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Subsistence Farmers' Mycotoxin Contamination Awareness in the SADC Region: Implications on Millennium Development Goal 1, 4 and 6

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ABSTRACT In this paper, the authors have explored small holder farm households' awareness regarding the possible effects of consuming fungal infected maize and discussed the implications of the former on the achievement of Millenium Development Goals (MDGs) 1, 4 and 6 in the Southern African Development Community (SADC). The implications of climate change on mycotoxin contamination of staples in SADC have been discussed with special focus on Rungwe district, Tanzania and Makhatini area, South Africa. Data collected through interviewing 260 randomly selected small holder farm households in Rungwe district and secondary data for SADC region were used. Both, primary data collected from interviews and secondary data revealed that people used fungal infected staples for food, implying that people are not fully aware of health hazards associated with the ingestion of mycotoxins. Moroever, in the 2000s minimum temperatures increased by 2 - 7 ^{0}C and 3 - 8 ^{0}C in Rungwe and Makhatini, compared to 1979 and 1975 minimum temperatures, respectively. The existence of erratic rains across the SADC was also noted. It was concluded that current weather patterns propagate fungal infections and mycotoxin contamination of staples. This, together with farm households' unawareness of mycotoxins threaten the achievement of MDGs 1, 4 & 6 in SADC. Education and training to raise awareness of SADC smallholder farmers and consumers on mycotoxins are recommended.

INTRODUCTION

Smallholder farmers' awareness of mycotoxin contamination of food and feed is critical to MDGs 1, 4 and 6 by 2015 in the SADC region. MDG 1 deals with the eradication of extreme poverty and hunger. It involves improving employment rate and ensuring economic growth by the year 2015 (United Nations (UN) 2013). MDG 4 targets child mortality rate, while MDG 6 combats HIV/AIDS, malaria and other diseases (Lehohla 2013). Despite the recommendable progress observed with regard to MDGs worldwide, sub-Saharan Africa is still faced with the challenges of having the highest child mortality rate, high prevalence of diseases (UN 2013) and extreme poverty (Lehohla 2013).

Eighty percent of farms in sub-Saharan Africa are small holder farms (Livingstone et al. 2011), and most of them are in the form of subsistence farms (Issa 2011). These small holder farms contribute up to 90 % of agricultural productivity, and are sources of employment and food for 70 % of the people in the SADC countries (Louw et al. 2008). Therefore agriculture plays an important role in safeguarding food security and livelihood options. The occurrence of diseases and deaths associated with the consumption of mycotoxin contaminated foods and feeds have been acknowledged in several parts of Africa (Wild and Gong 2010; Muthoni et al. 2009).

In KwaZulu-Natal province, South Africa, in a study conducted on commercial maize by Chilaka et al. (2012) using layer chromatography and high performance liquid chromatography (HPLC) unacceptable levels of fumonisins aflatoxins, zearalenone and ochratoxins were detected. In 2001 the occurrence of cancer of the oesophagus among males in KwaZulu-Natal was associated with the consumption of beer made locally from fumonisin contaminated maize (Cheule et al. 2001). Currently, in a study conducted by Kamika et al (2014) using HPLC on peanuts collected from informal markets in Pretoria, South Africa and Kinshasa, Democratic republic of Congo high levels of aflatoxins were detected. In Tanzania, Kimanya et al. (2011) as-

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sociated stunting in children aged below five years with the exposure of infants to fumonisins through the consumption of fumonisin contaminated maize porridge. However, in the SADC region the incidence of diseases and deaths associated with the consumption of mycotoxin contaminated staples have not been adequately studied.

Furthermore, mycotoxin regulations are not strictly adhered to in SADC region even where the regulations have been put forth. The perception that the SADC region has only one rainy season has led some traders to wrongly believe that mandatory regulation of mycotoxin would be an unnecessary additional cost (Keyser 2012). This perception is detrimental to farm household's well-being, the regions' economy and the achievement of MDGs 1, 4 and 6 in Sub-Saharan Africa. In some of the SADC countries such as Mozambique, Tanzania, Malawi and Zambia fungal infections of staples have been shown to negatively impact on the export and marketing of staples (Rios and Jaffee 2008; Rios et al. 2013). Plans to improve resistance of grains to fungal infections have been or are being piloted in a few places within SADC countries. However, these plans prove to be either inadequate or to take too long to accomplish. For example in Tanzania a programme to combat aflatoxins is being carried out in only two out of the 30 administrative regions of this country (Issa 2011). The limitation with this programme includes the fact that it is pitched at a higher level with focus to improve seed resistance to aflatoxin producing fungi. The reality is that there are several mycotoxins that contaminate staples, which seem to currently be overlooked. In Malawi pilot programmes to combat mycotoxin contamination of staples started in 1980s. However, mycotoxin contamination remains one of the key challenges in the groundnut sector in this country (Monyo et al. 2012).

Of much concern is that farmers are hardly sensitized about the dangers of mycotoxin contamination of food and feed to their food security and well-being. Small holder farmers' awareness regarding mycotoxin contamination of staples affects the extent of farmers' health, economic engagement, and agricultural productivity. Therefore raising awareness amongst small holder farmers regarding mycotoxins should be given high priority rather than allowing mycotoxin contamination of staples to become a threat to the achievement of MDGs 1, 4 and 6.

The authors' main point of reference in this paper is a study conducted by Mboya in 2009 in Rungwe district, Tanzania (Mboya et al. 2011). The authors used Elisa kits to investigate the incidence and quantities of mycotoxins on 130 maize samples randomly collected from 130 out of the 260 farm households that participated in the survey being reported in this paper. The study revealed extremely higher amounts of mycotoxins compared to the internationally acceptable standard limits. An average of 0.6 mg/kg aflatoxins, 8.8 mg/kg fumonisins, 1.8 mg/kg T-2 toxins and 7.5 mg/kg ochratoxins were reported (Mboya et al. 2011). Internationally acceptable standard limits for the indicated mycotoxins per kilogram of maize are as follows: 0.02 mg for aflatoxins (Munkvold et al. 2009), 4 mg for fumonisins (Wu 2004) and up to 0.05 mg (The World Food and Agriculture Organization (FAO) 2004) for ochratoxins. The occurrence of such high amounts of mycotoxins in maize is detrimental to the health of maize consumers. Mycotoxins have capacity to suppress the immune system of both humans and animals. The mycotoxins reported by Mboya et al 2011) are also specifically associated with the following diseases (Table 1).

The diseases listed in Table 1 can be fatal. More so, chronic exposure to high levels of mycotoxins can be fatal. (Munkvold et al. 2009). In 2004 death of more than 100 people in Eastern Kenya alone was associated with the consumption of aflatoxin contaminated maize meals (Muthoni et al. 2009). As opposed to Kenya, in SADC there is dearth of documentation regarding illnesses and death associated with the ingestion of mycotoxin contaminated food and feed.

Favourable Conditions for Fungal Infection and Mycotoxin Production

Temperatures between 20 - 40 ^{0}C are favourable for growth of several fungal species (FAO 1985). In the presence of moisture temperatures at 20 - 30 ^{0}C are favourable for the production of fumonisins (Marin et al., 1995) and T-2 toxins (Herman and Trigo-Stockli 2002). Likewise at 15 - 37 ^{0}C and 15 - 43 ^{0}C ochratoxins (FAO 2004) and aflatoxins are produced, respectively. Temperatures at 5 - 8 ^{0}C impede fungal growth (Agrios 2005), whereas at temperatures below 5 ^{0}C most fungi may become inactive. Although some fungal species such as *Fusarium Sporotrichioides* can grow at -2 ^{0}C, temperatures below 0 ^{0}C are most unfavourable for the development and growth of most fungal species (Anonymous 2013a). This implies that climatic conditions that

Table 1: Diseases specifically associated with the ingestion of fumonisins, aflatoxins, ochratoxins and T-2 toxins

Type of mycotoxin	*Diseases specifically associated with the ingestion of the particular type of mycotoxin*
Aflatoxins	Cancer of the liver in human beings, decreased eggs production in chickens (Exarchos and gentry 1982; Oliveira et al. 2002), decreased milk production and interference with reproductive efficiency in animals (Comell University 2008).
Fumonisins	Cancer of the oesophagus, kidney, pancreas, gastrointestinal tract and blood cells problems, and they may interfere with brain, liver, and lungs function (Vincelli and Parker 2002), Kidney problems in animals, retarded growth to chickens that are raised for slaughter, decreased egg production to layers (Tardieu et. al. (2007).
Ochartoxins	Kidney problems in aniamls and human beings, retarded growth to chickens that are raised for slaughter, decreased egg production to layers (Diekman and green 1992). Also cancer of the liver in human beings (Munkvold et al, 2009; Wood et al., 2003) and animals (Comell University 2009). (Diekman and green 1992).
T-2 Toxins	Aleukia, a diseae of the alimentary canal, digestive disorders (Bennet and Klich 2003), lesions in cickens, low egg production, reduced witht, reduced milk production, hemorrhage, inhibition of protein snthesis, disruption of DNA and RNA synthesis, interference with cell division of actively dividing cells such as skin cells (Anonymous, 2013a).

allow temperatures to drop below 0 ^{0}C would be helpful in discouraging the development of most fungal species, thus containing their spread. For a place characterized by rainfall throughout the year and cool temperatures such as Rungwe district (Administrator 2010), a rise in minimum temperatures may further accelerate fungal development. It was hypothesized that: 1. Small holder farm households in SADC countries are uninformed regarding mycotoxin contamination of staples, and 2. Mycotoxins threaten the achievement of MDGs 1, 4 and 6 by 2015.

Objectives

1. To investigate climate change in SADC region with special focus on the highland agro-ecological zone of Rungwe district, Tanzania and Makhatini area, South Africa.
2. To explore subsistence farm households' use of fungal infected maize and determine the awareness regarding the possible effects of consuming fungal infected maize with special focus on the highland agro-ecological zone of Rungwe district.
3. To discuss the implications of subsistence farm households awareness of mycotoxins on the achievement of MDGs 1, 4 and 6.

This paper highlights the critical necessity of raising smallholder farmers' awareness regarding mycotoxin contamination of staples for achieving MDGs 1, 4 and 6 in the SADC region.

METHODOLOGY

Two types of data were used, namely primary and secondary data. In Rungwe district, primary data was collected using semi-structured and structured interviews, administered to 260 randomly sampled households. Data collected includes the frequency at which farm households were visited by extension staff per year, household head's age, gender of household heads and number of years that heads of households had spent on obtaining formal education. Data regarding various ways in which farm households utilized fungal infected maize was also collected.The latter was necessary for assessing farm households' understanding of mycotoxins. Heads of households who were born before the 1970s were interviewed regarding their experiences of climatic conditions. This was necessary for understanding temperature patterns in Rungwe district. To ensure involvement of key persons involved in agriculture, interviews were conducted at the farm households' homes.

For Makhathini area and other SADC countries secondary data was used. In Rungwe district and Makhatini, June and July are normally the coldest months. For Rungwe district June temperatures for the years 2001 – 2012 were compared with temperatures for June 1979. For Makhatini, July temperatures for the years 2001 – 2012 were compared to July 1975 temperatures. The comparison of temperatures was to explore climate changes and its implications on fungal development. Raw data for Rungwe were obtained from Meoweather (2012), whereas for Makhatini raw data were obtained from the South African weather services (2013). Selection of specific years for which temperatures were scrutinized depended on the availability of the necessary data. The inclusion of Makhatini area was based on the involvement of this area in maize production. Maize is grown all throughout the year in Makhatini.

Statistical Analyses

Primary data was analysed using the STATA. Figures were created using the Excel programme. The probability for male and female headed households in Rungwe district to use fungal infected maize for food was assessed using dummy regression analysis.

RESULTS

Erratic Rainfall and Temperatures in the SADC Region

For the past decade the SADC region has been experiencing erratic rainfalls ranging from normal to below and above to normal chances of rainfall (Fig. 1).

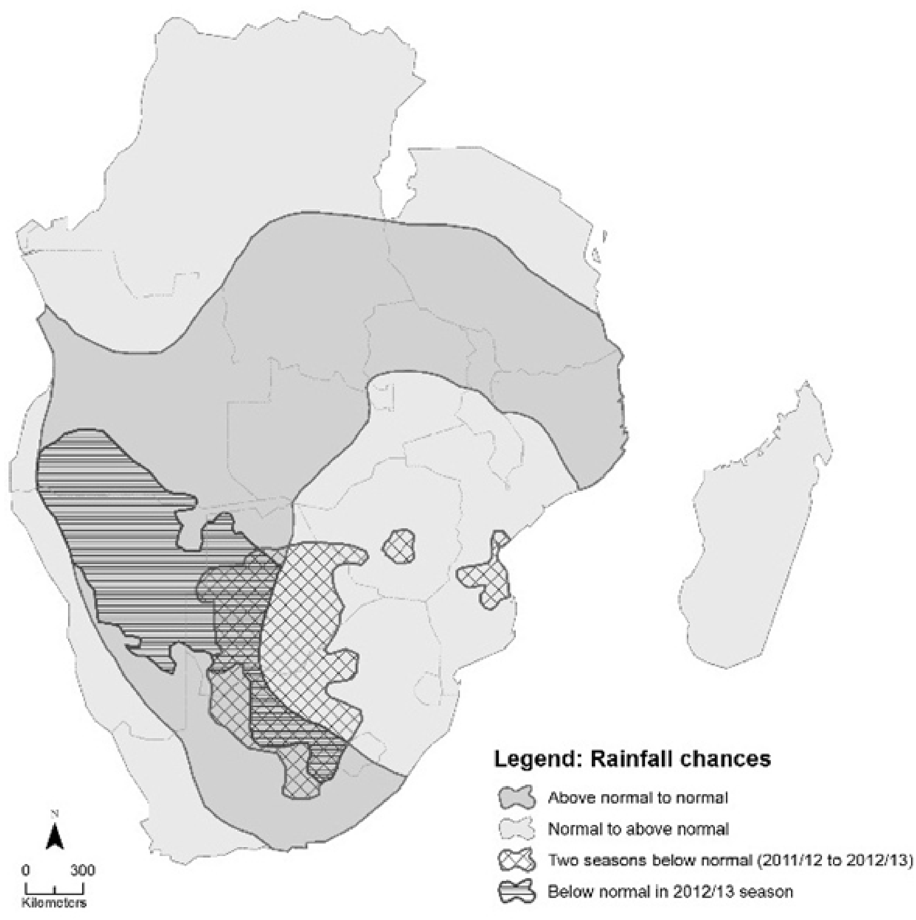

Fig. 1. Current rainfall patterns in SADC region
Source: SADC Regional Vulnerability Assessment Committee (RVAC) 2013

Climate (Temperature) Change in Rungwe and Makhatini

Figure 2 shows that in 1979 minimum temperatures in Rungwe district dropped to as low as -2 in June. Findings also showed that for eleven consecutive years (from 2001 - 2012) minimum temperatures in June in Rungwe district were e” 2 ^{0}C. This indicates a persistent rise in minimum temperatures in the 2000s during this cold month compared to minimum temperature in June 1979. Likewise, in Makhatini, minimum temperatures in the 2000s have been e” 2 ^{0}C (Fig. 3).

Findings presented in Figure 2 were further confirmed by 70.8 % of the participants who indicated that in the 1970s temperatures for the month of June would occasionally drop to the extent that vegetation especially grass and banana/plantains' leaves died. Damage to plant cells can occur when they are exposed to frost (Waraich et al. 2012; Phelps 2013). In the presence of high humidity, when the atmosphere is at 0 ^{0}C crops can be 4 - 5 ^{0}C cooler. This could lead to death of plant leaves depending on the severity of frost and the length of time during which plants are exposed to it (Waraich et al. 2012). Banana leaves could die if banana plants are exposed to temperatures below 0 ^{0}C just for a few hours (Hunter 2003). The occasional experience of death of plant leaves in Rungwe district implies that temperatures below 0 ^{0}C were occasionally reached in the 1970s.

Small Holder Farm Households' Awareness of Pathogenic Moulds and the Associated Mycotoxins and Diseases

A total of 58.5 % of the participants had the perception that fungi could not produce harmful substances/mycotoxins. Yet there was a suspicion that fungal infected maize could be harmful to humans if directly consumed by humans. Table 2 shows the various ways in which mouldy maize was used by small holder farmers in Rungwe district. As indicated in Table 2, infected maize was hardly thrown aware. It is clear that smallholder famers had grading systems for infected maize to identify whether the infected maize was to be used directly as food, for brewing beer or as animal feed.

Farm households perceived that there could be some human health risks associated with the consumption of fungal infected crops. The belief was that if the crop is slightly infected boiling or cooking would make it safe, or if the infected crop is consumed in another form such as beer or used for feed chances of fungi harm-

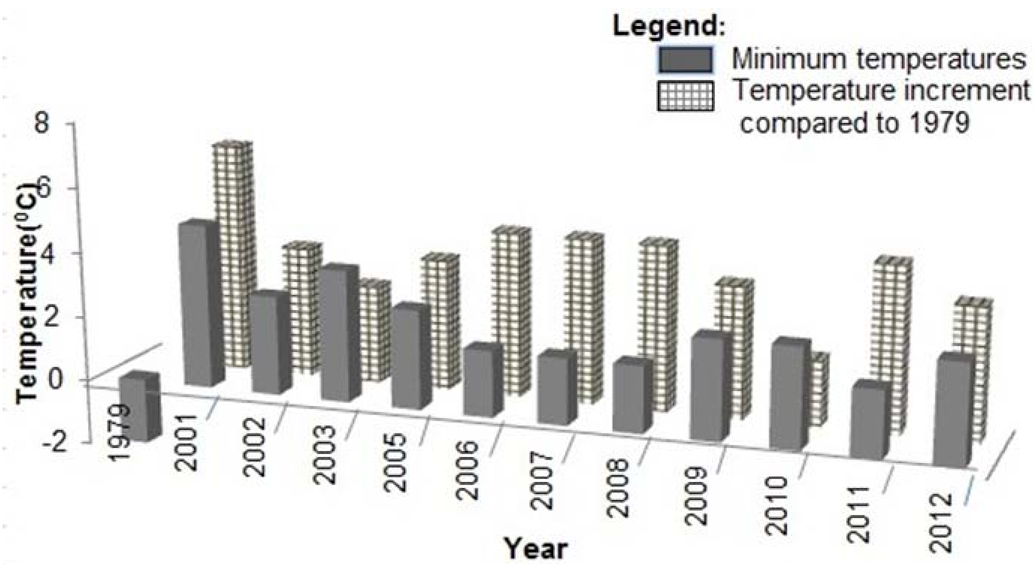

Fig. 2. June minimum temperatures for Rungwe, 1979 and 2000-2012
Source: Created using raw data from Meoweather, 2012

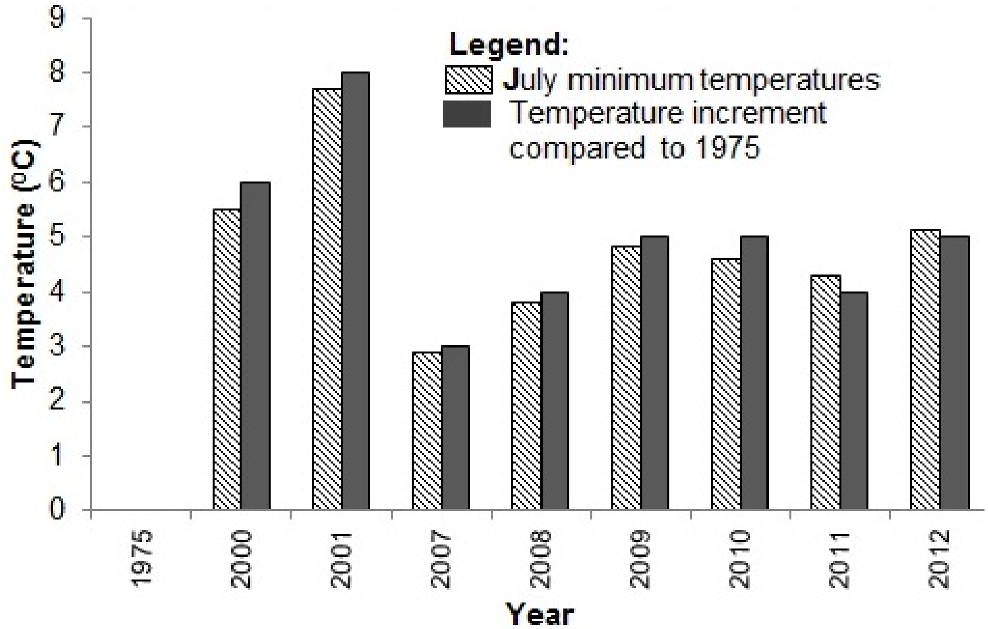

Fig. 3. July minimum temperatures in Makhatini, 1979, 2000, 2001 and 2007- 2012
Source: Created using raw data from South Africa Weather Services 2013

Table 2: Variou ways in which farm households in Rungwe district used fungal infected maize

Fungal infected maize use	*% of farm households for whom the response was applicable*
Throw away	0.8
Animal feed	38.4
Brewing beer	0.4
Throw away if badly affected, otherwise dehull and use for food	58.8
Use as animal feed if badly affected, otherwise dehaull for food	1.2
Sell to beer brewers	0.4

fulness on humans would be eliminated. This implies that farmers are not informed about the dangers of mycotoxins. The same attitude was noticed in Malawi in a study conducted by Monyo (2010). Monyo reported that about 60 % of farmers were able to associate fungal infection of groundnuts with mycotoxin contamination, and traders could reject fungal infected groundnuts, yet at the local market fungal infected groundnuts were not rejected (Monyo 2010).

Farm Households' Access to Agricultural Information

It was also found that 80 % of small holder farm households in Rungwe district had never been visited by agricultural extension staff, whereas only 15 % had been visited with respect to livestock keeping in a range of 1 - 4 times per year.

Farm Households' Probability of Exposure to Mycotoxins in Rungwe District

Cross-tabulation results showed that 45 % of the female headed households used fungal infected maize for feed and 55 % used it for food, whereas 38 % of the male headed households used it for feed and 62 % used it for food. These findings show that the tendency for farm households to use fungal infected maize for human consumption increases with male headed households, whereas the tendency to use it for feed increased with female headed households. Dummy regression analysis results revealed a positive association, statistically significant association between farm household's tendency to use fungal infected maize for feed with head of farm household being female headed at coefficient value of 0.416, significant at á = 0.038, which presents a 17 % overlap between the two variables. Although the tendency for farm households to use fungal infected maize for food decreased with households being female headed at -0.394 coefficient value, the association was not statistically significant, showing that both male headed and female headed households consumed fungal infected maize. Farm households' tendency to use fungal infected maize for feed also slightly decreased with increase in heads of farm household's years of formal education at coefficient value of 0.073 and was significant at á = 0.013, indicating a very small overlap of 0.5 % between the two variables.

Farm households' tendency to use fungal infected maize for food slightly decreased (at -0.079 coefficient value) with increase in head of households' number of years of formal education. This association was significant at á = 0.012, and it indicated a 0.6 % overlap. The small overlap revealed by the indicated statistical results show that head of households' gender and number of years of formal education had very little influence on farm households' tendency to use fungal infected maize for consumption purposes. This, together with the fact that about 66.1 % of the farm households that reported having been visited by agricultural extension officers in relation to livestock keeping also used mouldy maize for feed imply that both male and female headed household were at risk of exposure to mycotoxins either directly through consumption of fungal infected maize or indirectly through consumption of animals that feed on fungal infected maize or products made from them. These findings are support an argument made by Cardwell et al. (2001) indicating that in developing countries farmers tend to sell the best quality crops and retain the poor quality ones for consumption purposes.

DISCUSSION

The Implications of Irregular Weather Patterns on Mycotoxin Production

It has been shown that irregular weather creates favourable conditions for the production of mycotoxins, increasing the risk of mycotoxin ingestion (Tran-Dihn 2013). Thus the irregular weather patterns observed in the SADC pose a threat to humans' and livestock's' health in this region.

The Importance of Low Temperatures (Below 0 ^{0}C) For Controlling Fungal Infection of Staples

Low temperatures at 0 ^{0}C and below are helpful in suppressing the development of fungal infections because very few fungal species such as *Fusarium Sporotrichioides* (Anonymous 2013b) can grow at such low temperatures. Moreover, it can also be argued that in the 1970s somehow the occasional occurrence of temperatures below 0 ^{0}C naturally discouraged the development of fungal infections on crops in Rungwe and Makhatini. This explains the claim by the 70.8 % of farm households in Rungwe district who indicated that fungal infection of staples was hardly experienced in the 1970s, implying that conditions were possibly not favourable for the development and growth of fungi in crops during that period. On the contrary, the persistent increase in minimum temperatures in Rungwe and Makhatini in the 2000s implies that the means through which nature controlled fungal infections are no longer applicable. The increased minimum temperatures would keep fungal species alive until temperatures are warm enough for their growth. This further implies that the implementation of ways other than nature's natural means of containing fungal infections is critically important. Raising small holder farmers' awareness regarding mycotoxins is therefore critical, because it will help them to deliberately make effort to find appropriate means to prevent fungal infections of crops.

The Implications of Farm Households' Unawareness of Mycotoxins

Farm households' ignorance regarding mycotoxins is detrimental to their food security and health because it creates possibilities for them and livestock to consume mycotoxin contaminated staples. Consequently, the sustainability of livelihoods is challenged as health is endangered creating a vicious cycle as the skilled and bread winners become at risk.

The Implications of Inadequate Extension Services on Farm Households' Access to Agricultural Information

The inadequacy of extension services is known to be a major challenge in developing countries, especially to rural farm households (Dulle et al. 2000; Swanson and Samy 2002).

SADC is no different. The agricultural extension system is important for linking agricultural research with farmers so that knowledge obtained through research can improve agricultural awareness and productivity (Subair 2002). However, the inefficiency of extension systems hinders the flow of the necessary information. In turn, this shortfall hinders agricultural prosperity and compromises the achievement of MDGs 1, 4 and 6.

The Possible Effect of the Consumption of Mycotoxin Contaminated Staples on Undernourishment

Although there is limited empirical evidence on the relationship between undernourishment and the consumption of mycotoxin contaminated food, studies have shown that fungi and mycotoxins have capacity to reduce the nutritive value of food (Owaga et al. 2011; Wu 2013). The latter promotes the vulnerability of both livestock and small holder farm households to undernourishment. This enhances malnutrition and other health problems, especially where staples are concerned. Stunting, which is a form of malnutrition, and food insecurity are quite prevalent in the SADC region (Figs. 4 and 5). Although stunting cannot be pinned down on mycotoxin contamination alone, there is growing concern that the consumption of mycotoxin contaminated food is a major underlying contributing factor causing this health problem (Owaga et al. 2011). In South Africa, a country regarded as more developed than the rest of African countries, stunting still persists (Fig. 5). Furthermore, Fig. 5 demonstrates that despite efforts to improve food security chronic food insecurity still remains a challenge in the SADC region.

The number of people suffering from chronic food insecurity has risen from 3,116,131 people in 2009/2010 to 5,477,613 in 2012/2013 (SADC Regional Vulnerability Assessment Committee (RVAC) 2012). The increasing prevalence of stunting and food insecurity is a concern because it threatens health of future generations and life expectancy. Stunting and chronic malnutrition may occur as consequences of a compromised nutrition. Mycotoxins have the capacity to reduce the nutritive value of food and to cause stunting. Therefore, underestimation of mycotoxin contamination and the ingestion of mycotoxin contaminated staples could have ad-

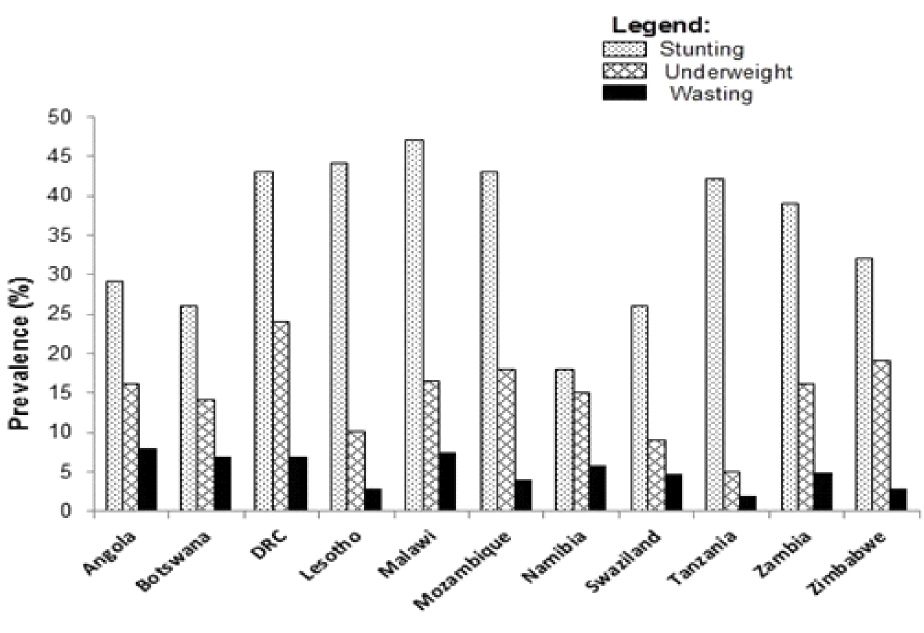

Fig. 4. Malnutrition prevalence in SADC (2013)
Source: VAC presentations, WHO, SOW, as cited by SADC National Vulnerability Assessment Committee, 2013.

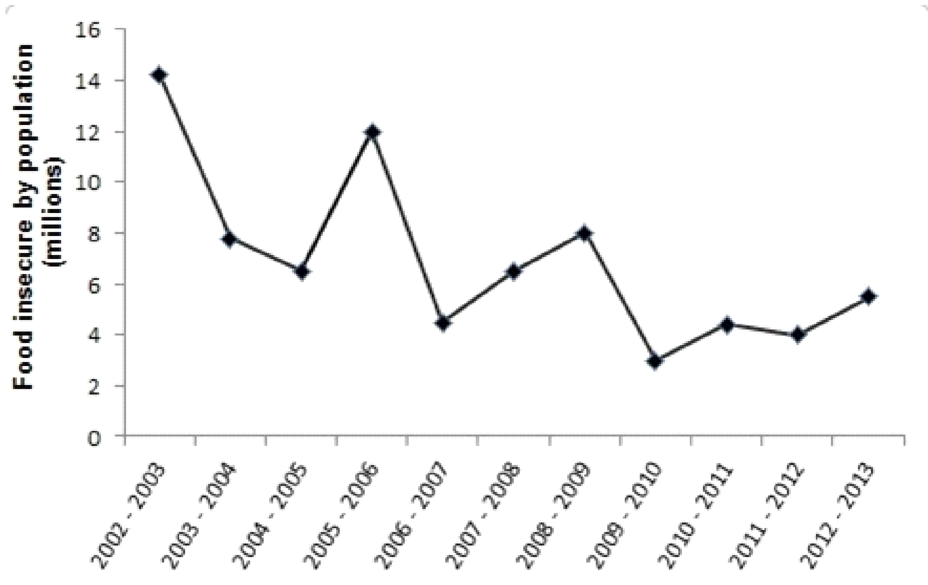

Fig. 5. Chronic food insecurity by population (Millions) in SADC (2002-2013)
Source: Created using data from VAC presentations, WHO, SOW, as cited by SADC National Vulnerability Assessment Committee, 2013

verse effects on the achievement of MDGs 1, 4 and 6.

The Implications of Small-Holder Farm Households' Lack of Awareness Regarding Mycotoxins on the Achievement of MDGs 1, 4 And 6

Small holder farm households constitute 70 - 80 % of farmers that produce food consumed in SADC region (Livingstone et al. 2011). Maize is a staple food in the entire SADC region. This exposes farm households and other consumers especially the most vulnerable groups, namely, pregnant women, infants, elderly and those who have compromised immune systems to ill health risk. Furthermore, the adverse health effect of mycotoxin contamination of staples has potential to aggravate child mortality rate in this region especially where infants' foods are staple based. Moreover, the capacity of mycotoxins to suppress the immune system further exposes consumers to the attack by diseases other than those caused directly by mycotoxins. Small holder farmer's awareness of mycotoxins could help to ensure mycotoxin free food for pregnant women, infants and other consumers.

The SADC countries currently encourage trade across borders within this region so that smallholder farmer's opportunities to generate more income can be maximised and moderation of price volatility can be achieved (Louw et al. 2008). Yet, this valuable intention could be wasted if mycotoxin contamination continues to be overlooked. This statement is raised because SADC region compared to other countries lacks strict regulations when it comes to mycotoxin contamination. Fungal infected and mycotoxin contaminated commodities cannot be accepted at the international market. This reduces the chance for small holder farmers to market their commodities at the international market. Failure of farmers to engage in trading at international market would hinder improvement of not only their own economy, but also the economy of their countries at large thus continuing the cycle of poverty. There is a need for raising farmer's awareness on mycotoxin contamination to promote better understanding of its implications on agricultural productivity, especially because in most of SADC countries agriculture plays a critical role in combating poverty and food insecurity.

CONCLUSION

Sensitisation of smallholder farmers concerning mycotoxin contamination of staples is hardly being implemented in the SADC region. The fact that farm households are not informed on the implications of using fungal infected maize for food and feed renders both, farm households and livestock vulnerable. Mycotoxin contamination of staples threatens the productivity, well-being and prosperity of farm households and consumers, both humans and livestock in the SADC region. The SADC region has a potential to feed itself, however, if mycotoxin contamination continues to be overlooked this capacity could completely diminish. Consequently MDGs 1, 4 & 6 cannot be achieved by 2015.

RECOMMENDATIONS

There is a need for rigorous research to investigate the prevalence of mycotoxin contamination; to provide concrete results on the relationship between stunting and the ingestion of mycotoxin contaminated staples and gather factual data to inform the public. It is recommended that education and training on the implications of mycotoxin contamination in feed and food should be provided to both farmers and grain consumers in the SADC region and other countries in the Sub-Saharan Africa.

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