IRON AND ZINC CONTENT OF SORGHUM GENOTYPES AND THE INFLUENCE OF WATER STRESS

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ABSTRACT – To minimize injury due to water stress, plants have developed multiple strategies by which they resist. Hence, Fe and Zn were researched in relation to the influence of drought stress, because, they are the most frequently minerals lacking in human diet especially in the semi-arid regions such as Northeast Brazil. A large variability was observed in the zinc and iron content of 100 sorghum genotypes grown in environments without (WoWS) and with water stress (WtWS). A water stress effect was detected for Fe and Zn content, whose means were 31.94 and 29.54 and 22.02 and 22.40 mg/kg in WoWS and WtWS environments, respectively. Approximately 29% of the sorghum samples were classified as excellent sources of Fe and 47% of Zn. The genotypes; SC320, SC655, SC53 and SC414_12 showed great potential for use in biofortification projects.

RESUMO – Para minimizar os danos causados pelo estresse hídrico, as plantas desenvolvem várias estratégias para resistência. Assim, Fe e Zn foram pesquisados em relação a influência do estresse hídrico, pois eles são os minerais que mais frequentemente faltam na dieta humana, especialmente nas regiões semi-áridas do Nordeste do Brasil. Uma grande variabilidade foi observada no conteúdo de ferro e zinco nos 100 genótipos de sorgo cultivadas em ambientes com e sem estresse hídrico. O efeito do estresse hídrico foi detectado para Fe e Zn, cujos níveis foram de 31.94 e 29.54 e 22.02 e 22.40 mg/kg no ambiente sem e com estresse hídrico, respectivamente. Cerca de 29% das amostras de sorgo foram classificadas como excelentes fontes de Fe e 47% de Zn. Os genótipos; SC320, SC655, SC53 e SC414_12 mostraram grande potencial para uso em projetos de biofortificação.

KEYWORDS: Sorghum bicolor (L.) Moench; drought stress, genetic variability; sorghum biofortification.

PALAVRAS-CHAVE: Sorghum bicolor (L.) Moench; estresse hídrico; variabilidade genética; biofortificação de sorgo.

1. INTRODUCTION
Minerals are inorganic elements widely distributed in nature and essential for growth and proper development of the human organism. The mineral deficiencies in diets may impair mental and physical development, decrease work output and contribute to morbidity from infections, especially among children and of pregnant and lactating women (Hussain et al., 2010; Kayodé et al., 2006; Ng’uni et al., 2011).

Minerals can usually be supplied by an appropriate diet. However, the diets of populations subsisting on cereals, or inhabiting regions where soil mineral imbalances occur, often lack some minerals. The elements most frequently lacking in human diets are Fe, Zn and I, although other elements, such as Ca, Mg, Cu and Se can be deficient in the diets of some populations (White, & Broadley, 2005).

Nowadays several biofortification projects have recently emerged to an effort to resolve the inadequate Zn and Fe intake problem. These projects aim to increase the nutrient density or their bioavailability in staple crops through agronomic intervention, genetic selection or other techniques. There is considerable genetic variation in crop species that can be harnessed for sustainable biofortification strategies. However, to ensure success in this work a multidisciplinary approach is necessary, and the screening of crops with high content of essential nutrients is a preliminary and basic stage. Cereals grains are the most common foods used in biofortification programs because they have been the major source of calories for human diets (Taylor et al., 2012; White, & Broadley, 2005).

*Sorghum bicolor* L. Moench is an important cereal in the world and can grow under adverse environmental conditions, such as very dry, saline and hot areas, where the production of other cereals is uneconomical (Dicko et al., 2006). Sorghum is used for food in Africa and Asia and for animal feed and ethanol production in the Americas and Australia. On the other hand, there has been an increased interest in also using sorghum in foods due to its gluten-free (Pontieri et al., 2013) and other health promoting properties, such as cholesterol-lowering, anti-inflammatory and anti-cancer properties and slow digestibility (Awika et al., Moraes et al., 2012).

In Brazil, Embrapa (Brazilian Agricultural Research Corporation) Maize & Sorghum and partner institutions have been conducting breeding programs seeking the selection of sorghum genotypes with improved quality for human consumption. There is a large collection of sorghum accessions that has not been characterized for this food quality characteristics at Embrapa; consequently, there is a great potential to be explored for the use some of these genotypes to develop biofortified sorghum cultivars. Furthermore, the effect of water stress on zinc and iron of these genotypes has not been investigated.

Thus, the main objective of this study was to screen sorghum genotypes for zinc and iron content and to investigate the effect of water stress on their contents. In addition, this research aimed to identify superior source materials to use in breeding programs in order to successfully develop biofortified cultivars with high iron and zinc density and availability.

2. MATERIAL AND METHODS

One hundred sorghum accessions from the IGD (Institute of Genome Development) association panel (Casa et al., 2008) with high genetic variability were used in this study. Trials were planted at the Embrapa Maize and Sorghum research station, located in Nova Porteirinha, MG in June 2010. The genotypes were grown in two environments; without water stress (WoWS) and with post-flowering water stress (WthWS) in order to evaluate the effect of water stress on zinc and iron contents of sorghum grain. The experimental plots consisted of two rows three meters long, spaced 0.50 m between rows. Three hundred kg/ha of the NPK (nitrogen, phosphorus and potassium) formula 08-28-16 was applied at planting. Twenty five days after planting, 150 kg/ha of urea was applied. Supplemental water was applied by sprinkler irrigation for two hours once a week. In the WoWS environment, the irrigation remained until the grain filling phase and in the WthWS irrigation was suspended about 50 days after planting, at the boot stage, that is just prior to the emergence of the
panicle where the panicle is extended into flag leaf sheath. At maturity, in October 2010, the panicles were harvested and transported to Embrapa Maize and Sorghum in Sete Lagoas, Minas Gerais, where they were threshed and the grain was stored in a cold chamber at 10°C until analysis.

Levels of zinc and iron in sorghum grain genotypes: The Long et al. (2004) methodology was used to remove any mineral contaminants from the field. The analysis of Fe and Zn were determinate according to the methodology proposed by Silva (2009). The digestion of organic matter was performed in a nitroperchloric solution in the ratio 4:1, using a hot block. Sorghum flour (200 mg) was digested in a solution and analysed by optical emission spectrometer with inductively coupled plasma (Varian, Model 720-ES Axial, Santa Clara, CA, USA) with power of 1.2 kW, air flow auxiliary 1.5 L min⁻¹, plasma flow 15 L min⁻¹, the nebulizer pressure 200 kPa, argon. The accuracy of the method used for determination of the elements in sorghum flour samples was confirmed by analysis of certified reference material, furnished by the National Institute of Standard and Technology (Gaithersburg, MD, USA), corn bran NIST 8433.

All results were expressed on a dry matter basis. Samples were analyzed in duplicate.

Statistical analysis: The average mineral content of each genotype was plotted on scatterplots, the WoWS environment averages were plotted on the y-axis, and the WthWS environment averages were plotted on the x-axis as proposed by Guimarães et al., 2009.

3. RESULT AND DISCUSSION

Fe and Zn content in sorghum grain genotypes: A high amount of variability was observed among the genotypes in both environments (WoWS and WthWS) for the content of all minerals (Table 1).

Table 1. Range, means and standard deviation (SD) values in 100 sorghum genotypes grown in environments with and without water stress

<table>
<thead>
<tr>
<th>Mineral</th>
<th>WoWS Range (mg/kg)</th>
<th>Mean ± SD</th>
<th>WthWS Range (mg/kg)</th>
<th>Mean ± SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fe</td>
<td>19.54-54.57</td>
<td>31.94 ± 6.62</td>
<td>12.50-76.64</td>
<td>29.54 ± 7.32</td>
</tr>
<tr>
<td>Zn</td>
<td>14.64-35.81</td>
<td>22.02 ± 4.45</td>
<td>12.81-38.98</td>
<td>22.41 ± 5.11</td>
</tr>
</tbody>
</table>

Sorghum grown in the WoWS environment showed higher Fe and Zn means than those grown in the WthWS (Table 1). When compared with maize, the Fe content in sorghum genotypes of this study was higher (31.94 mg/kg) in both environments (Bänziger & Long, 2000; Ortiz-Monasterio et al., 2007; Queiroz et al., 2011). The mean level of Fe found in the present germplasm is lower than the values reported for other sorghum samples, but the mean level of Zn (22.02 mg/kg) was similar to other sorghum data (Kayodé et al., 2006; Martino et al., 2012; Ng’uni et al., 2011; Pontieri et al., 2014). Compared to wheat, the levels of Fe and Zn in sorghum were lower in relation to most other studies (Zhao et al., 2009; Hussain et al., 2010; Zhang et al., 2010).

Considering the Fe content in 100 g of grain, 71% of genotypes grown in the WoWS environment were classified as a good source of this mineral because they can supply between 10 to 19% of Fe daily intake recommendation for adult females (19–30 years) and 29% were classified as an excellent source of Fe, because may supply 20% or more of this recommendation (Institute of Medicine U.S., 2003). The genotypes with high iron contents were: SC319, SC320, Shan Qui Red, SC725, R9188 and SC21. Considering the intake recommendation for adult males (19–30 years), 53% of the sorghum genotypes were classified as a good source of Zn, and 47% were classified as an excellent source of Zn in 100 g of sorghum flour. The genotypes with high zinc contents were: SC319,

Dispersion of genotypes in two contrasting environments to Fe and Zn: To facilitate the visualization of Fe and Zn content variability in 100 grains sorghum accessions in both environments, the averages were plotted in scatterplots, considering the WoWS and the WthWS environments (Figure 1). The joint data analysis in these two environments showed that the genotypes positioned in the upper right quadrants of the graphs were those with the highest levels of each mineral. In contrast, the lowest concentrations were represented in the lower left quadrant. The genotypes with red color in the Figure 1 (A and B) were identified as an excellent source of Fe and Zn (Institute of Medicine, U.S., 2003) when they were grown in both environments. The genotypes; SC320, SC655, SC53 and SC414_12 were identified as excellent sources of both the Fe and Zn (Institute of Medicine, U.S., 2003) in both environments.

![Fig. 1](image1.png)

**Fig. 1.** Dispersion of the iron (A) and zinc (B) contents (mg/kg) of 100 sorghum genotypes grown in environments without (WoWS) and with water stress (WthWS). The genotypes with color point in (A) and (B) were identified as an excellent source of Fe and Zn (Institute of Medicine, U.S., 2003).

Bänziger and Long (2000) found highly significant effects of “environment” and “genotype x environment” interaction on grain Fe and Zn content in maize germplasm cultivated in Zimbabwe and Mexico. Likewise, Kayodé et al. (2006) found a significant effect of the environments in sorghum grown in various locations. Hussain et al. (2010) have also related that location had a significant effect on mineral concentration for all genotype groups of wheat studied, but for primitive wheat, genotype had a higher impact than location, although these studies did not considered the drought stress.

5. CONCLUSIONS

The Fe and Zn levels were investigated in 100 sorghum genotypes from the IGD (Institute of Genome Development) panel grown in environments with and without post-flowering water stress. There was a large amount of variability in Fe and Zn levels. The sorghum grown in WthWS...
environment showed significant lower Zn and Fe contents than WoWS environment. Approximately 29% of sorghum samples were classified as excellent source of Fe and 47% as an excellent source of Zn. The following genotypes; SC320, SC655, SC53 and SC414_12 were highlighted as potential sources for use in sorghum improvement programs for nutritional quality and the biofortification programs.

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7. BIBLIOGRAPHIC REFERENCES


