephenson, R.E. 1940. Sunflower as an indicator plant of boron deficiency in soils. Journal of the American Society of Agronomy. 32:607-621.

Shorrocks, V.M. 1997. The ocorrence and correction of boron deficiency. Plant and Soil. 193:121-148.

Souza, A. de 2002. Seleção de cultivares de girassol para eficiência no aproveitamento de boro em hidroponia. M.S. Thesis. Universidade Estadual de Londrina, Londrina.

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