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A survey of pre-harvest ear rot diseases of maize and associated mycotoxins in south and central Zambia

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ABSTRACT

Maize ear rots reduce grain yield and quality with implication on food security and health. Some of the pathogenic fungi produce mycotoxins in maize grain posing a health risk to humans and livestock. Unfortunately, the levels of ear rot and mycotoxin infection in grain produced by subsistence farmers in sub-Saharan countries are not known. A survey was thus conducted to determine the prevalence of the ear rot problem and levels of mycotoxins in maize grain. A total of 114 farmsteads were randomly sampled from 11 districts in Lusaka and southern provinces in Zambia during 2006. Ten randomly picked cobs were examined per farmstead and the ear rot disease incidence and severity were estimated on site. This was followed by the standard seed health testing procedures for fungal isolation in the laboratory. Results indicated that the dominant ear rots were caused by *Fusarium* and *Stenocarpella*. Incidence of *Fusarium verticillioides* ranged from 2 to 21%, whereas that of *Stenocarpella maydis* reached 37% on ear rot diseased maize grain. In addition, 2–7% *F. verticillioides*, and 3–18% *Aspergillus flavus*, respectively, were recovered from seemingly healthy maize grain. The mean rank of fungal species, from highest to lowest, was *F. verticillioides*, *S. maydis*, *A. flavus*, *Fusarium graminearum*, *Aspergillus niger*, *Penicillium* spp., *Botrydiplodia* spp., and *Cladosporium* spp. The direct competitive ELISA-test indicated higher levels of fumonisins than aflatoxins in pre-harvest maize grain samples. The concentration of fumonisins from six districts, and aflatoxin from two districts, was 10-fold higher than 2 ppm and far higher than 2 ppb maximum daily intake recommended by the FAO/WHO. The study therefore suggested that subsistence farmers and consumers in this part of Zambia, and maybe also in similar environments in sub-Saharan Africa, might be exposed to dangerous levels of mycotoxins due to the high levels of ear rot infections in maize grain.

1. Introduction

Ear rots occur worldwide wherever maize is grown, reducing yield and quality (Kommedahl and Windels, 1981). Approximately 19 genera of fungal species, among them *Fusarium* spp., *Aspergillus* spp., *Penicillum* spp. and *Stenocarpella* spp., affect maize (William and McDonald, 1983; Payne, 1999). Under certain environmental conditions, such as high temperature and high rainfall, maize grain is infected by ear rot fungi which produce mycotoxins (Bilgrami and Choudhary, 1998; Miller, 2001; Logrieco et al., 2002; Fandohan et al., 2005), leading to contamination of maize grain before harvest or under post-harvest conditions (CAST, 2003), Examples of the mycotoxins, which are produced as secondary metabolites by the ear rot fungi, are fumonisins (B1, B2 and B3) by *Fusarium verticillioides* (formerly *F. moniliforme* = *Gibberella fujikuroi*), *F. proliferatum*, and *F. nygamai*; deoxynivalenol (DON), and zearalenone, which are produced by *Fusarium graminearum* (telemorph *Gibberella zeae*) (Edward, 2004); aflatoxin B1 by the *Aspergillus flavus* and *A. parasiticus* (Campbell and White, 1995; Wagacha and Muthomi, 2008); ochratoxin A by *Penicillium verrucosum* and *A. ochraceus* (CAST, 2003); and diplodiotoxin by *Stenocarpella* spp. (Olatinwo et al., 1999).

High levels of ear rot infection and mycotoxin accumulation have been reported in pre-harvest maize in Europe, North and South America, and Asia (MacDonald and Chapman, 1997; Vigier et al., 1997; Logrieco et al., 2002), South Africa (Rheeder et al., 1992), East Africa (Kedera et al., 1994; Bigirwa et al., 2007) and Malawi (Kapindu et al., 1999). The occurrence of mycotoxins in pre-harvest maize is of great concern, because they cause health disorders in both human and livestock who consume contaminated grain (Munkvold and Desjardins, 1997; Miller, 2001).

The Food and Agricultural Organization of the United Nations (FAO) has estimated that up to 25% of the world's food crops are contaminated with both pre-harvest and post-harvest mycotoxins (Adams and Motarjemi, 1999). In Africa, lack of public awareness, scarcity of food and lack of regulatory mechanisms have been advanced as some of the reasons why the problem of mycotoxins is not

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given adequate attention. Among the groups of mycotoxins, two that have received some attention by African scientists in the last two decades are aflatoxins and fumonisins (Bankole and Adebanjo, 2003). Surveys conducted have revealed high levels of these two mycotoxins in maize grain in sub-Saharan Africa (Kedera et al., 1994; Doko et al., 1995; Bigirwa et al., 2007). According to Wagacha and Muthomi (2008), ingestion of higher doses of aflatoxin for example can result in acute aflatoxicosis, which manifests as hepatotoxicity or, in severe cases, fulminant liver failure. In East and central Kenya during 2004, high levels of aflatoxins were reported in maize grain from the informal market, and caused outbreak of aflatoxicosis to which 317 cases and 125 deaths were attributed (Lewis et al., 2005). Previously, about 20 cases had been reported in Eastern Kenya in 1981, and aflatoxicosis has also been reported in other areas in Africa and Asia (CDC, 2004). The statistics of mycotoxin related health problems could be higher because some of the cases go unreported or victims die without visiting health facilities in remote areas in developing countries. The joint FAO/WHO Expert Committee on Food Additives (JECFA) has set the provisional maximum tolerable daily intake of 2 μg/kg of body weight/day for fumonisins; whereas in the U.S.A, the Food and Drug Administration (FDA) has set industry guidelines for levels of fumonisin acceptable in human food and animal feed, with a recommended total fumonisin of 2 ppm (FAO, 2004). In Kenya more than half of the maize product samples had aflatoxin levels that were greater than the 20 ppb which is the regulatory limit for the country (Lewis et al., 2005).

In Zambia, very little information exists on the occurrence of ear rot and mycotoxins in maize (Doko et al., 1995; Schjøth et al. (2008)), although the ear rot has previously been ranked among the top three important maize diseases (Rao et al., 1987). Therefore the overall objective of this study was to determine the relative importance of maize ear rot and mycotoxin contamination in maize grain in the smallholder farming sector in central and southern Zambia. The specific objectives were to identify the fungal microbiota associated with maize ear rot infection; assess the incidence and severity of maize ear rot infection, and to determine the mycotoxin levels in maize grain from the smallholder farms in south and central Zambia.

2. Materials and methods

2.1. General features of the study area

The 11 districts covered in the survey (Fig. 1) were spread out over two provinces. Four of these districts are in Lusaka Province: Chongwe, Kafue, Luangwa and Lusaka. The other seven districts are in Southern Province: Kazungula, Choma, Sinazongwe, Monze, Namwala, Itezhi tezhi and Mazabuka. Three of the districts surveyed, Kazungula, Sinazongwe and Luangwa lie wholly in agro-ecological zone one (AEZ I), together with the southern parts of Kafue and Choma, and the eastern part of Chongwe, AEZ I is generally a dry area with less than 800 mm annual rainfall, and often has recurrent droughts. The soil conditions are dominated by the Zambezi-Luangwa rift valley, which has solonitzi soil with a steep slope, semi-arid plain and sandy soil (MAFF, 2001). The growing season is 80 to 120 days. Lusaka, Chongwe, Kafue, Mazabuka, Monze, Choma, Namwala and Itezhi tezhi are in agro-ecological zone II (AEZ II). AEZ II is characterised by an annual rainfall in the range of 800–1000 mm with a growing season of 90 to 150 days. It includes the plateau areas with elevations between 1000 and 1520 m. The area is part of the most productive region in the country for both food and cash crops. In general, the climate of these two provinces is favourable for the different forms of agriculture, with an abundance of arable land. The average maximum and minimum temperature, rainfall and relative humidity data are presented in Figs. 2,3,4 and 5, respectively, for the agricultural natural regions I and II.

The selection of districts was based on maize production levels and accessibility. Areas of high maize production were selected for the study because there is large diversity of both local varieties (landraces) and improved maize varieties. Individual farmsteads were randomly selected within the district and were spaced about 5–20 km apart. A global positioning system (GPS) data recorder was used to determine altitude, longitude and latitude data for the areas surveyed. Rainfall, relative humidity and temperature data were collected from the Department of Meteorology. The agro-climatic data were clustered and grouped together to define the environmental groupings for the occurrence of maize ear rot. Based on macro-climatic data, i.e.

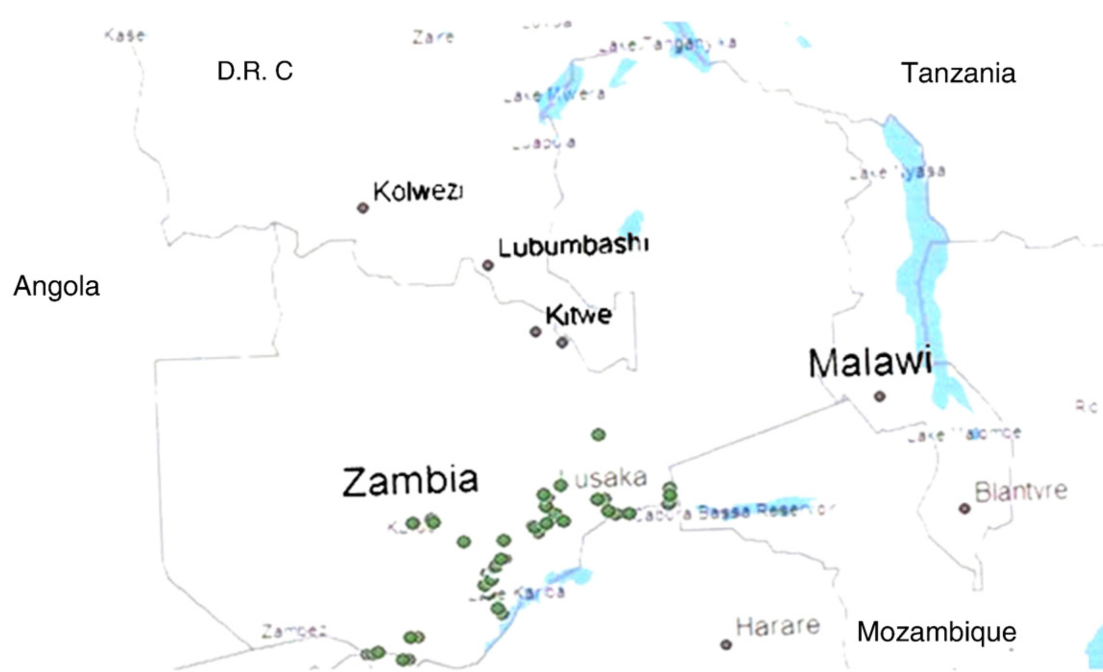

Fig. 1. Map of Zambia showing the surveyed sites for maize ear rots and mycotoxins during 2006 (green dots).