Mineral grain content and association among Zn and other mineral in yellow QPM and normal endosperm maize lines

Paulo Evaristo de Oliveira Guimarães [1]; Robert E. Schaffert[1]; Paulo E. A. Ribeiro[1]; Marcus R. Sena [1]; Lígia P. Costa[1]; Maria .C.. D. Paes[1]; Vera M. C. Alves[1]; Antônio M. Coelho[1]; Marília R. Nutti [2]; José L. M. de Carvalho[2]; Kevin Pixley[3], Ana R. de A. Nogueira[4]; and Gilberto B. de Souza[4]

[1] Embrapa Maize and Sorghum, Rod.MG km 424, Sete Lagoas, PC 151, 35701-970, Minas Gerais, Brazil (evaristo@cnpms.embrapa.br)
[2] Embrapa Food Science, Rio de Janeiro, Brazil
[3] CIMMYT, Mexico
[4] Southeast Embrapa Cattle, São Paulo, Brazil

INTRODUCTION

Maize provides a large proportion of the daily intake of energy and nutrients, including micronutrients, for more than 1.2 billion people in Sub-Saharan Africa and Latin America. Developing cultivars of maize with high available micronutrients, mainly zinc and iron, could improve the health and nutritional status of the poor population (Maziya-Dixon et al., 2000). The objectives of this study were to evaluate the variation in mineral grain content and to estimate the level of association among mineral contents in maize lines

METHODS

Seed of maize inbred lines from Embrapa Maize and Sorghum produced at Embrapa in Sete Lagoas, MG, Brazil were rinsed, dried (80 ^{o}C), ground and digested in concentrated HNO_3:$HClO_4$ (4:1, v/v) at 130 ^{o}C, followed by further digestion at 220 ^{o}C. The digested material was diluted to 15 mL with deionized water and analyzed for Fe, Zn, Ca, S, P, K, Mg, Al, Ba, Cu, Mn, Na, Si, V and Mo by simultaneous inductively coupled plasma-optical emission spectrometry. Two sets of grain samples were obtained: Set 1 (189 QPM, Quality Protein Maize, S_2 inbred lines and 1205 normal endosperm S_2 lines) and Set 2 (615 normal endosperm S_2 lines).

RESULTS AND DISCUSSION

A large degree of variation in maize grain content was observed for the 15 minerals evaluated. The Zn contents of these samples ranged from 14 to 54 mg kg^{-1} , 5 to 63 mg kg^{-1} and 14 to 54 mg kg^{-1} for QPM 1, Normal 1 and 2 sample sets, respectively (Table 1). The distribution of Zn contents in the maize grain samples are presented in Figure 1. The inbred lines didn't show a normal distribution for zinc contents. The majority of the frequencies were between 21,7-28,1; 14,3-24,0; and 17,4-24,0 mg.kg^{-1} in QPM, normal 1, and normal 2 sample sets, respectively. For the normal endosperm group, the correlations among mineral contents in the grains ranged from -0.08 to 0.83 (Table 2). The majority of the coefficient coefficients were less than 0.2. The highest correlations were observed for P x K (0.83**), Mg x S (0.78**), P x S (0.73**), and Zn x S (0.72**). With regard to Zn, the highest correlation coefficients were observed for Zn x S (0.72), Zn x P (0.50**), and Zn x Mg (0.44).). Fe with Zn (0,38**) showed an intermediate positive correlation, indicating

the possibility to increase the grain content for both minerals. For the QPM group, the correlations among the grain mineral contents ranged from 0.00 to 0.85 (Table 3). The majority of the correlation coefficients were also less than 0.2. The highest correlation coefficients were observed for Zn x Cu (0.85**), Mg x V (0.79**), Zn x Al (0.72**), and Al x Cu (0.70**). With regard to Zn, the highest correlations were observed for Zn x Cu (0.85**), Zn x Al (0.72), and Zn x Ca (0.36**). Fe x Zn (0,16**) showed a positive, but low correlation coefficient. Some correlations, such as Mg x S, Zn x S, Zn x Cu, and Zn x Al showed different values between the two groups of lines. These differences may be explained by endosperm type and/or environment, since the two groups of lines were not planted in the same environment.

Table.1 Screening of yellow QPM and normal endosperm maize lines for mineral contents in grain [1] **(mg kg^{-1})**

	Set		N	Zn	Fe	Ca	S	P	K	Mg	Al	Ba	Cu	Mn	Na	Si	V	Mo
QPM	1	Avg	189	25	20	87	1324	2815	3486	948	13	11	1	6		7	2	
QPM	1	Max		54	47	307	1873	4283	6180	1347	146	42	20	11		45	4	
QPM	1	Min		15	11	43	829	1749	2280	577	3	0	0	2		3	0	
		Max / Min		4	4	7	2	2	3	2	43	#	#	7		15	##	
Normal	1	Avg	1205	22	17	56	1239	3820	4732	1063	19	7	2	4	5	1	2	0.2
Normal	1	Max		63	71	351	3048	13555	22310	2855	669	235	28	23	65	5	5	0.7
Normal	1	Min		5	3	11	508	1475	1274	406	0	0	0	0	0	0	1	0.0
		Max / Min		14	28	31	6	9	18	7	#	#	#	#	#	#	6	#
Normal	2	Avg	615	19	17	54		3203	4405	1082	18	4	3	6				
Normal	2	Max		44	70	209		6218	19600	2163	50	27	24	22				
Normal	2	Min		4	0	7		263	183	377	0	0	0	2				
		Max / Min		11	240	28		24	107	6	#	183	#	14				

[1] From set 2, 27 lines were excluded where the Al contents of grains were higher than 50 mg kg^{-1}

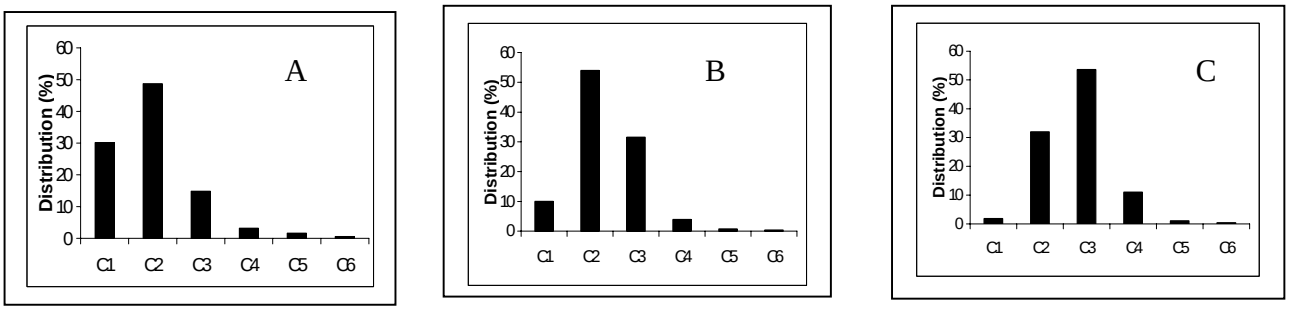

Fig. 1. Distribution of zinc contents in QPM (A), Normal 1 (B) and Normal 2 (C) maize. a) The letters C1, C2, C3, C4, C5 and C6 in X axis indicate, respectively, the zinc concentration (mg kg^{-1}) range as following: A) 15,2-21,7; 21,7-28,1; 28,1-34,5; 34,5-40,9; 40,9-47,4; 47,4-53,8. B) 4,5-14,3; 14,3-24,0; 24,0-33,8; 33,8-43,6; 43,6-53,3; 53,3-63,1.; and C) 4,2-10,8; 10,8-17,4; 17,4-24,0; 24,0-30,6; 30,6-37,2; 37,2-43,8.

Table 2: Correlations among grain mineral contents for 1820 normal endosperm maize lines.

	Zn	Ca	S	P	K	Mg	Al	Ba	Cu	Mn	Na
Fe	0,38**	0,16**	0,47**	0,24**	0,18**	0,26**	0,27**	0,07**	0,29**	0,23**	0,09**

Zn	0,31**	0,72**	0,50**	0,33**	0,44**	0,31**	0,09**	0,20**	0,31**	0,02ns
Ca		0,57**	0,34**	0,18**	0,53**	-0,01ns	0,14**	0,09**	0,25**	0,06ns
S			0,73**	0,54**	0,78**	0,12**	0,07*	0,16**	0,42**	0,09**
P				0,83**	0,45**	0,05*	0,04ns	0,24**	0,15**	0,22**
K					0,15**	0,11**	0,00ns	0,30**	0,04ns	0,22**
Mg						-0,03ns	0,12**	0,05*	0,40**	0,11**
Al							-0,01ns	0,26**	0,16**	0,05ns
Ba								-0,07**	-0,08**	0,00ns
Cu									0,41**	0,08**
Mn										-0,04ns

*,** significant at the 0,05 and 0,01 probability levels, respectively

Table 3: Correlations among grain mineral contents for 189 QPM maize lines.

	Zn	Ca	S	P	K	Mg	AL	Ba	Cu	Mn	Si	V
Fe	0.16*	0.09ns	0.15ns	0.14*	0.00ns	0.10**	0.32**	0.03ns	0.14*	0.18*	0.17ns	-0.12ns
Zn		0.36**	0.06ns	0.14*	0.14ns	0.07ns	0.72**	-0.15*	0.85**	0.13ns	0.11ns	-0.18*
Ca			0.17*	0.18**	0.32**	0.27**	0.25**	0.21*	0.27**	0.33**	-0.05ns	0.10ns
S				0.44**	0.17*	0.30**	0.05ns	0.24**	0.08ns	0.32**	0.01ns	0.14ns
P					0.64**	0.68**	0.06ns	0.25**	0.05ns	0.04ns	0.07ns	0.48**
K						0.52**	0.08**	0.32**	0.03ns	0.06ns	-0.23*	0.23**
Mg							-0.06ns	0.31**	-0.03ns	0.35*	-0.18ns	0.79**
AL								-0.20**	0.70**	-0.04ns	0.12ns	-0.42**
Ba									-0.21**	0.22**	-0.21*	0.22**
Cu										0.08ns	0.05ns	-0.25**
Mn											-0.21*	0.26**
Si												-0.12ns
V												

*,** significant at the 0,05 and 0,01 probability levels, respectively

CONCLUSIONS

A large degree of variation in the content of Zn and other minerals was observed in the maize grains analyzed. This research showed the possibility for increasing Zn and Fe contents simultaneously, mainly for the group of normal endosperm maize lines. New research may address the effects of endosperm type and environments on the level of association among mineral contents of grains from inbred lines of maize.

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