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Review

A review of the effects of climate change on occurrence of aflatoxin and its impacts on food security in semi-arid areas of Kenya

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There are adverse impacts by the changing climate on the agricultural sector; Kenya's back borne may exacerbate the challenges of ensuring food safety and security, and reducing poverty in Africa as a whole. Understanding how climate change scenarios will affect agriculture is essential in ensuring future food security. In this paper whose objective was to review the potential impact of climate change on important mycotoxins that contaminate maize in Kenya, it focused on climatic factors: temperature and relative humidity, which affect fungal infection of crops and mycotoxin production by these fungi. Aflatoxins are potent mycotoxins that cause immune weakening, cancer and even death. Aflatoxin contamination causes significant loss for farmers, businessmen, marketers and consumers of varied susceptible crops. Climate change alters the complex communities of aflatoxin-producing fungi. This includes changes in space, time and in the quantity of aflatoxin-producers. Generally, if the temperature increases in cool or temperate climates, the respective countries may become more susceptible to aflatoxins. However, tropical countries may become too inhospitable for conventional fungal growth and mycotoxin production. Although some regions can afford to control the environment of storage facilities to minimize post-harvest problems, this happens at high additional cost.

Key words: *Climate change, maize,* aflatoxins.

INTRODUCTION

Kenya has experienced several aflatoxicosis outbreaks during the last twenty five years, most of which have occurred in Makueni and Kitui districts in Eastern Province (CDC, 2004). Both districts are prone to food shortage because of poor and unreliable rainfall and very high temperatures.

Aflatoxins are toxic metabolites of the fungi *Aspergillus flavus* (Figure 1) and *Aspergillus parasiticus* which live in soil (Diener et al., 1987). These toxins are potent carcinogens that frequently contaminate agricultural commodities and pose a serious threat to humans and domestic animals (Edds, 1979; Mixon, 1980). Aflatoxins were first identified in 1961 in animal feed responsible for the deaths of 100 000 turkeys in the United Kingdom (Sargeant et al., 1961).

Acute aflatoxin poisoning in humans causes hepatitis, impaired growth in children, jaundice and gastrointestinal injuries with high morbidity and mortality (CDC, 2004). Prolonged chronic exposure is suspected to increase the risk for hepatocellular carcinoma (Marcel and Wild, 1995; Julia, 2005).

Aflatoxin can be produced in many food products after plants are infected by species of the *A. flavus* group (Hill *et al.* 1983; Lillehoj 1987; Shahin 1993; Hammad *et al.* 1995). Typically, *A. flavus* comes in contact with crops before harvest, it however remains associated with the crop through harvest and storage (Lillehoj, 1987). Thus seed kernels become contaminated with aflatoxin B_1, both before and after harvest (Diener et al., 1987; Cotty 1989, 1990). The contamination is however, more likely to occur in the post-harvest stage if the produce is not handled properly to minimize the thriving of the fungal species (Yadgiri, 1970, Wilson and Abramson, 1992). During high humidity, initially dry seed develops water content conducive to contamination. The combination of moisture content and temperature dictate the extent of contamination, according to Jaime-Garcia and Cotty (2003), influences of delayed harvest on contamination

Figure 1. Yellow-green powdery growth of *Aspergillus flavus* on a com rootworm-damaged ear (**Source:** Allson Robertson – Iowa State).

are most severe when crops are caught by rain just prior to or during harvest.

Severe aflatoxin outbreaks were reported in Eastern Province of Kenya during April through June of 2004 and during 2005. During the 2004 outbreak, widespread aflatoxin contamination of maize in Makueni, Kitui, and neighbouring districts was reported. This contamination resulted in 317 human cases of severe aflatoxin poisoning, with 125 deaths (CDC, 2004; Julia, 2005). In 2005, another aflatoxicosis outbreak in Makueni and Kitui districts affected 75 people, resulting in 32 deaths. Outbreak investigations and follow-up studies suggested that locally produced maize from subsistence farming was the likely source of contaminated grains responsible for the two outbreaks (CDC, 2004).

The effect of climate change on mycotoxins is extremely complex, which involves many factors. Optimal conditions for fungal development are 25 to 28℃, with a high humidity of above 65 - 80% (Diener et al., 1987). *Aspergillus flavus* in particular, only grows when relative humidity in the air is above 85 percent or moisture content in the grain is above 16 per cent.

The main objective of the research is to raise awareness of aflatoxin's impact on health, agriculture and trade. Specific objectives of the course were: to review the general effect of weather and climate change on aflatoxin, and to review the challenges and potential solutions of controlling aflatoxins in Kenya and Africa at large.

Problem statement and justification

Aflatoxin contamination endangers the food supplies and health of both people and livestock. This threatens the economic livelihood of farmers, commercial feed users, and numerous feed and food industries. What a loss?

Many studies attest to the fact that fatal and frequent outbreaks of human and domestic animal mycotoxicoses from foods and feeds in Kenya are attributed to maize meal products. Other than Kenya, the situation is serious particularly in other developing countries such as Pakistan, where there are poor production practices. In addition, there is inadequate storage, transportation and marketing conditions, which contribute to mould growth and increase the risk of mycotoxin contamination.

Peers and Linsell (1973) revealed a significant association between ingested mycotoxin levels in maize meal and human liver cancer cases in Murang'a. In 1981, mycotoxin food poisoning occurred in Kenya and 64% mortality rate was recorded (Ngindu et al., 1982). A number of surveys have revealed heavy mycotoxin contamination in most commercial maize kernels and popular brands of maize meal on the market shelves in Kenya (Muriuki and Siboe, 1995). Hospital records from Chogoria, Meru District Hospital, Maua Mission Hospital, and Nkubu Mission Hospital show a sharp increase in liver cancer cases attributed to mycotoxin contamination in maize meal in the region (Siboe, 2002). In recent years, outbreaks of acute aflatoxicosis were reported in

Kenya: 125 deaths occurred out of 317 reported cases resulting from consumption on aflatoxin contaminated maize during 2004 (Nyikal et al., 2004) with repeated events in 2005 and 2006.

Unless aflatoxin levels in crops and livestock are effectively managed, national development efforts to achieve food security and improve health in Kenya will be undermined.

The understanding of the outbreak and spread of aflatoxin in these areas is crucial to ensure food security and human safety. The knowledge of the impact of climate will allow development of improved management procedures, better allocation of monitoring efforts, and adjustment of agronomic practices in response to projected global climate change.

This study basically involved desk paper review. The reviewer collected relevant recently published papers authored by: Easterling et al. (2007), Miraglia et al. (2009), Stern (2007), Cotty and Jaime-Garcia (2007), Lewis et al. (2005), and Wu et al. (2011).

LITERATURE REVIEW

Here, works done by other scientists in the area of study were reported. The reviewer divided the review areas into: climate change, and aflatoxicosis.

Climate change has been occurring, probably since the earth existed, for instance, global temperatures averagely show that seven of the top ten warmest years on record have occurred since 1990, similarly, 2000-2009 was the warmest decade on record worldwide (EPA, 2010). The change would have significant impacts on agriculture worldwide. According to IPCC (2007), increase in temperatures of beyond 3°C is expected to decrease global agricultural production, particularly in the tropic and sub-tropic regions of the world where Kenya is situated.

According to Easterling et al. (2007), there would be difficulties associated with the timing of crop planting and harvesting due to changes in weather patterns, worsened by increase in extreme weather events affecting rainfall, pests, and plant disease. In the event, food quality is as well likely to be compromised.

Several climate scenarios have been identified: temperature increase, variation in precipitation, drought, and atmospheric carbon dioxide that have impact on agriculture and food safety. The amount of precipitation is very likely to increase at high latitudes, while in most subtropical land regions, decreases in precipitation are likely to occur. This is in accordance to IPCC (2007). The change is viewed to be due to general intensification of the global hydrological cycle (Solomon et al., 2007). Rainfall projections in Kenya are inconsistent; a range of models and scenarios suggest both increases and decreases in total precipitation (Osbahr and Viner, 2006).

The highest temperature increase is projected at high Northern latitudes and over land, with less warming over the Southern oceans and North Atlantic (Solomon et al., 2007). It is also very likely that hot extremes and heat waves will continue to become more frequent and long lasting (Bernstein et al., 2007). According to GoK (2009), in Kenya, temperatures rose by 1°C over the past 50 years. The warming is expected to accelerate with temperatures rising by nearly 3°C by 2050 (IPCC, 2007).

Atmospheric CO_2 concentration has continued to increase from the pre-industrial time and is now almost 100 ppm. The capacity of land and ocean to absorb CO_2 has reduced resulting into global warming. Higher amount of anthropogenic CO_2 will thus stay in the atmosphere under a warmer climate (Solomon et al., 2007).

According to IPCC, (2001), East Africa depends heavily on rain-fed agriculture making rural livelihoods and food security highly vulnerable to climate variability such as shifts in growing season conditions. Climate variability therefore has the highest impact on agricultural production. Rainfall and temperature regimes are perhaps the most important factors in determining the potential productivity of various agricultural activities. The effects of rainfall and temperature are both direct and indirect. Indirectly, climate change will have an impact on crop production by reducing the capacity of natural resources to support productive agriculture. The effects include nutrient leaching and erosion, reduced availability of water, and changes in the distribution and incidence of pests and diseases including weeds.

The projected climate change is foreseen to have a negative impact on food security, especially in developing countries. The agricultural system is likely to be the most affected, but also the marine system and the livestock production are likely to be vulnerable. With the changing climate, mycotoxins will definitely be affected. However, agricultural and natural ecosystems of plants are affected by climate change (Miraglia et al., 2009; Stern, 2007).

High temperature and drought stress are key factors that increase concentrations of aflatoxins. The two climatic factors directly have an impact on maize and *A. flavus*. High temperatures and dry conditions necessitate the growth, conidiation, and dispersal of *A. flavus* that impair growth and development of maize (Cotty and Jaime-Garcia, 2007).

Accordance to Lewis et al. (2005), drought and semi-arid to arid conditions are linked to contamination and the poor subsist on frequently contaminated staples especially in tropical countries; the shift in weather patterns may lead to acute aflatoxicoses and thus death.

In the near future, there is reason to believe that increased climate variability associated with climate change trends may result in higher pre-harvest levels of mycotoxins in maize, posing both economic and health risks (Wu et al., 2011). The fungi that produce aflatoxins are more likely to infect maize and produce toxins in warmer temperatures. Warmer temperatures combined with greater extremes in precipitation or drought increase plant stress, further predisposing maize to fungal infection and mycotoxin contamination.

Although there are many factors, other than environmental factors (temperature and available moisture) involved in mycotoxin contamination, climate is the most important. The occurrence of aflatoxin on crops is strongly influenced by weather during and after the growing season. Cool, wet growing seasons may delay grain maturity, especially for corn, and result in mold and mycotoxin formation in the field. Climate change is likely to lead to an increase in hot and dry spells; this implies an expectation of increased risk of aflatoxin contamination.

CONCLUSION AND RECOMMENDATIONS

Although crop farming is recognized as a relatively susceptible part of the food and feed production sector that could be affected by climate change, livestock production could be heavily influenced.

It is important to determine impacts of climate change to future Kenyan food security, in terms of mycotoxin-related economic and health risks. Assuring food safety entails the active involvement of a number of stakeholders performing agreed, clearly defined roles. Climate change has both direct and indirect impact on the occurrence of food safety hazards at various stages of the food chain. This work recommends:

i) Public awareness on how to avoid or prevent attacks by aflatoxin; this would help in both short-term and long-term planning of mycotoxin control during harvesting and grain handling: storage and marketing strategies that ensure economic viability and food security.
ii) The government has a mandate to catalyze the process of technology transfer to assist farmers tackle aflatoxin in maize. Crop yields can be predicted using climate model output and crop models.
iii) Storage; to avoid contamination with aflatoxin, maize must be stored in conditions that prevent exposure to and growth of *Aspergillus* fungi, such as maintaining cool air temperatures and low humidity.
iv) Development of maize varieties and hybrids with tolerance to infection by *A.* fungi.

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