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Sulfur, Boron, and Zinc Fertilization Effects on Grain and Straw Quality of Maize and Sorghum Grown in Semi-Arid Tropical Region of India

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ABSTRACT

Experiments were conducted on-farm during two seasons (2003–2004) to determine the effects of sulfur (S), boron (B), and zinc (Zn) fertilization on the grain and straw quality of sorghum and maize grown under rainfed conditions in the semi-arid zone of India. The farmers' fields were deficient in S, B, and Zn; in addition the soils were low in organic matter and extractable phosphorus (P), but adequate in extractable potassium (K). Results showed that the applications of S, B, and Zn (SBZn) with nitrogen (N) and P (SBZn + NP) significantly increased the grain N, S, and Zn concentrations in maize and sorghum compared to farmer inputs (FI) and SBZn treatments; the results relative to P and B composition of the grain of the crops were not consistent and did not show any definite trend. The application of SBZn + NP over FI generally increased N, S, and Zn concentration in sorghum and maize straw compared to FI and SBZn treatments. The straw composition of the crops relative to P and B did not show a consistent trend. The results of this study along with the results of our earlier research demonstrate that balanced nutrition of rainfed crops not only increases yields but also enhances N, S, and Zn contents in grain and straw of these crops.

Keywords: grain and stover quality, balanced plant nutrition, sulfur, boron, zinc, rainfed crops, maize, sorghum

INTRODUCTION

Earlier research reported the occurrence of widespread deficiencies of sulfur (S), boron (B), and zinc (Zn), so much so that 73–95% of the farmers' fields in

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the semi-arid tropical region of India were deficient in S, 70–100% in B, and 62–94% in Zn. On-farm studies conducted during three seasons (2002–2004) demonstrated significant yield responses of maize, castor, groundnut, and mung bean to the applications of S, B, and Zn; the yield responses were larger when S, B, and Zn were applied along with N and P (Rego et al., 2007). It was concluded that balanced nutrition of crops was essential for sustained increases in yields of field crops.

However, there have been little research on the effects of secondary nutrients such as S and micronutrients such as B and Zn on the nutritional quality of crops (for food, feed, and fodder use), especially under rainfed conditions in the semi-arid tropical regions. The importance of mineral nutrition of crops along with improved cultivars and crop management cannot be overemphasized for producing nutritious food (Graham et al., 1998; Welch et al., 1997; Welch and Graham, 2002; Graham et al., 2007) and fodder (Kelly et al., 1996).

This paper presents the results of studies made during two seasons (2003–2004) to determine the effects of S, B, and Zn fertilization on grain and straw quality of maize (*Zea mays* L.) and sorghum [*Sorghum bicolor* (L.) Moench] crops grown under rainfed conditions in the semi-arid region of India.

MATERIALS AND METHODS

The details of the on-farm trials made along with description of the experimental sites and organic matter and nutrient status of soils in farmers' fields are provided in an earlier paper (Rego et al., 2007).

Briefly, the on-farm sites were Alfisols located in three districts (Mahabubnagar, Nalgonda, and Kurnool) in the hot moist semi-arid agro-ecological subregion of Andhra Pradesh state, India. The results of the analysis of soil samples taken before conducting on-farm trials showed that the farmers' fields were low in organic carbon (C) and total nitrogen (N) and low to moderate in extractable phosphorus (P), but adequate in extractable potassium (K). The results further showed that 73–95% of the farmers' fields were deficient in extractable S, 70–100% in B, and 62–94% in Zn (Rego et al., 2007).

The trials were laid out on farmers' fields during the south-west monsoon season (June through October); the sites on average receive 450 to 540 mm rainfall in the growing season. The on-farm trials were conducted during 2003–2004 seasons to determine the effects of fertilization on the grain and straw chemical composition of maize (2003 and 2004 seasons) and sorghum (2003 season) crops. The trials involving maize were conducted on nine farmers' fields each in 2003 and 2004 seasons, while the trials using sorghum as the test crop were carried out on nine farmers' fields in the 2003 season. Other details of the trials were the same as described earlier (Rego et al., 2007).

Grain and straw samples of maize and sorghum crops were collected from three nutrient treatments: (i) farmer inputs (FI), (ii) FI + SBZn (gypsum added to supply 30 kg S ha^{-1}, 5 kg borax added to supply .5 kg B ha^{-1}, and 50 kg zinc sulfate applied to supply 10 kg Zn ha^{-1}), and (iii) FI + SBZn + NP (S, B, and Zn as in SBZn; N was applied at a rate 60 kg N ha^{-1}; and P at 30 kg P_2O_5 ha^{-1}). Other details of crop husbandry, harvest, and processing the grain and stover samples for analysis are in an earlier paper (Rego et al., 2007).

Total N and P in sorghum and maize grain and straw samples were determined by digesting the samples with sulfuric acid-selenium. Nitrogen and P in the digests were analyzed using autoanalyzer (Sahrawat et al., 2002a). Zinc in plant materials was determined by digesting them with triacid and Zn in digests was analyzed using atomic absorption spectrophotometry (Sahrawat et al., 2002b). Total S and B in plant samples were determined by inductively coupled plasma- atomic emission spectroscopy (ICP-AES) in digests prepared by digesting them with nitric acid (Mills and Jones, 1996).

The data were subjected to statistical analysis using the Genstat 7th edition package (Genstat, Hempstead, UK).

RESULTS AND DISCUSSION

The application of SBZn + NP over FI (FI + SBZn + NP) significantly increased the concentrations of N, S, and Zn in maize grain as compared to FI and SBZn treatments during 2003 and 2004 (Table 1). However, results on the P and B composition of grain samples during the two seasons did not show a consistent or definite trend. The application of SBZn + NP nutrient treatment over FI generally increased N, S, and Zn concentrations in maize straw as compared to FI and SBZn nutrient treatments. The results on the effects of nutrient applications on P and B concentrations in the maize straw were not consistent (Table 1). These results demonstrate the value of balanced mineral nutrition of the maize crop for not only increasing productivity but also grain and straw quality relative to N, S, and Zn.

As in the case of maize, the balanced nutrition of the sorghum crop during 2003 season increased N, S, and Zn content in the grain and straw of the crop. As compared to farmer inputs (FI) and the application of SBZn, FI + SBZn + NP treatment significantly increased N, S, and Zn contents in sorghum grain and straw (Table 2). The results on the grain and straw composition relative to P and B did not show any consistent or definite trend.

Globally, a number of reports are available which deal with the role of S, B, and Zn fertilization on crop production, mostly from irrigated agriculture (Pasricha and Fox, 1993; Takkar, 1996; Scherer, 2001; Fageria et al., 2002). However, relatively few studies have been reported which deal with the role of S, B, and Zn fertilization on grain and straw quality of crops (Welch, 1986; Johnson et al., 2005). Nevertheless, from a recent study of B and Zn nutrition of field crops in Nepal, Johnson et al. (2005) reported that soil B fertilization

Table 1
Chemical composition of the grain and straw of the maize crop in response to fertilization under rainfed conditions in the semi-arid region of India (2003–2004)[a]

	gkg^{-1}				mgkg^{-1}					
	N		P		S		B		Zn	
Treatment	03	04	03	04	03	04	03	04	03	04
	Grain composition in 2003 (03) and 2004 (04) seasons									
FI[b]	12.7	14.0	2.9	3.2	902	1095	0.5	1.4	23	23
FI + SBZn	13.7	13.5	3.2	2.7	996	1087	0.7	1.8	32	24
FI + SBZn + NP	16.5	15.1	3.2	3.0	1147	1153	0.6	1.8	34	22
LSD (0.05)	0.9	1.0	0.3	0.4	69	52	0.14	0.67	5.2	1.7
	Straw composition									
FI	3.8	7.9	0.8	1.5	500	798	1.9	5.1	14	18
FI + SBZn	3.7	7.2	0.7	1.1	577	884	2.7	4.4	21	22
FI + SBZn + NP	4.8	6.6	0.7	1.3	654	921	2.9	5.9	19	20
LSD (0.05)	0.7	0.7	0.2	0.4	65	193	0.57	1.45	3.0	4.0

[a]Nine trials each were conducted on farmers' fields in 2003 and 2004.
[b]Farmer inputs.

Table 2
Chemical composition of the grain and straw of the sorghum crop in response to fertilization under rainfed conditions in the semi-arid region of India, 2003[a]

	N	P	S	B	Zn
Treatment	gkg^{-1}		mgkg^{-1}		
	Grain composition				
FI[b]	10.7	2.5	535	0.18	21
FI + SBZn	11.2	3.1	856	0.17	28
FI + SBZn + NP	13.2	2.8	766	0.22	31
LSD (0.05)	0.9	0.5	46	0.08	5.8
	Straw composition				
FI	2.2	0.7	491	0.7	22
FI + SBZn	3.5	0.7	699	1.9	24
FI + SBZn + NP	2.6	0.6	537	1.1	31
LSD (0.05)	1.0	0.2	92	0.63	5.7

[a]Trials were conducted on nine farmers' fields.
[b]Farmer inputs.

compared to seed priming increased the B content of the grains of lentil (*Lens culinaris*), chickpea (*Cicer arietinum*), and wheat (*Triticum aestivum*). The application of Zn increased Zn content only in wheat grain. Clearly, while grain legumes are sensitive to B deficiency, the cereals such as sorghum, maize, and wheat are more sensitive to Zn deficiency.

In addition to the importance of nutritious quality of the harvestable produce in human nutrition (Bunziger and Long, 2000; Welch and Graham, 2004; Graham et al., 2007), the quality of non-grain parts of the various field crops (straw, stover, or haulms) including maize and sorghum used as feed and fodder for animals, assumes added importance in developing countries. For example, for farmers in the arid and semi-arid regions of India, the production of both nutritious food, and feed of sorghum and maize are of importance as the animals are an integral part of the farmer households and provide an additional source of income and livelihood options (Kelly et al., 1996; Blümmel and Reddy, 2006).

Also, an approach that integrates the use of efficient crop cultivars with balanced plant nutrition is more likely to be sustainable in the longer turn. Moreover, the nutritional quality of grains of crops such as maize and sorghum used as feed for producing meat, also impacts human nutrition as well. Staples such as maize and sorghum are cheaper resource of nutrients for human nutrition. For example, a study made in India showed that crops such as sorghum and pearl millet are cheaper source of energy, protein and Fe and Zn as compared to fruits, vegetables, meat, egg, fish and dry products (Parthasarathy Rao et al., 2006).

CONCLUSIONS

The results of this study show that the balanced mineral nutrition (through S, B, Zn, N, and P fertilization) of the sorghum and maize crops can enhance N, S, and Zn concentrations in the grain and straw of these crops under rainfed cropping in the semi-arid tropical region of India.

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