ASSESSMENT OF PHENOTYPIC INDEXES FOR ALUMINUM TOLERANCE IN MAIZE USING NUTRIENT SOLUTION. Geraldo Magela de Almeida Cançado[(1)]; Paulo Roberto Martins[(1)]; Maurício Antônio Lopes[(1)]; Sidney Netto Parentoni[(1)] & Aluízio Borém de Oliveira[(2)]. [(1)] - Embrapa Milho e Sorgo, Sete Lagoas-MG, [(2)] - Universidade Federal de Viçosa, Viçosa-MG.

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The aluminum (Al) toxicity is one of the most limiting factor for agricultural productivity in acid soils. In Brazil, these soils are mainly located in the savanna region, which occupies approximately 20% of the national territory (Lopes, 1987). The utilization of plant species and cultivars well adapted to those soils would solve the problem. Despite representing with fidelity the natural conditions, field evaluations are laborious and suffer the interference of several environmental factors. One of the best parameters to identify maize genotypes that are tolerant to Al is the seminal root elongation of plants grown in nutrient solution (Magnavaca, et al., 1987). For this same purpose, root staining with hematoxylin is a simple technique that is based upon the staining property of this compound, which produces blue-purple color when complexed with the Al present in the roots. In this work, we compared the efficiency of hematoxylin root staining relative to the phenotypic indexes of net and relative seminal root length (NSRL and RSRL, respectively), by using an incomplete diallelic cross among nine inbred lines of maize (L11, L13, L16, L20, L22, L36, L64, L723 e L724) and their respective F1 generations. Uniform seedlings at the 7^{th} day post-germination were selected and transferred to trays with capacity for 8.5 liters of nutrient solution (Magnavaca, 1982). The Al concentration in the solution was 222 μM, and the experiment was conducted in growing chamber, with the pH in the solution adjusted to 4.0 on a daily basis. The seminal root length of the seedlings was measured at the moment of their transfer to the solution-trays (initial seminal root length, or ISRL), and at the 7^{th} day post-germination, in the end of the experiment (final seminal root length, or FSRL). The NSRL was obtained by subtracting the ISRL from the FSRL, whereas the RSRL was estimated by dividing the NSRL by the ISRL (Magnavaca, 1982). The hematoxylin staining procedure was performed at the end of the experiment, according to Polle et al (1978), and the stained root apices were scored visually by four different people, using an arbitrary numeric scale ranging from '0' (no staining – tolerant) to '5' (complete staining – susceptible). Random blocks with 42 treatments replicated three times were used as the experimental design, making up a total of 126 plots with seven seedlings each. To study the recombination capacity of the maize lines in the incomplete diallelic cross, the RSRL and NSRL averages and the scores of hematoxylin staining were used. The general and specific capacities of recombination for those inbreds (GCR and SCR, respectively) were estimated by the Method Two of Griffing. These results are presented in Tables 1 and 2. The highest values of GCR for the NSRL index were obtained by the L724 and L13 lines, whereas L36 and L11 showed the lowest values. Regarding the RSRL index, the lines L724, L723 and L13 displayed the highest values of GCR, while the lowest ones were presented by L11, L22 and L36. Considering that negative values of GCR for hematoxylin staining represent progenitor lines with elevated Al tolerance, desired values were observed for L13 and L16, contrasting to the lowest values of GCR shown by L36 and L20. For the indexes showing statistically significant values of GCR and SCR (Table 3), it is suggested that additive and non-additive effects are important in the genetic control of these traits, such that it is feasible to select progenitors and hybrid combinations to increase their expression. We observed that additive effects appeared to be more important than non-additive ones; the GCR values for hematoxylin staining and NSRL index were four times superior to the corresponding SCRs, whereas the GCRs for the RSRL index were only twice as much superior to the corresponding SCRs (Table 3). Thus, among the nine inbreds tested, the L13, L724, L723 and L16 lines would be the best options for hybrid production aiming an increased Al tolerance, since they presented the best values of GCR in nutrient solution for all indexes investigated. On the other hand, the best SCR values were obtained for the following crosses: L13 x L16, L13 x L20, L13 x L723, L16 x L22, L16 x L723, L16 x L724, L723 x L22, L723 x L64, and L723 x L11. As it could be expected, the lines used in this work did not show increased Al tolerance *per se*, based on the results of the three investigated indexes (Lopes et al, 1987).

Taking into consideration that a high correlation between the phenotypic indexes here investigated is desirable to facilitate breeding procedures, we verified the statistical correlation between their averages. The best correlation result was identified for NSRL and hematoxylin staining (r^2 = 0.76), followed by the correlation between RSRL and NSRL (r^2 = 0.63). By contrast, the correlation between RSRL and hematoxylin staining appeared to be low (r^2 = 0.27). We can conclude that the technique of hematoxylin staining, as well as the NSRL and RSRL indexes, were able to discriminate maize genotypes showing high and low Al tolerance in nutrient solution, in a rapid, efficient and non-destructive way.

Table 1 – Estimates of the general capacity of recombination (GCR) among nine inbred lines of maize for the NSRL, RSRL and hematoxylin staining indexes.

Maize inbreds	NSRL	RSRL	Hematoxylin
L11	-0,5416	-0,0614	-0,1798
L13	0,7628	0,0365	-0,4237
L16	0,2880	-0,0129	-0,2821
L20	-0,2751	-0,0177	0,2211
L22	-0,0608	-0,0297	0,0604
L36	-0,9702	-0,0276	0,5759
L64	-0,4323	0,0186	0,1242
L723	0,1774	0,0384	0,0848
L724	0,9297	0,0551	-0,1263

Table 2 – Estimates of the specific capacity of recombination (SCR) among nine inbred lines of maize for the NSRL, RSRL and hematoxylin staining indexes.

Crosses	NSRL	RSRL	Hematoxylin
L11	**-0,9395**	**-0,0114**	**0,5236**
11 X 13	0,1294	-0,0205	-0,3398
11 X 16	-0,3191	0,0044	0,0365
11 X 20	0,6239	0,0292	-0,1988
11 X 22	0,5997	0,0338	-0,0560
11 X 64	-0,1255	-0,0396	0,2373
11 X 723	0,5748	0,0341	-0,1518
11 X 724	0,3958	-0,0186	-0,5747
L13	**-1,8617**	**-0,1331**	**0,9041**
13 X 16	1,2098	0,0459	-0,8357
13 X 20	2,1495	0,0534	-1,1782
13 X 22	-0,6581	-0,0336	-0,0175
13 X 36	-0,5887	-0,0034	0,3197
13 X 723	0,5104	0,2163	-0,0597
13 X 724	0,9714	0,0081	0,3031
L16	**-1,5787**	**-0,0717**	**0,8352**
16 X 20	-0,6357	-0,0219	0,0731
16 X 22	0,7201	0,0695	-0,1859
16 X 36	0,2728	-0,0100	0,0666
16 X 64	-0,4284	-0,0594	-0,0265
16 X 723	0,4619	0,0555	-0,3977
16 X 724	1,8762	0,0595	-0,4010
L20	**-1,0960**	**-0,0380**	**0,4716**
20 X 22	0,2364	-0,0110	0,0966
20 X 36	0,2692	-0,0442	0,0544
20 X 64	0,3246	-0,0314	-0,2529
20 X 723	-0,1918	0,0071	0,2776
20 X 724	-0,5841	0,0948	0,1851
L 22	**-1,0712**	**-0,0570**	**0,4805**
22 X 36	-0,2351	-0,0416	-0,2581
22 X 64	0,5170	0,0019	-0,5118
22 X 723	1,2873	0,0336	-0,2849
22 X 724	-0,3250	0,0615	0,2565
L36	**-0,2990**	**-0,0613**	**-0,2914**
36 X 64	0,4964	0,2142	0,3254
36 X 723	0,3834	0,0075	0,0747
L 64	**-0,4481**	**-0,0397**	**0,2547**
64 X 723	0,2522	0,0031	-0,4201
64 X 724	-0,1401	-0,0094	0,1391
L 723	**-1,6909**	**-0,1289**	**0,5300**
723 X 724	0,1035	-0,0994	-0,0982
L 724	**-1,1488**	**-0,0483**	**0,0950**

Table 3 – ANOVA for the RSRL, NSRL and hematoxylin staining.

Sources of Variation	D.F.	A.S.		
		NSRL	RSRL	Hematoxylin
Blocks	2	0,4770$^{n.s.}$	0,00700$^{n.s.}$	1,7310**
Treatments	41	1,5242**	0,00785$^{n.s.}$	0,3485*
model (GCR)	8	3,9120**	0,01518*	0,9262*
desvios (SCR)	33	0,9453**	0,00608$^{n.s.}$	0,2085$^{n.s.}$
Erro	82	0,4235	0,00600	0,2135
Total	125			
C.V. (%)		16,97	30,48	12,66

** Significant at 1% of probability, F-test
* Significant at 5% of probability, F-test
n.s. Non-significant, F-test

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