# ASSESSING OCCURRENCE AND DISTRIBUTION OF AFLATOXINS IN MALAWI

**Supported by**
**The McKnight Foundation, USA**

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**Project Final Report**
**(Grant No. 08-598)**

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1. International Crops Research Institute for the Semi-Arid Tropics (ICRISAT)
2. National Smallholder Farmers' Association of Malawi (NASFAM)

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## Acknowledgement

This study was conducted to analyze the occurrence and distribution of aflatoxin contamination in two major staples in Malawi (groundnut and maize). The activities include a comprehensive analysis of contamination as observed in the 2007/2008 and 2008/2009 Malawi cropping seasons. The distribution of *Aspergillus Flavus* (the aflatoxin producing fungus) in the soils covering 11 study districts is reported. The team has also attempted to relate the observed results with long term climatic data and develop GIS based risk maps for Malawi. The Project acknowledges the collaboration of key individual and Government Departments in Malawi and institutional support from ICRISAT. It is for this reason the team is indebted to Dr Gray Munthali and Adam Chavula of the Malawi Department of Meteorological Services for their assistance with long term climatic data, Dr Andre van Rooyen of ICRISAT Bulawayo and his GIS team comprising of Dr Suraj Pandey and Mr Albert Chirima for assistance with the GIS work. The principal investigator is also indebted to ICRISAT staff Ms Ethel Sichone for input in the Laboratory Aflatoxin and *A.Flavus* analysis work and Mr. Harry Msere for the field survey. The main users of this information are expected to be traders, food processors, farmer organizations, researchers (Agriculture and Health), extension officers, development agencies and decision makers interested in Mycotoxin contamination of food in Malawi in particular, and sub-Saharan Africa in general. The study was supported financially by The McKnight Foundation's Collaborative Crops Research Program (CCRP).

# Executive Summary

The International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) in collaboration with the National Smallholder Farmers Association of Malawi (NASFAM) have for the past year been implementing a project to map the occurrence, significance and distribution of Aflatoxin contamination in Malawi and enhance national capacity for its management in food. The study covered major groundnut producing districts of Malawi: The study covered major groundnut producing districts of Malawi: Lilongwe, Mchinji, Kasungu, Mzimba but also high altitude areas of Phalombe and Ntchisi and the low lying areas of Salima, Nkhotakota and Chikwawa. Sample collection was undertaken from February – March, 2009 targeting samples harvested from the previous (2007/08) season and stored for 8 – 11 months under different conditions as is the common practice in Malawi. A total of 1708 samples of groundnuts and maize inclusive of grains and processed foods were collected from farmer's households, local market vendors, shops, supermarkets and warehouses. Like wise, 1053 soil samples were collected from the farms where grain samples were obtained. For each sample, passport data inclusive of GPS coordinates were captured to facilitate development of a GIS based risk map. Grain samples were prepared for analysis using the ELISA procedure. Soil samples were plated on media culture to determine the abundance of *A. flavus*. Results revealed aflatoxin contamination in groundnut samples ranging from 0.0 ppb to as high as 3871 ppb and in maize 0.0 ppb to 1335 ppb. The abundance of *A. flavus* in the soil ranged from 829 – 16,108 colony forming units (cfu) per gram of soil. Some of the highest contaminated lots were found in the drought prone districts of Chikwawa and Salima. By sample category, groundnut powder had the highest proportion of highly contaminated samples - 73% registering levels above the European Union (EU) acceptance. Approximately 25% of all market samples of powdered groundnut had contamination levels above 100ppb. 43% of all groundnut samples in farmers households, 49% from local markets, 58 – 60% from shops and supermarkets, and 41% from warehouses, had aflatoxin levels above the EU safe limit. The proportion of samples qualifying for the EU export market declined by approximately 30% after 11 months of storage under smallholder conditions from 77% - 54% while the proportion of samples deemed unsafe for human consumption i.e. ($\geq$20ppb) increased by 62%. Similarly for maize, 29% of samples in farmer's households, and 14% in the local markets exceeded the EU safe limits. This study has determined the distribution of aflatoxin in Malawi; tracked crop materials rejected for export on the basis of high aflatoxin accumulation to establish if they form part of peoples diets; established farmer perceptions of mycotoxins in the food chain and developed a GIS based risk map for aflatoxin. Study findings indicate that aflatoxin is a significant problem in Malawi, both in local markets, as well as in shops and supermarkets, which requires urgent and concerted action. The study findings reveal that, in general, aflatoxin contamination was a bigger problem in groundnut than in maize samples from similar sources in Malawi for the reported period. This study has implications for planning an integrated approach for management of aflatoxin contamination in food in sub-Saharan Africa.

## Project Background

Malawi is a land-locked country in southern Africa with a total land area of 118,485 square kilometers (11.78 million hectares, of which 34% is arable). Agriculture contributes over 35% of the country's Gross Domestic Product (GDP) estimated at about $200 per capita. The majority of Malawi's 13 million persons are smallholder farmers and Malawi is still classified as one of the poorest countries in SSA (Action Aid International, 2006). Infant mortality in 2002 was 113 per 1,000 persons (*globalis.gvu.unu.edu/indicator_detail.cfm?IndicatorID=25*) compared with an average of 92 for SSA. The country relies heavily on rain-fed agriculture increasing threats in the event of variations in rainfall as well as commodity price shocks. Between 1970 and 2006, Malawi experienced 40 weather-related disasters, many leading to famines affecting the most parts of the country (Action Aid International, 2006). Average life expectancy, standing at 37 years at birth, is declining due to the impact of HIV/AIDS, which in 1999 affected 16 percent of the adult population and 31 percent of women in ante-natal care (Clay *et al*., 2003). Close to one million adults and children in Malawi are living with HIV/AIDS, with women representing 56.8% of HIV positive adults (15 – 49yrs), one of the highest HIV prevalence rates in the World (UNAIDS, 2004).

In recognition of the foregoing, the Government of Malawi has put in place the Malawi Growth and Development Strategy (MGDS) as an overarching operational medium-term (2006-2011) strategy to attain the nations' Vision 2020. The Strategy, in line with Africa's Comprehensive African Agricultural Development Program (CAADP) (NEPAD, 2003), recognizes the current status of poverty in Malawi as detailed in the Malawi Integrated Household Survey report of 2005, which reveals that 52.4% (or 6.3 million persons) of Malawi's population is poor, with the poorest people largely in the southern region and rural areas being poorer than urban areas (GoM, 2007). As such, the MGDS is cognizant that improving nutrition and income security through agricultural led growth is of paramount importance to the reduction of poverty in the country. Groundnut is a priority crop in Malawi and the increased production of groundnuts is part of a multi-pronged strategy being pursued by the Government to improve national nutrition and income security.

### The role of groundnuts

Groundnuts (*Arachis hypogaea* L) in terms of importance rank sixth among oilseed crops and thirteenth among the food crops of the world. In addition to providing high quality edible oil (48-50%), easily digestible protein (26-28%), nearly half of the 13 essential vitamins and seven of the essential minerals necessary for normal human growth, it produces high quality fodder for livestock. It thus plays a significant role in the livelihoods of marginal farmers through income and nutritional security. Groundnut is grown on 26.4 million hectares worldwide with a total production of 36.1 million metric tons. Developing countries account for 97% of the world's groundnut area and 94% of the total production (ICRISAT, 2006).

In Malawi, groundnut is the most important grain legume grown in terms of the total production and area under cultivation. The crop provides an important source of food and cash income for smallholder farmers and until the mid-1990s was a key export crop. However production and export of the crop has steadily declined since the late 1980s as a result of declining area under production and reduced yields (Freeman 2002). Various reasons have been forwarded for this decline, including climate variability, pest and diseases contamination, including mycotoxins, and competition for export markets. Nutrition security is, however, further dampened by high incidences of mycotoxins that are favored by the tropical temperatures in the semi-arid tropics (SAT), lack of dietary diversity, poor use/access of available technologies and increasingly shorter but unpredictable rainfall patterns.

Mycotoxins are chemical substances naturally produced by fungi that contaminate crops during production, harvest, storage and food processing. Although thousands of mycotoxins exist, few pose significant risks with regards to food safety. In this regard, three genera of mycotoxin-producing fungi are dominant- *Aspergillus*, *Fusarium* and *Penicillium* (Murphy *et al.*, 2006). Aflatoxins, caused by *Aspergillus* spp. are reported to be some of the most potent mycotoxins characterized by carcinogenic, mutagenic, teratogenic and immunosuppressive properties (Ibid; Moss, 2002). Aflatoxins can be found on a wide range of crop species including groundnuts, maize, sorghum, cassava, cottonseed, Brazil nuts, pistachios, spices, dried coconut and figs (Murphy *et al.*, 2006; Mkoka, 2007a). Those common in cereals and legumes are produced by two species of *Aspergillus- A. flavus and A. parasiticus.* The native habitat of *Aspergillus* is the soil, decaying vegetation, hay and grains undergoing microbiological deterioration. Four chemical 'types' of aflatoxins are known- $B_1$, $B_2$, $G_1$ and $G_2$ named from the fluorescence produced when exposed to ultraviolet radiation (B for blue and G for green). Aflatoxin $B_2$ and $G_2$ are dihydroxylated derivatives of $B_1$ and $G_1$ while aflatoxins $M_1$ and $M_2$ are hydroxylated derivatives of $B_1$ and $B_2$ found in milk of cows that have been fed aflatoxin contaminated fodder (Lu, 2003).

**Effects of aflatoxin to humans and livestock**

Known for decades, aflatoxin contamination of groundnut and maize has gained global significance due to the improved knowledge of the deleterious effects that contaminants have on human and animal well-being and the heavy reliance of smallholder populations on the two crops. Sufficient evidence that $AFB_1$ and mixtures of $B_1$, $G_1$ and $M_1$ are proven carcinogens has been provided by the International Agency for Research on Cancer who classifies them as Group 1 carcinogens (IARC, 1993) while $M_1$ and $B_2$ are designated to Group 2B. The deleterious pathway is as follows: $AFB_1$ is metabolized (by the liver) to $AFB_1$-8,9-epoxide (AFBO) or to less mutagenic forms which then can either result in (1) cancer, (2) toxicity or (3) be excreted from the organism. The cancer is thus a result of formation of DNA-adducts by AFBO bonding with genetic material (IARC, 1993; Crespi *et al.*, 1991; Shimada and Guengerich, 1989). Prolonged exposure to doses of 50 micrograms aflatoxin B1/kg/day has clinically significant effects. No animal species has been found to be immune to the effects of aflatoxins (Murphy, 2006).

Outbreaks of acute aflatoxicosis from highly contaminated food have been documented in Kenya, India and Thailand (CAST, 2003). In rural Kenya the outbreak resulted into 317 cases and 125 deaths (CDC, 2004). Aflatoxin-contaminated homegrown maize was the source of the outbreak as was the case in north-western India in 1974 where 25% of the exposed population died from molded maize with levels from 6250 mg to 15,600 mg/kg (ibid). The immunosuppressive effects of aflatoxin have also been shown to be transferred across the placenta and affect the unborn foetus in porcines, suggesting that unborn babies could equally be affected. Consequently, poor nutrition usually attributed to food insecurity, is clearly exacerbated by exposure to aflatoxins, leading to increased disease prevalence and further reduction in the ability of individuals to cope with mycotoxin exposure.

Important here also, is the linkage between aflatoxins and hepatic cellular carcinoma (HCC), hepatitis B and hepatitis C viruses (HBV and HCV, respectively). Many studies, some as early as 1965, have shown linkage between aflatoxin and HCC (Carnaghan, R., 1965; Svoboda *et al.*, 1966; Wogan, 1977; Sun *et al.*, 1999) and later HBV and HCV were also identified as 'etiological risks' (IARC, 1993). Thus, in many regions of the world where there is high aflatoxin contamination, HBV and HCV infections are prevalent and a strong synergism has been reported (Lu, 2003; Qian *et al.*, 1994; CDC, 2004).

The Food and Agriculture organization estimates that mycotoxins contaminate 25% of agricultural crops worldwide (FAO, 2001) and remain a threat to food safety. Close to 4.5 billion people in the developing world are exposed to large amounts of aflatoxin through their diets. According to international standards the allowable levels of aflatoxins in human food are set at 2-30 parts per billion (ppb) depending on the countries involved; animal feeds are allowed up to 300 ppb in United States; while the established maximum safe consumption levels of aflatoxin in maize are 4ppb in the EU and 20ppb in South Africa. Allowable levels in milk are generally significantly lower (Murphy *et al.*, 2006). Regardless, there are still relatively few frameworks and related capacity in place to control movement of contaminated food and feed within the SSA region. Where such frameworks are in place, implementation is often lax or nonexistent. Nonetheless, huge economic losses continue to be attributed to incidences of aflatoxin. According to World Bank studies, European Union regulation on aflatoxins costs Africa huge amounts, one report estimating US$ 750 million each year in exports of cereals fruits and nuts (Otsuki *et al.*, 2001; Diaz Rios and Jaffee, 2008).

**Conditions suitable for occurrence of aflatoxin**

It was once thought that aflatoxin formation only occurred postharvest, i.e. during storage, but it is now well documented that aflatoxin production also occurs in the field prior to harvest. Aflatoxin contamination has been associated with prolonged high day and night temperatures during the growing season and severe drought conditions during grain fill. Risk factors for aflatoxin contamination include three or more weeks drought during pod formation (end of season drought), high moisture/ relative humidity ($83\pm1\%$ or higher at $30^oC$ varying with substrate and length of incubation period) and high temperature with optimum temperatures between $25\text{-}35^oC$ (Schroeder, 1969; Hill *et al.*, 1983; Ramos *et al.*, 1996a&b) or more, rainfall at the end of the growing season that postpones harvest and prevents dry-down. In terms of storage conditions, grains with moisture levels above 9% and moderate temperatures ($28^oC$ to $33^oC$) increase the risk of aflatoxin contamination. Grain damage by insects, rodents, birds, as well as drought stress, which predispose the crop to colonization by the fungus and aflatoxin contamination, can lead to aflatoxin occurrence in groundnuts and maize (Williams et al, 2004 and Desai et al 2008). Evidence suggests that use of low technology approaches at farmer level in SSA at both pre and post harvest could substantially reduce the aflatoxin contamination in Malawi (Mkoka, 2007a & b). However, conditions increasing the likelihood of acute aflatoxicosis, as seen in Kenya in 2004 (CDC, 2004) in humans include limited food availability, optimal environmental conditions for fungal development in crops and commodities, coupled with inadequate regulatory systems for their control. Socio-economic factors that influence crop management practices such as labour shortages, poor access to mechanization, existence of credit mechanisms, power relations and social structure of livelihood pattern influence all have implications on aflatoxin contamination (http://www.cphp.uk.com/projects/default.asp?step=5&projid=42).

**Why the proposed research on aflatoxins in Malawi?**

In Malawi, agriculture is typified by low yields, a heavy reliance on rain-fed agriculture and poor utilization of improved technologies. Household diets are often largely based on two to three major food crops (maize, rice & groundnuts), lacking the diversity that would improve food and nutrition security while simultaneously increasing the occurrence of and potentially aggravating the impact of aflatoxin outbreaks. Various recent reports (Diaz Rios and Jaffee, 2008; Mkoka, 2007a; Malawi Bureau of Standards, personal communication) indicate that aflatoxin contamination could be endemic in many areas of Malawi. Aflatoxins have been reported on various crops and their products including groundnuts, maize, and chilies (Mkoka, 2007b). The nature and extent of distribution of this problem needs to be documented as the basis for intervention programs.

***Aflatoxin and trade:*** One of the key factors behind the reduction in groundnut exports from Malawi during the mid 1980's was the establishment of stiff standards for aflatoxin following improved knowledge on aflatoxins. This arose both as a result of the increasingly unpredictable rainfall patterns and subsequently higher aflatoxin loads in Africa as a whole and particularly Malawi, but also due to the improvement in capacity of trading partners to detect aflatoxins and parallel introduction of trade regulations and limitations based on levels of aflatoxin contamination in food. Aflatoxins continue to be a major limitation to groundnut trade from Malawi. For example, 42% (by volume) of Malawi's exports were rejected by the EU market in 2005 (Diaz Rios and Jaffee, 2008). Thus, any improvement in management of contamination at farm level would potentially result in increased trade with regional and international partners in addition to improved local food safety and health. Making available better information on the distribution of aflatoxins in Malawi, and underlying factors will support efforts to manage contamination at farm level, a critical aspect, in light of the small land holdings characteristic of farming systems in Malawi, and Africa.

***Pre-harvest infection***: Pre-harvest contamination control is critical to success because once infection occurs; it is difficult to completely eliminate it. This stage of control focuses on controlling critical factors that predispose crops to mycotoxin contamination which although difficult in nature, have high potential to mitigate the contamination and its effects. Use of poor quality seed increases pest and disease susceptibility facilitating infection by *Aspergillus* spp, as does poor plant nutrition. Pre-harvest infection by aflatoxin is associated with drought stress (facilitates pod damage and exposure to mould), particularly at the end of season and insect damage (providing entry point for fungus) in the field. Pre-harvest infection is difficult to control without irrigation and pesticide application (FAO, 2001; Craufurd, 2006). Dry pod zones at pre-harvest results into cracks in the pod providing entry for the fungus. These types of cracks are often the main source of contamination and may account for more than 80% of the pre-harvest contamination. Additional contamination may occur at harvest (Craufurd, 2006). A pre-harvest treatment combination including fertilizer and disease management options resulted in permissible levels of aflatoxin contamination when compared with farmer practice in India (http://www.cphp.uk.com/projects/ default.asp? step=5&projid=42). Aflatoxin contamination was found mainly in small and damaged pods while well-filled pods had no aflatoxin (ibid).

***Post harvest infection***: Pre-harvest contamination is very much related to post-harvest accumulation as higher aflatoxin loads at harvest provide inoculum sources for subsequent contamination during storage (Craufurd *et al.*, 2006). After harvest, *Aspergillus* infection and growth is likely if crops are not dried adequately within a short period of time (FAO, 2001). Rain on drying peanuts also often results in contamination. Post harvest practices such as physical separation (sorting) of kernels are very effective in the reduction of mycotoxin levels, with reductions of up to 91% reported (Lopez-Garcia and Park, 1998; Fandohan *et al*., 2005). Studies conducted in Guinea where a postharvest package was compared to usual postharvest practices showed that aflatoxin concentration in blood samples in intervention villages was less than 50% of that in control villages (Turner *et al.,* 2005). Winnowing, washing, crushing and dehulling of maize have also been reported to effectively reduce aflatoxin contamination (Fandohan *et al.*, 2005). ICRISAT has shown that drying methods (avoiding high moisture, slow drying, and air circulation) are common practices that can help reduce or stop contamination (Diaz Rios and Jaffeee, 2008, ICRISAT 2006).

## Objectives of the study

The main objective of the Project was to improve the general understanding of food related aflatoxin contamination risks in Malawi and enhance capacity for management options. Specifically, the study aimed at addressing the following objectives:

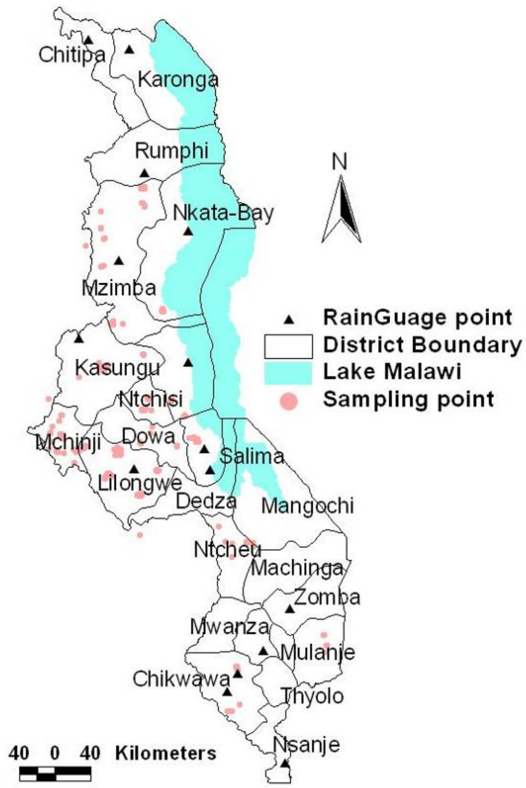
1. Assess the occurrence and distribution of aflatoxin in food in Malawi and trace the pathways for any local products unsuitable for export and,
2. Strengthen capacity of national agricultural research and extension staff for management of mycotoxins in food

## Project outputs

In view of the first objective, the project has provided three major outputs.

a) The distribution of aflatoxin in Malawi was determined by defining the scale of the aflatoxin contamination problem and identifying hotspots where mycotoxin occurrence is higher and assessing levels of aflatoxin contamination in maize and groundnuts.
b) Groundnut lots rejected on basis of aflatoxin load were tracked;
    I. Crop materials rejected for export on the basis of high aflatoxin accumulation were tracked to establish if they form part of people's diets.
    II. Farmer perceptions of mycotoxins in the food chain were established.
c) A GIS based risk map for aflatoxin was developed.
    I. factors that influence aflatoxin contamination in food were identified
    II. The GIS based risk map was developed

*Figure 1: Aflatoxin Project Sites in Malawi*




## Project Sites

The survey was conducted in 11 districts of Malawi. The districts were selected purposively based on maize and groundnuts production levels in the previous cropping season (2007/08), number of cancer cases as reported by Kamuzu Central Hospital and agro ecological zones with respect to altitude. The survey districts included Mzimba (high altitude), Lilongwe, Mchinji, Kasungu, Phalombe (mid altitude), Chikwawa, Nkhotakota and Salima (low altitude).

Dowa, Ntchisi and Ntcheu were included based on cancer cases reported.

## Selection of respondents

Respondents were selected purposively using simple random sampling technique. Only farmers who had both groundnut and maize were interviewed. Proportional probability to sampling (PPS) was used based on groundnut acreage. Three-stage sampling was used to select farmers. Major groundnut and maize producing EPAs were selected at random followed by major producing sections in each EPA. Within the section farmers to be interviewed were selected at random.

## Sample and data collection tool used

Data was collected for a period of three weeks starting from 10 June 2009 to 2 July 2009.

Quantitative data was collected using a structured questionnaire. All interviews were conducted in vernacular language (Chichewa) across all the districts apart from Mzimba where the questionnaire was administered in Tumbuka. Data collected included: respondent and site identification, household composition and characteristics, cropping information for the 2007/08 and 2008/09 seasons, crop production characteristics for the seasons for groundnut and maize, preferred traits in groundnut and maize varieties, post harvest practices, groundnut quality and aflatoxin occurrence information on marketing channels, nutrition and health related information.

Samples were also picked from each interviewed household. Samples collected included maize and groundnut grain but also soil samples where groundnut was produced. A 250g composite sample was collected. Each sample was accompanied by sample data form. The form required enumerators to collect information on farmer's or trader's name, date collected, district, Extension Planning Area (EPA), name of pest and diseases present, field conditions, physical condition of sample and GPS coordinates.

GPS units were used to capture coordinates (latitudes and longitudes) and altitude for all locations of households and crop fields where the data was collected. The data will be used to delineate extent of aflatoxin contamination in the study areas.

## Training of enumerators and quality control

A three day training workshop was conducted in order to acquaint enumerators with the questionnaire. The training sessions concentrated on translation of the questionnaire, interview procedures, mock interviews and pretesting. The training process enabled standardized administration of the questionnaire to all respondents to ensure precision of data collection across households. Pretesting was conducted in order to identify gaps in the data collection instrument particularly validity and reliability, wording and flow of the questions, compliance to time taken to complete the task, and any other unexpected challenges.

## Data entry and analysis

Socioeconomic data were analyzed using statistical package for Social Sciences (SPSS 12). T-test and chi-square were used to test the significance of relationships across variables. Groundnut and maize samples were analyzed using the Indirect Enzyme Linked Immunosorbent Assay (ELISA). The principle of ELISA lies in immobilizing the antigen onto solid surface capturing antigen by specific antibodies and probing with specific immunoglobulin carrying an enzyme label (Waliyar et al 2009). The enzyme retained in case of positive reaction is detected by adding suitable substrate. The enzyme converts substrate to a product, which can easily be recognized by its colour (Anonymous, 2004). Data on aflatoxin levels was summarized using Microsoft Excel.

# RESULTS AND DISCUSSION

### Demographic characteristics

***Sex of the household head***

The survey findings indicated that about 77% of interviewed households were male headed and 22.3% were female headed. Chikwawa had the highest proportion (36.1%) of female headed households while Phalombe (10%) had the least percentage of female headed households. Female headed households are likely to be food insecure as in most cases do not have the capacity to cultivate bigger pieces of land. Furthermore, female headed households are deprived of productive assets due to gender based violence in the name of property grabbing. In Malawi, women are culturally marginalized when it comes to access to credit facilities due to lack of collateral and entrepreneurial skills among other reasons.

***Education levels of household head***

Education is one of the key issues as far as a country's development is concerned. Educated people can easily understand new ideas that can transform their livelihoods. The survey findings indicated that male household heads had more years (6 years) of formal education compared to their female counterparts. An analysis of education levels by district indicated that Mzimba had a better average of number of years of formal education while Dowa registered the lowest average (Refer table 1). This implies that male headed households are likely to adopt technologies that are meant for educated people. The few years of formal education for female households also explains why women in Malawi mostly do farming as it is considered as trade for the uneducated poor families.

***Marital status and age of household head***

The survey findings indicated that about 79% of households were married and stayed with their spouses while 14% were widows and widowers. Phalombe had the highest (90%) percentage of married couples while Ntcheu had the least proportion (71.2%). In terms of age the average age across the all the districts was 47.1 years and the range was 77 years. The minimum age of household head was 18 years. There was a significant age difference between female household heads and male household heads. On average male heads were younger than their female counterparts. This could impact negatively on the male heads particularly on decisions carried out on the farm as age and experience plays a significant role in farming.

*Table 1: Demographic characteristics of household heads*

| | Socioeconomic characteristics of household heads by district | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Characteristics** | **Nkhotakota** | **Salima** | **Dowa** | **Ntchisi** | **Kasungu** | **Mzimba** | **Mchinji** | **Phalombe** | **Chikwawa** | **Ntcheu** | **Lilongwe** | **Total** |
| **Sample size** | 43 | 48 | 35 | 69 | 109 | 122 | 171 | 20 | 36 | 66 | 233 | 952 |
| **Sex** | | | | | | | | | | | | |
| Male | 76.7 | 68.8 | 85.7 | 72.5 | 77.1 | 82.8 | 81.9 | 90.0 | 63.9 | 69.7 | 78.1 | 77.7 |
| Female | 23.3 | 31.3 | 14.3 | 27.5 | 22.9 | 17.2 | 18.1 | 10.0 | 36.1 | 30.3 | 21.9 | 22.3 |
| **Mean age (years)** | | | | | | | | | | | | |
| Male | 46.3 | 43.4 | 49.9 | 41.4 | 45.7 | 46.2 | 44.9 | 48.6 | 48.5 | 43.8 | 47.2 | 45.8 |
| Female | 39.4 | 49.8 | 52.4 | 62.2 | 50.1 | 54.4 | 48.4 | 65.5 | 48.9 | 46.7 | 55.7 | 52.0 |
| **Education (years)** | | | | | | | | | | | | |
| Male | 5.5 | 5.6 | 3.8 | 5.7 | 7.4 | 7.0 | 5.8 | 5 | 5.1 | 5.9 | 5.7 | 6.0 |
| Female | 1.8 | 3.5 | 0 | 4.5 | 4.4 | 5.2 | 3.0 | 2.5 | 1.5 | 4.9 | 3.1 | 3.5 |
| **Marital status** | | | | | | | | | | | | |
| Married living together | 79.1 | 79.2 | 85.7 | 76.8 | 73.6 | 81.0 | 82.5 | 90.0 | 75.0 | 71.2 | 78.1 | 78.7 |
| Married but spouse is away | 4.7 | 4.2 | .0 | .0 | 7.3 | .8 | 1.8 | 5.0 | .0 | .0 | .9 | 2.0 |
| Divorced/separated | 7.0 | 6.3 | .0 | 5.8 | 3.6 | 3.3 | 4.7 | .0 | 5.6 | 9.1 | 3.9 | 4.5 |
| Widow/widower | 9.3 | 10.4 | 14.3 | 17.4 | 13.6 | 14.9 | 9.9 | 5.0 | 19.4 | 16.7 | 16.3 | 14.0 |
| Never married | .0 | .0 | .0 | .0 | 1.8 | .0 | 1.2 | .0 | .0 | 3.0 | .9 | .8 |
| **Occupation** | | | | | | | | | | | | |
| Farming | 95.3 | 97.9 | 94.3 | 94.3 | 94.5 | 95.8 | 98.8 | 100.0 | 94.4 | 93.8 | 93.5 | 95.5 |
| Salaried employment | 2.3 | .0 | 5.7 | 5.7 | 2.8 | 2.5 | .0 | .0 | 2.8 | 3.1 | 1.7 | 2.1 |
| Self employed off farm | 2.3 | 2.1 | .0 | .0 | 1.8 | 1.7 | .6 | .0 | 2.8 | 1.5 | 4.8 | 2.1 |

## Varieties grown by district

The rate of adoption of improved groundnut varieties has picked up in recent years due to a number of factors. The poor rainfall pattern has prompted farmers to exchange good taste in the traditional Chalimbana for high yielding varieties such as Nsinjiro and CG 7. The role of NGOs and other non state actors in distribution of seed has also improved access to quality seed therefore improving adoption of improved groundnut varieties. This has led to displacement of local varieties such as Kasawaya, Chitembana a variety famous for its large kernel, manipintar among others. The most widely adopted groundnut varieties identified during the survey were CG 7, local Chalimbana and Nsinjiro (Table 2). There were also other varieties, which were identified in specific districts due to the agro ecological nature of the areas. JL 24 and Baka are short duration varieties and were common in Nkhotakota, Salima and Chikwawa, places where drought is experienced almost every year and drought induced aflatoxin contamination common. RG1 variety was identified by 21% of farmers interviewed in Phalombe because it requires high amount of rainfall but also perform well in high altitude areas. Majority of farmers sampled are growing local open pollinated maize varieties (49%). A substantial proportion have also adopted the modern high yielding maize hybrids such as MH 18 (18%) DK 8033 (8.3%), SC 627 (4.7%) and the early maturity maize OPV SC 403 (8.5%)

*Table 2: Important groundnut varieties grown in Malawi*

| Groundnut variety | Groundnut varieties cultivated by district during the 2008/09 season | | | | | | | | | | | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Nkhotakota | Salima | Dowa | Ntchisi | Kasungu | Mzimba | Mchinji | Phalombe | Chikwawa | Ntcheu | Lilongwe | |
| CG 7 | 46.7% | 41.0% | 51.8% | 45.7% | 32.0% | 23.0% | 43.8% | 26.1% | 2.3% | 12.2% | 56.6% | 39.1% |
| JL 24 | 2.2% | 29.5% | 3.6% | .0% | 4.0% | 2.5% | 1.0% | 21.7% | 16.3% | .0% | .4% | 4.2% |
| Chalimbana | 6.6% | 2.6% | 30.4% | 39.1% | 32.7% | 47.8% | 25.7% | 17.4% | 7.0% | 64.9% | 28.5% | 30.8% |
| Nsinjiro | 28.9% | 2.6% | .0% | 6.5% | 21.3% | 11.8% | 12.4% | .0% | 4.7% | 1.4% | 9.9% | 10.6% |
| Chitala | .0% | 1.3% | .0% | .0% | .0% | .0% | .0% | .0% | 11.6% | .0% | .0% | .5% |
| Baka | .0% | 2.6% | 1.8% | 3.3% | .0% | .6% | .0% | .0% | 51.2% | .0% | .4% | 2.5% |
| Kalisere | .0% | 3.8% | 1.8% | 3.3% | 6.0% | 5.0% | 5.7% | 4.3% | 2.3% | 6.8% | 1.1% | 3.8% |
| Kasawaya | .0% | .0% | .0% | .0% | .7% | 3.7% | .5% | .0% | .0% | .0% | .0% | .7% |
| Malimba | 2.2% | .0% | .0% | .0% | 1.3% | .0% | .0% | .0% | .0% | 2.7% | .7% | .6% |
| Tchailosi | .0% | 1.3% | .0% | .0% | .0% | 3.7% | 1.0% | .0% | .0% | .0% | .0% | .7% |
| Chitembana | .0% | .0% | 1.8% | 1.1% | 1.3% | .6% | .0% | .0% | 2.3% | 8.1% | .4% | 1.1% |
| Manipintar | .0% | .0% | 3.6% | .0% | .7% | .0% | 1.0% | .0% | .0% | 1.4% | .4% | .6% |
| Solontoni | .0% | .0% | .0% | .0% | .0% | .6% | .0% | .0% | .0% | .0% | .0% | .1% |
| Gambia | .0% | 11.5% | 1.8% | .0% | .0% | .0% | .0% | .0% | .0% | .0% | .0% | .8% |
| Wintoni | 13.3% | 1.3% | .0% | .0% | .0% | .0% | .0% | .0% | .0% | .0% | .0% | .6% |
| Katelera | .0% | 2.6% | .0% | .0% | .0% | .0% | .0% | .0% | .0% | .0% | .0% | .2% |
| RG1 | .0% | .0% | .0% | .0% | .0% | .6% | 4.3% | 21.7% | .0% | .0% | .0% | 1.2% |
| Kanjute | .0% | .0% | .0% | .0% | .0% | .0% | 1.9% | .0% | .0% | .0% | .0% | .3% |
| Mixed gnut varieties | .0% | .0% | 3.6% | 1.1% | .0% | .0% | 2.9% | 8.7% | 2.3% | 2.7% | 1.8% | 1.6% |
| # of samples | 45 | 78 | 56 | 92 | 150 | 161 | 210 | 23 | 43 | 74 | 274 | 1206 |
| | 100.0% | 100.0% | 100.0% | 100.0% | 100.0% | 100.0% | 100.0% | 100.0% | 100.0% | 100.0% | 100.0% | 100.0% |

## Main seed sources in Malawi

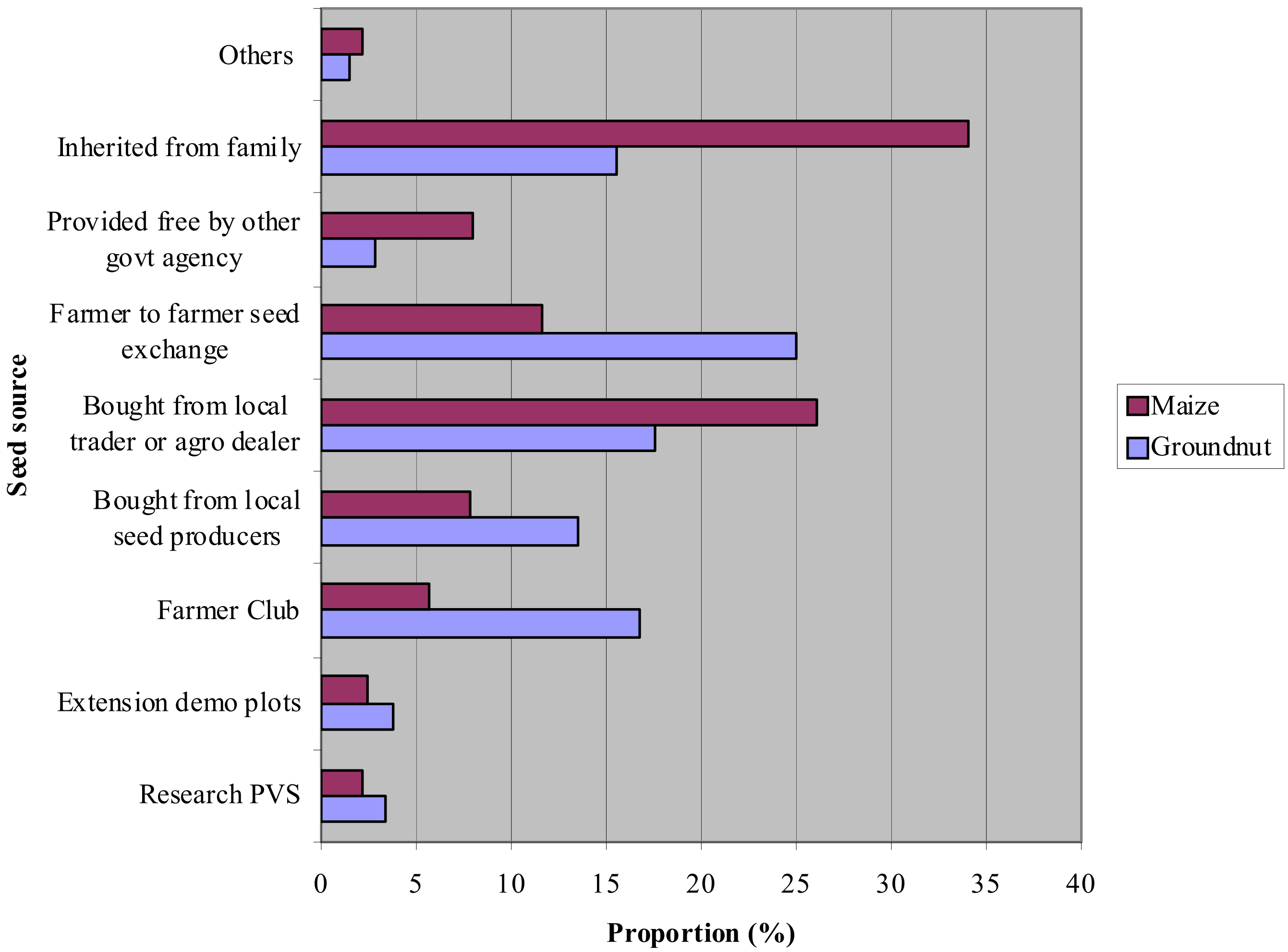
### *Groundnut seed sources*

The quality of seed planted is also determined by the seed source. Seed sources are very crucial as far as attainment of high yields and planting of disease resistance varieties is concerned. About 31% of farmers indicated that they bought their seed either from local seed producers or agro dealers. However, most of the seed producers in the surveyed areas are not registered seed producers who can sell certified seed. The other important source of seed identified was through farmer to farmer seed exchange whereby about 25% of farmers interviewed mentioned this source, which is very common in Phalombe and least, practiced in Chikwawa. Farmers club were introduced with the aim of promoting new agricultural technologies and the tool lived to its billing providing seed to about 16.8% with Chikwawa having the highest proportion of 51.2% followed by Kasungu (32.4%). Chikwawa had the highest proportion of farmers because of a previous Nordic Development fund (NDF) Project, which established community seed banks where farmers club accessed seed in form of credit. Use of low quality seed can promote occurrence of aflatoxin in groundnuts as it may affect crop establishment and growth. Farmers who obtained seed from accredited sources are assured of planting disease and pest resistant materials.

### *Maize seed sources*

The low adoption of improved maize varieties has resulted from the susceptibility of improved varieties to storage pests and the costs attached to buying improved seed every season. Other farmers subscribe to the idea that improved maize is not poundable as a result farmer's stick to the local maize variety. Seed inherited from family members constituted the biggest share (34.1%) of maize seed sources followed by seed bought from local traders and agro dealers (26.1%). Those farmers who at some point hosted trials and demonstrations also utilized the grain from the demonstration plots as seed. This source was mentioned by 4.6% of farmer respondents and this may result to planting materials, which are not ready to be used as seed hence compromising on yield and other traits under scrutiny by plant breeders. Farmer to farmer seed exchange cannot be ignored in rural communities. The practice was identified mainly in Dowa where 24% of respondents exchanged their maize seed with other maize varieties and least practiced in Salima. The proportion of farmers obtaining seed from formal sources was very high among maize farmers unlike in groundnuts. The trend is like this because of increased number for maize seed than groundnut. Agrodealers have expressed concern on over reliance of recycled seed among groundnut farmers hence making selling of groundnut seed unprofitable. Figure 2 summarizes the main sources of seed by crop.

*Figure 2: Seed sources in Malawi*



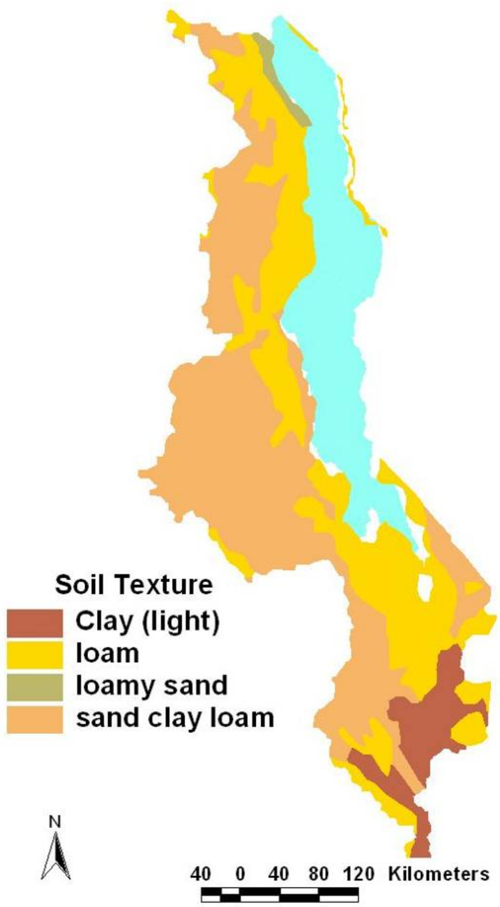

## CROP PRODUCTION CHARACTERISTICS

Occurrence of aflatoxin contamination is a function of several factors which include field conditions in terms of soil fertility levels, soil types, soil and water conservation structures, water logging conditions and occurrences of drought. Post harvest handling of the crop can also influence aflatoxin contamination.

### Soils and Soil fertility levels

About 24% of interviewed farmers indicated that their fields had good fertile soils. The survey findings indicated that 37% of interviewed farmers in Mzimba had good fertile land due to availability of virgin land while Dowa was the lowest. Respondents in Dowa were cultivating in rocky soils due to the mountainous nature of the area and high population pressure. Those farmers who reported to have good fertile soils are likely to produce crops that can resist aflatoxin contamination because the plants will grow vigorously and be able to overcome drought. As for groundnuts soils that are rich in calcium will produce pods that are tough and able to resist fungal infection. A total of 59.8% of farmers in the study area indicated that their soil fertility levels were low to medium.

*Figure 3: Soil types in the surveyed districts*




**The major soils of Malawi**

The types of soil where plants are cultivated will determine the speed at which the plants will grow other factors being constant. Generally, loam and clay soils are more fertile than the sandy soils in Malawi. The survey results indicated that about 36% of interviewed farmers were cultivating in fields that had loam and sandy clay loam soils while 34.4% of farmers were cultivating in loamy red soils (katondo). The proportion of farmers cultivating in sandy soils was high in Kasungu (50%) followed by Chikwawa.

**Soil-water management technologies**

Soil-water harvesting technologies are very essential in ensuring that moisture and fertility levels are maintained. Availability of moisture enhances plant growth hence need to construct water conservation structures in the fields. In total about 40% of interviewed farmers reported to have constructed soil water management technologies in their fields.

These farmers are likely to produce crops that will resist aflatoxin contamination due to drought stress because the plants will be able to use conserved moisture in times of plant stress. Use of irrigation facilities to boost crop growth was almost non-existent as relatively few farmers reported to have irrigated their crop. In terms of distribution, Phalombe had the highest proportion of farmers with soil and water conservation structures in their fields while Kasungu and Chikwawa recorded the least proportions of farmers who had soil-water conservation structures.

Water logging is one of the factors that also determine availability of *A. flavus* that can result to contamination of crops while in the field. Growth of fungus favors moist conditions and fields that are waterlogged are likely to have fungus, which can result to pre-harvest infection. About 25% of interviewed farmers reported that they cultivated in waterlogged fields during the 2008/09 season. It will be important to assess contamination levels of crops produced under these conditions in order to correlate the two parameters. The proportion of farmers who were cultivating in waterlogged soil conditions was high in

Chikwawa because most farmers in the district cultivate in the shire riverbanks in order to exploit the alluvial soils coupled by the readily available moisture.

## Time of planting and end of season drought

Occurrence of aflatoxin in crops is also affected by time of planting. Crops that are planted with the first rains are likely to escape end of season drought therefore allowing adequate time for grain filling. End of season drought is very critical as it affects grain filling and pod formation in groundnut. Grain filling and pod formation requires sufficient moisture and drought during this critical period will affect these physiological processes. Under severe drought conditions, the groundnut pod cracks providing entry points to *A.Flavus* which then establishes itself inside the kernel. The kernel is thus immature and looks shriveled. These shriveled kernels contain higher amounts of aflatoxin contamination as a result of the *A.Flavus* invasion.

The study findings indicated that at least 90% of interviewed households planted with the first rains increasing probability of the crops completing grain filling and pod formation before the cessation of rains. In Phalombe all the interviewed farmers had planted with the first rains whereas Nkhotakota 83% had planted with the first rains. Generally crops planted three weeks after the first rains are likely to be affected by aflatoxin contamination due to lack of moisture at pod filling stage. The proportion of farmers who had planted very late was significantly high (above 10%) in tobacco producing districts of Dowa, Nkhotakota, Lilongwe, Kasungu, Mchinji, Salima and Mzimba (Table 3). Most farmers in these districts were giving priority to tobacco before maize and groundnut, as it is their main source of cash income. Generally, groundnuts are the last crop to be planted in tobacco growing areas. Due to shortage of labor, many farmers plant their groundnuts crop late increasing chances that the crop may experience end of season drought. About 20% of households reported to have faced end of season drought in all the districts although rainfall distribution varied between districts. Chikwawa had the highest proportion (79.7%) of farmers who faced end of season drought followed by Kasungu (44.9%). These districts are likely to have crops that are contaminated with aflatoxin other factors such as post harvest handling, storage conditions and insect pests infestation being constant.

***Table 3: Crop production characteristics in Malawi***

| | Field conditions by district | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Characteristics** | Nkhotakota | Salima | Dowa | Ntchisi | Kasungu | Mzimba | Mchinji | Phalombe | Chikwawa | Ntcheu | Lilongwe | Total |
| | | | | | | | | | | | | |
| **Soil fertility levels** | | | | | | | | | | | | |
| Poor | 11.8% | 12.4% | 27.2% | 16.1% | 13.1% | 13.2% | 12.3% | 12.0% | 15.3% | 20.3% | 19.3% | 15.6% |
| Medium | 54.8% | 58.7% | 63.0% | 71.3% | 69.5% | 49.0% | 59.6% | 60.0% | 55.9% | 60.1% | 58.4% | 59.8% |
| Good | 33.3% | 28.9% | 9.9% | 12.6% | 17.1% | 37.8% | 28.0% | 28.0% | 28.8% | 19.6% | 21.5% | 24.3% |
| **Soil types** | | | | | | | | | | | | |
| Loam (dark brown) | 31.2% | 24.6% | 37.2% | 30.2% | 10.9% | 22.8% | 21.0% | 32.0% | 6.8% | 24.3% | 18.2% | 21.3% |
| Brown (Sandy) | 18.3% | 20.2% | 25.6% | 29.1% | 50.0% | 28.8% | 28.3% | 20.0% | 49.2% | 36.5% | 20.0% | 29.2% |
| Red (katondo) | 21.5% | 28.9% | 24.4% | 25.0% | 32.2% | 29.5% | 33.9% | 26.0% | 1.7% | 33.1% | 52.3% | 34.4% |
| Grey/black (clay) | 29.0% | 26.3% | 12.8% | 15.7% | 6.9% | 18.9% | 16.8% | 22.0% | 42.4% | 6.1% | 9.6% | 15.0% |
| **Soil water conservation structures** | | | | | | | | | | | | |
| Yes | 47.9% | 39.8% | 39.5% | 31.6% | 25.4% | 37.5% | 45.0% | 78.0% | 27.1% | 43.2% | 40.2% | 39.1% |
| No | 52.1% | 57.7% | 60.5% | 68.4% | 74.6% | 62.2% | 54.2% | 22.0% | 72.9% | 56.8% | 59.0% | 60.4% |
| Irrigated | .0% | 1.6% | .0% | .0% | .0% | .3% | .8% | .0% | .0% | .0% | .8% | .5% |
| **Water logging conditions** | | | | | | | | | | | | |
| Yes | 27.7% | 20.3% | 30.9% | 24.7% | 19.9% | 27.3% | 23.9% | 26.0% | 35.6% | 27.0% | 23.6% | 24.7% |
| No | 72.3% | 79.7% | 69.1% | 75.3% | 80.1% | 72.7% | 75.8% | 74.0% | 64.4% | 73.0% | 76.0% | 75.2% |
| **Time of planting** | | | | | | | | | | | | |
| Early planted | 83.0% | 90.2% | 78.2% | 95.4% | 87.3% | 91.1% | 90.0% | 100.0% | 94.9% | 95.9% | 89.2% | 90.1% |
| Late planted | 17.0% | 9.8% | 21.8% | 4.6% | 12.7% | 8.9% | 10.0% | .0% | 5.1% | 4.1% | 10.8% | 9.9% |
| **End of season drought** | | | | | | | | | | | | |
| Yes | 31.9% | 27.3% | 9.9% | 17.6% | 44.9% | 7.3% | 9.6% | 36.0% | 79.7% | 21.6% | 11.9% | 20.1% |
| No | 68.1% | 72.7% | 90.1% | 82.4% | 55.1% | 92.7% | 90.2% | 64.0% | 20.3% | 76.4% | 88.1% | 79.7% |

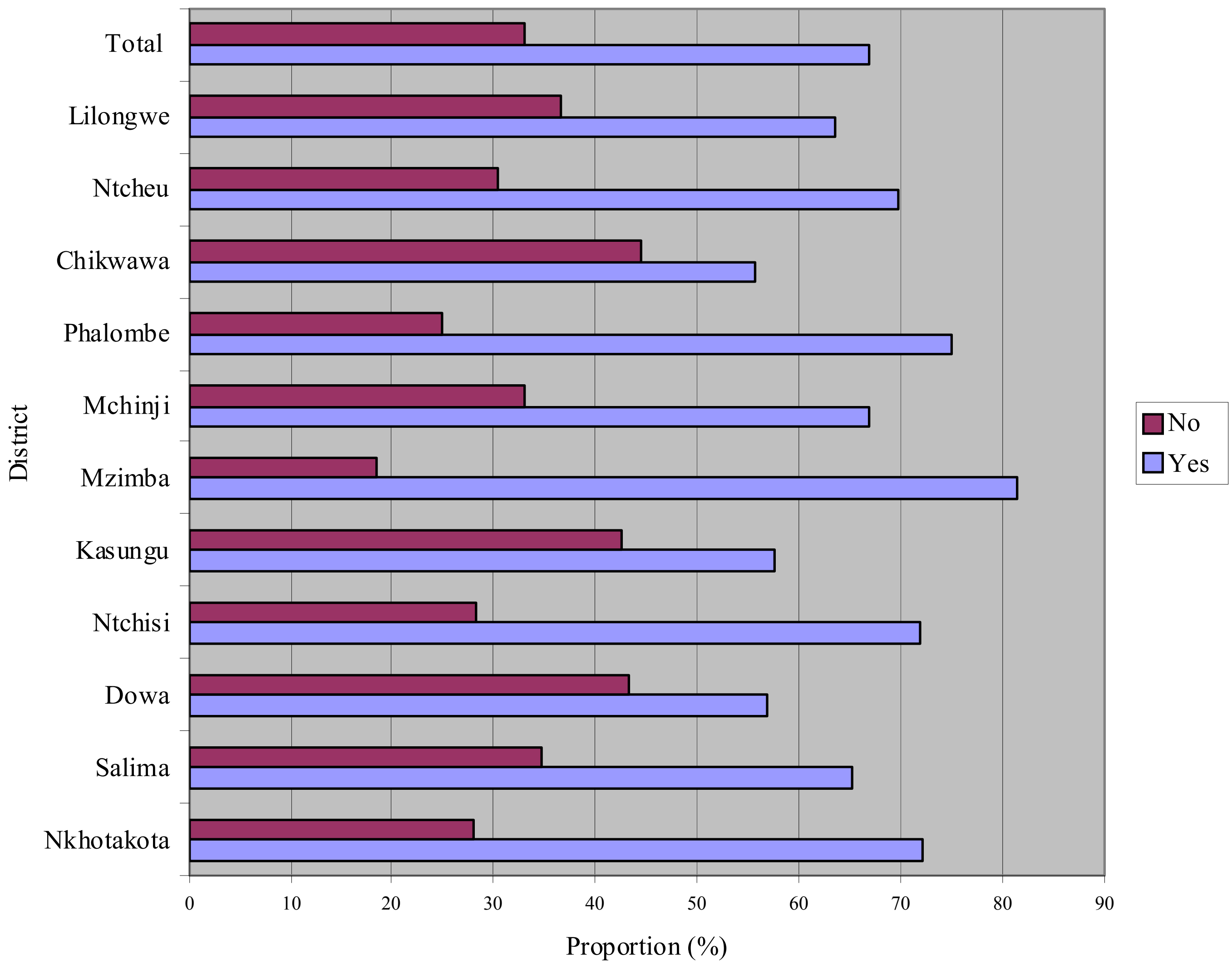
## Farmers awareness of aflatoxin

The study also wanted to assess farmers' awareness of aflatoxin in groundnuts. It was established that about 65% of respondents were aware of the condition. Mzimba registered the highest proportion (81%) of farmers indicating that they were aware of aflatoxin. This could be attributed to highest literacy levels of respondents. Even though this is the status, most of the respondents identified aflatoxin-infested nuts as only those, which were rotten. This poses a great threat to the nation as shrivels and mechanically damaged nuts were considered suitable for consumption. Even though two-thirds of respondents were aware, there is need to increase dissemination of aflatoxin information due to its fatal effects especially bearing in mind that at least 25% of respondents in each district indicated that they were not aware of aflatoxin.  Those that said were aware thought that their crop was only contaminated when they could see fungal growth and rotting.

The main identified sources of aflatoxin information were other farmers as reported by 52.6% of respondents, radio programs (31.9%) and other agricultural institutions. There is need to encourage formation of farmers clubs as they assist dissemination of new technologies. The public extension service was identified as the third important source of aflatoxin information. It was mentioned by 24% of respondents although the proportion was high in Kasungu. Although the department of agricultural extension was established to provide advisory services to farmers it is faced with a lot of challenges among them increased farmer- extension worker ratio, mobility problems and lack of training on emerging new technologies (Personal communication).  It will therefore be important to train private extension officers working for NGOs on effects of aflatoxin so that they can assist in creating awareness, as most of the NGOs were not mentioned as sources of aflatoxin information an indication that there is knowledge gap in the private sector as well.

Apart from awareness, the study also tried to assess proportion of farmers who had experienced aflatoxin problem in their households. About 80% of respondents had indicated to encounter the situation in their homesteads. Most farmers mentioned CG7 as the variety that was very susceptible to aflatoxin contamination Nkhotakota and Chikwawa registered the highest proportion of farmers who encountered the situation in their harvest. Most farmers associated aflatoxin with rotten nuts leaving out issues of shriveled grain. This could have negative implications as household members would be consuming shrivels hoping that it is safe from aflatoxin therefore increasing the risk of aflatoxicosis.

***Figure 4: Farmers awareness of aflatoxin***

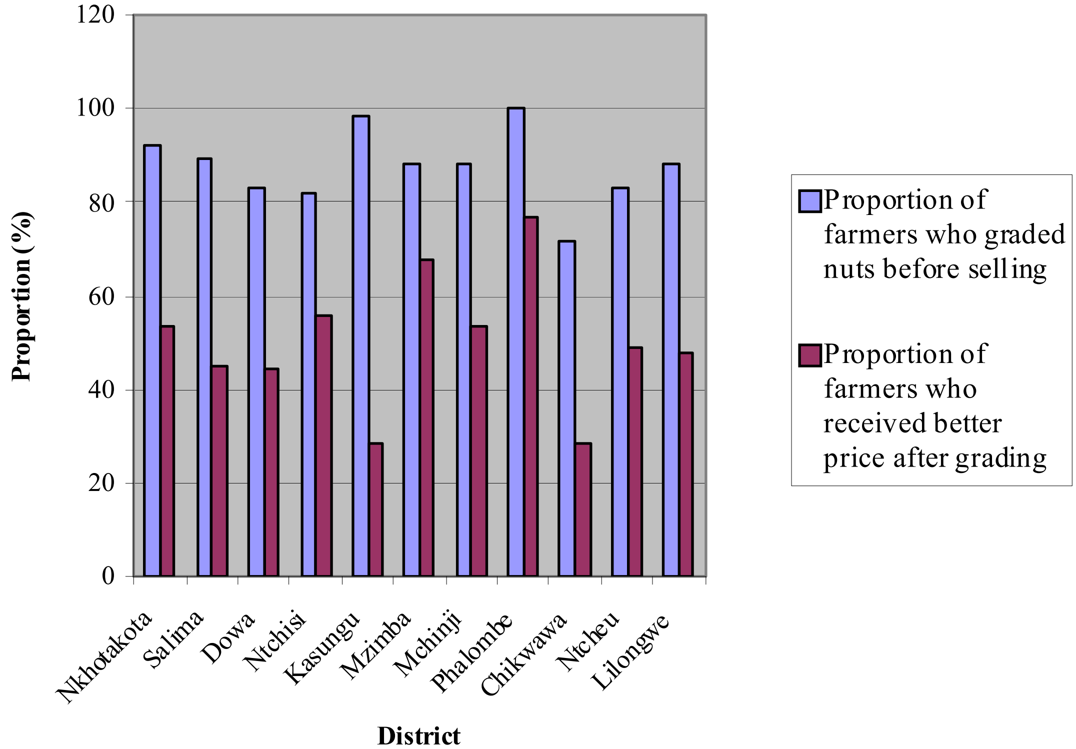



## Groundnut Grading

Groundnut grading used to be an important aspect in the days when ADMARC was exercising its monopoly in the marketing of agricultural products. The liberalization of the markets increased competition among buyers and this ultimately caused buyers to pick anything available. The findings indicated that 88% of farmers had graded their nuts before selling. However visits in the market had shown groundnuts, which was of high quality but soaked. Farmers were soaking the nuts to increase weight because some traders were cheating on them through use of defective weighing scales. However, in some other instances farmers were selling unshelled groundnut leaving out the question of grading.

Farmers were also interviewed regarding the issue of price incentive after grading. The findings indicated that 50% of the farmers received a better price while the rest indicated that there was no premium for quality nuts after grading. However, some farmers indicated that they used to enjoy better prices when ADMARC was active in buying farm produce from farmers. Lack of improved prices after grading acts as a disincentive to farmers hence most farmers ignoring issues of quality.

***Figure 5: Proportion of farmers grading nuts***




## Levels of aflatoxin contamination in groundnut and maize

Samples collected in the surveyed districts were analyzed in the laboratory to assess contamination levels of aflatoxin. A total number of 1708 samples were collected in all the districts. The breakdown of samples collected is summarized in table 4 below

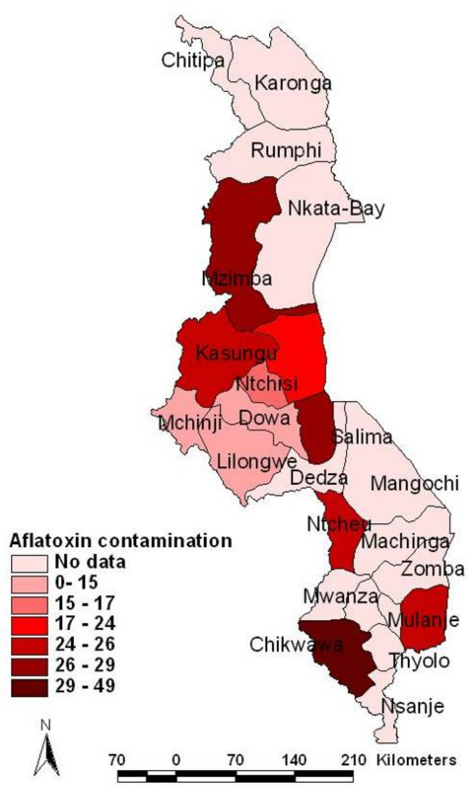
***Table 4: Number of samples collected***

| **District** | **Number of groundnut samples** | **Number of maize samples** | **Total** |
|---|---|---|---|
| Chikwawa | 38 | 4[a] | 42 |
| Dowa | 53 | 13 | 66 |
| Kasungu | 137 | 67 | 204 |
| Lilongwe | 284 | 101 | 385 |
| Mchinji | 210 | 98 | 308 |
| Mzimba | 150 | 85 | 235 |
| Nkhotakota | 52 | 38 | 90 |
| Ntcheu | 90 | 35 | 125 |
| Ntchisi | 86 | 41 | 127 |
| Phalombe | 21 | 13 | 34 |
| Salima | 68 | 24 | 92 |
| Total | 1189 | 519 | 1708 |

[a] *Very few maize samples available for collection in Chikwawa. Chikwawa district mainly grows sorghum and pearl millet.*

The results from the laboratory showed that some samples were free from aflatoxin while others were over contaminated. From the AFB1 analysis, a higher proportion (83.6%) of maize samples were within a safe range (0-4ppb) for human consumption as compared to 76.9% of groundnut samples within the same range. Analysis by district indicates that Mzimba, Nchisi and Phalombe had a higher proportion of their maize contaminated by aflatoxin than groundnuts. In all other districts groundnuts was more contaminated. The high rainfall experienced in these districts partly contribute to delay in harvesting or harvesting the crop with high moisture content exposing the grain to more contamination as a result of lack of dry down. Some of the short duration maize varieties are also not covered by the sheath at the tip therefore the moisture easily results to rotting of grain. A number of factors can be attributed to the differences among others the high adoption rate of improved maize varieties compared low adoption rate of improved groundnut varieties. A good proportion of farmers interviewed (26.1%) indicated that they had obtained maize seed from agro-dealers, which generally sell certified seed. Generally, these agro dealers sell short duration maize varieties, which escapes drought thereby avoiding aflatoxin contamination. In the drier areas, other predisposing factors such as nature of the crop also may contribute to contamination. The fact that groundnut pod filling takes place in the soil predisposes the pods to *A. flavus* fungus that produces aflatoxin. Agro ecological zones also have played a major role in aflatoxin contamination. This was evident in Chikwawa and Salima, which experienced erratic rains.

***Figure 6: Map of Malawi showing occurrence and distribution of Aflatoxin contamination in ppb in individual districts***

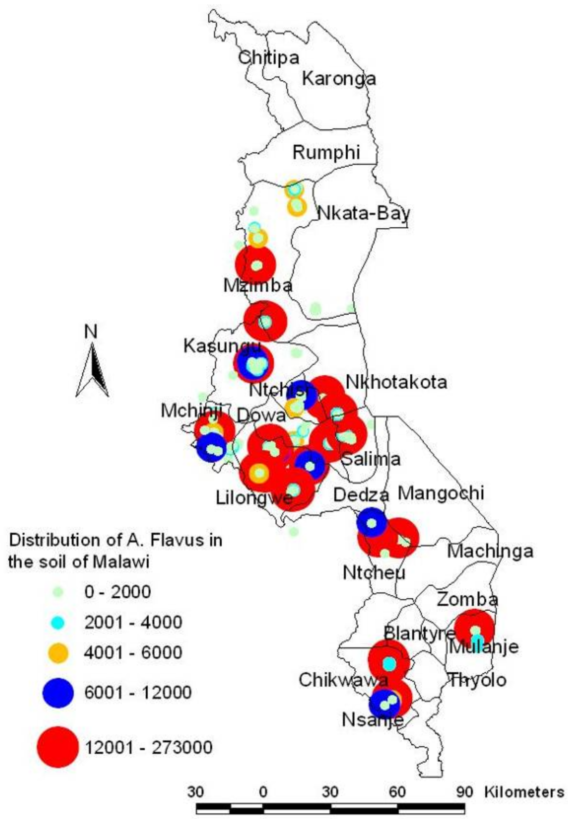



## Distribution of Aflatoxin Contamination by District in Malawi

Out of the 11 major groundnut growing districts sampled, as can be seen, the highest distribution of contamination is found in Chikwawa, Mzimba, Salima, Kasungu, Ntcheu, Mulanje, Nchisi, Nkhotakhota, Mchinji, Dowa, Lilongwe in this order. One has a 15% – 17% chance of pitching a sample that has 4 ppb or higher in Mchinji, Dowa and Lilongwe. The probability increases to 17 – 24% in Ntchisi and shoots to 24 – 26% in Kasungu, Ntcheu and Mulanje. The districts with highest levels of contamination are Mzimba, Salima and Chikwawa where the chance of pitching a sample with contamination level greater than 4ppb is between 26 – 49%.

It is gratifying to note that the districts where ICRISAT and NASFAM have invested in distribution of improved high yielding varieties and training in aflatoxin management, (Mchinji, Lilongwe and Dowa) have also registered the least contamination.

***Figure 7: Map of Malawi showing occurrence and distribution of the Aflatoxin causing fungus (A. flavus) in individual districts*.**




## Distribution of *A. flavus* by district in Malawi

**Soil sampling**

From each selected farmer, random spots were identified in a 0.5ha portion of the farm. The top 1 cm soil was removed and 50 g soil sample collected from 3 – 7 cm depth at 5 random spots in the field. A total of 1053 samples were collected from 11 important groundnut growing districts in the country. The samples were mixed and stored in a labeled brown paper envelop and brought to the research station where it was air dried at $35^0$C for 4 days, ground into fine powder and screened through a 20 wire mesh sieve to get rid of plant debris.

**Plating the soil samples**

From each sample, 10 g screened soil was suspended in 90 mls distilled water. Serial dilutions of 1 x $10^3$ and 1 x $10^4$ were prepared from which 0.5ml was spread in an AFPA medium plate. Two plates of each dilution or 4 plates per soil sample were then incubated at $28^0$C in the dark for three days. The plates were then examined on the fourth day for colony forming units (cfu) of *A.flavus*/ *A. parasiticus*. Bright orange yellow pigmented colonies from each plate were counted and the total number of CFU determined by multiplying with the dilution factor used in each sample.

***A.flavus* / *A. parasiticus* distribution**

The fungus is widely distributed across all groundnut production areas of Malawi. The distribution varies from as low as 0 in many parts of the counry to as high as 273,000 cfu / gram of soil in Chikwawa. Chikwawa district has the highest average contamination – registering 16,108 cfu/ g soil, followed by Lilongwe 9,833 cfu/ g soil and Salima 6767 cfu / g soil. The least contaminated district is Mzimba with 828 cfu / g soil. For details of the abundance see Table 5 and the risk map.

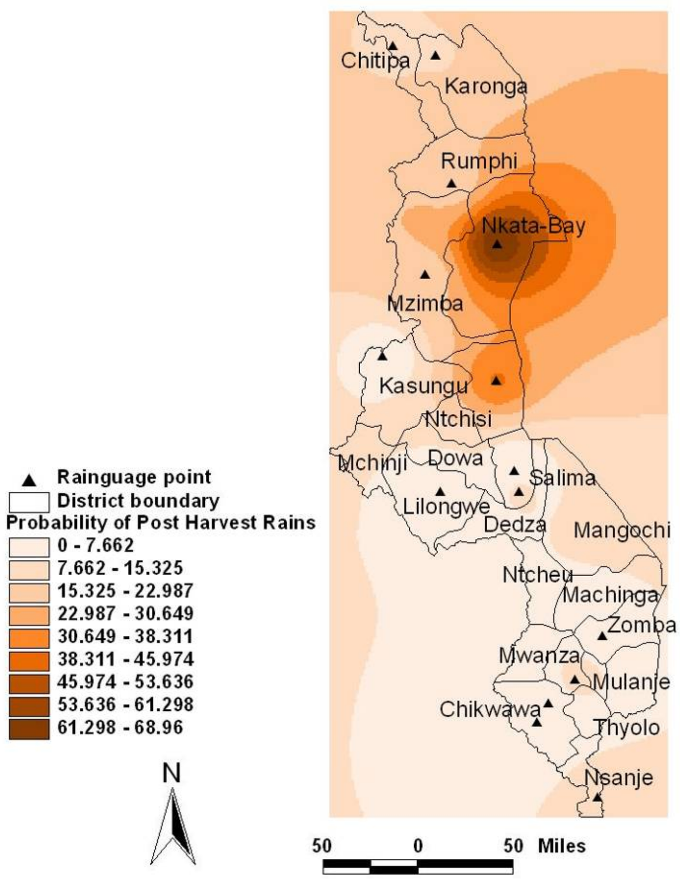
*Table 5: Distribution of A. flavus/ A.parasiticus across Districts in Malawi*

| District | CFU/g of soil |
|---|---|
| Chikwawa | 16108 |
| Dowa | 3260 |
| Kasungu | 2648 |
| Lilongwe | 9833 |
| Mchinji | 1935 |
| Mzimba | 828 |
| Nkhotakhota | 1975 |
| Ntcheu | 3550 |
| Ntchisi | 1193 |
| Phalombe | 1357 |
| Salima | 6767 |

The fungus is clearly abundantly distributed in the areas with highest pre-harvest aflatoxin contamination – or drought induced contamination Chikwawa, Salima, parts of Lilongwe and Ntcheu. In areas like Mzimba where the fungal load is low, much of the aflatoxin contamination is a result of poor post harvest handling of the crop. This suggests need for different strategies of tackling the aflatoxin contamination problem in different agro-ecologies of Malawi.

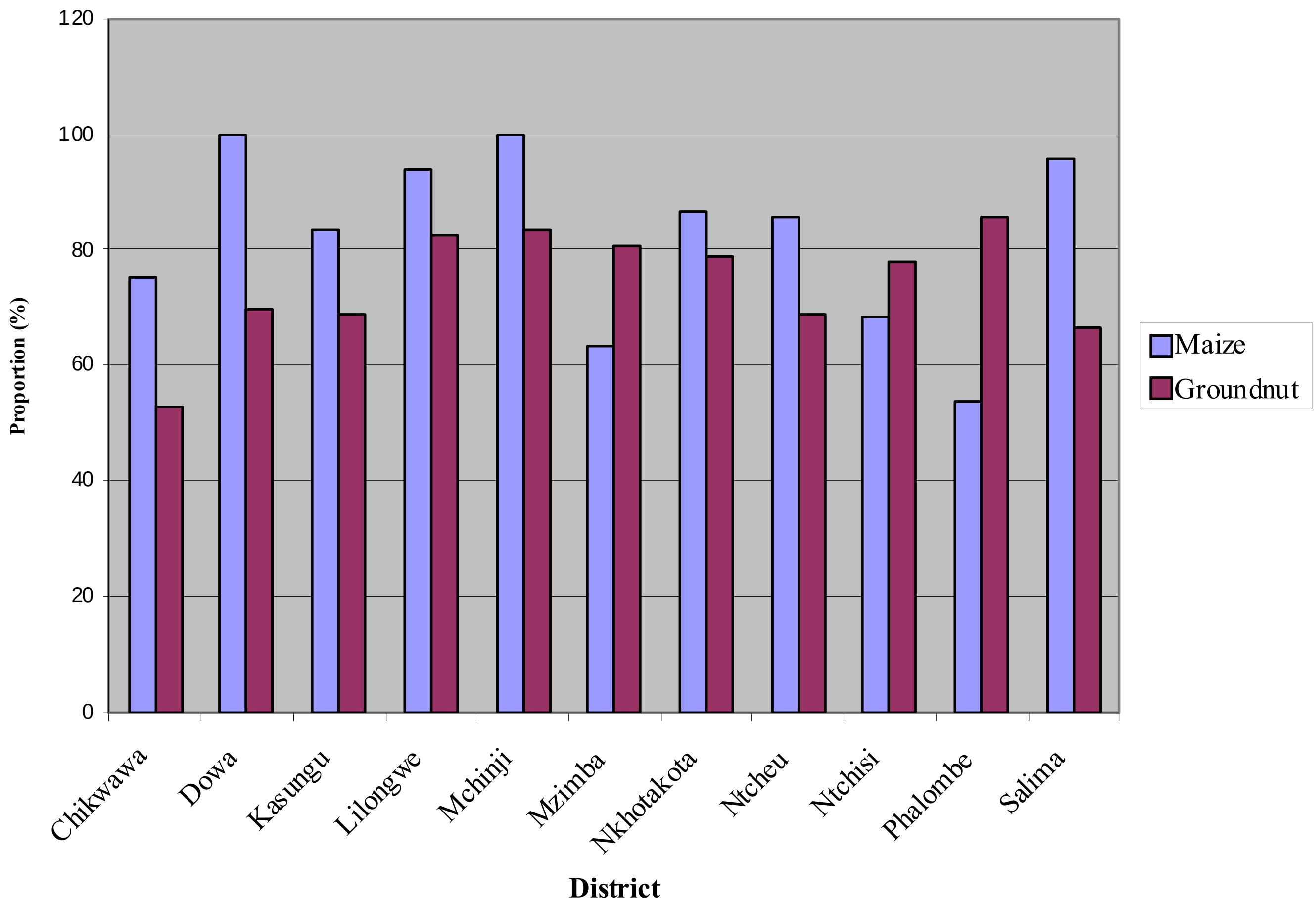
## GIS based risk map for post-harvest contamination

***Figure 8: Probability of Post-harvest Contamination***




In Malawi, groundnuts can be planted as early as mid November to mid January. The season also ends as early as end of March to mid May. Generally, in the higher potential areas, rains start early (November) and ends latest (April / May). The areas most prone to late rains and therefore potential for post harvest contamination includes Nchisi, parts of Mzimba, Rumphi, (30 – 45% probability of receiving more than 50mm rainfall in the month of April/May – when the crop is already mature and or being harvested). This agrees very well with the observed contamination of maize in Mzimba and Nchisi. Among groundnut producing areas, we have low probabilities of post harvest contamination due to late rains in Lilongwe, Dowa, Salima, Dedza, Ncheu, and Machinga (0 – 8% chance of receiving more than 50 mm rainfall in April).

*Figure 9: Proportion of samples meeting EU market requirements*




## Aflatoxin levels in groundnut by source

It is worth mentioning that some of the groundnut samples were collected from traders. Although in other cases the varieties purchased were mixed, it was necessary to analyze contamination levels by source bearing in mind that farmers sell the best nuts but also knowing that they soak their nuts before shelling. An interview with some of the traders and farmers indicated that they sun dry the soaked nuts to control the growth of fungus on the kernels. The fact that about 70% of groundnut produced in 8 of 11 sampled Malawi districts is safe for EU market is positive news, which can boost the country's income in the wake of volatile tobacco prices but the fact that more than 30% did not meet the standards needs attention. The greatest danger lies in the fact that these contaminated lots are consumed locally.

## Effect of storage form and time on aflatoxin contamination

The survey findings indicated that about 97% of respondents store their groundnuts in unshelled form. This is due to the labor-intensive nature of the crop at shelling but also keeps the grain from storage pests other than to maintain viability at germination. Storage form of groundnut has an effect on the levels of aflatoxin contamination. The shells impede penetration of moisture preventing germination of the fungus inside the pod thereby keeping the nuts aflatoxin free. After analyzing the samples based on storage form, it was observed that groundnuts stored in unshelled form had higher percentage (77.3%) of samples which were within the EU export (0-4.0 ppb) category unlike shelled nuts (70.1%). The effect of the shells is further vindicated in the other categories as the severity of contamination increases as summarized in table 6 below with double the proportion of nuts unsafe for human consumption (≥20ppb) in the shelled samples as was found in the unshelled samples (14.8% vs. 7.7%)

***Table 6: Extent of contamination in groundnuts by storage form***

| | Proportion (%) of samples within groundnut category | |
|---|---|---|
| Contamination levels (ppb) | Shelled | Unshelled |
| 0-4 | 70.1 | 77.3 |
| 4.1-10 | 13 | 12.8 |
| 10.1-20 | 2.6 | 2.2 |
| 20.1-100 | 7.8 | 2.6 |
| >100 | 6.5 | 5.1 |
| Total | 100 | 100 |

**Comparison of aflatoxin contamination in groundnuts over time**

Groundnuts samples collected from different sources between November 2008 to February, 2009 and kept for up to 11 months under typical smallholder storage conditions in Malawi were analyzed for aflatoxin contamination, and the results compared with newly harvested samples; collected between May and June 2009 or 1 – 2 months after harvest.

***Table 7: Aflatoxin results from different sample categories under storage.***

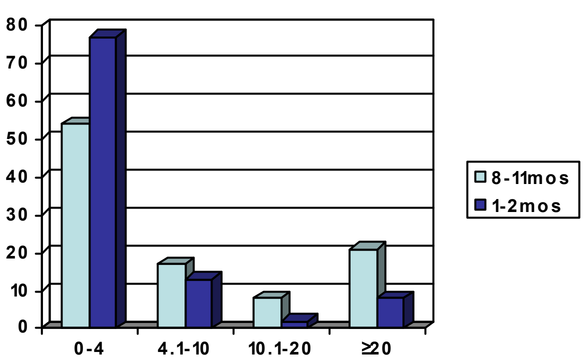
| Groundnuts sample category | AFB1 Concentration in ppb | Proportion within EU Limits ≤4ppb after 2months / or 11 months | Proportion exceeding Limits ≥4ppb after 2months / or 11 months |
|---|---|---|---|
| Shelled | 0.0 – 2273 | 70 / 59 | 30 / 41 |
| Unshelled | 0.0 – 3871 | 76 / 60 | 24 / 40 |
| Powder | 0.0 – 653 | 27 | 73 |
| Roasted | 0.0 – 367 | 57 | 43 |
| Peanut Butter | 5.3 – 543.6 | 0.0 | 100 |
| Peanut based Ready to Use Food (RTF) products | 2.8 – 57.8 | 20 | 80 |

Aflatoxin contamination in samples ranged from 0.0 ppb to as high as 3871ppb. At harvest, 76% of all samples were within the EU safety limit of below 4ppb. Only 24% would have been rejected of these 8% with dangerously high levels (20 - > 3000 ppb). After 11 months of storage, the category of nuts qualifying for the EU market had declined from 70% - 59% in among nuts stored shelled and from 76% to 60% among nuts stored in the shell (unshelled). The proportion of rejected nuts in the same period shot up from 30% of those shelled to 41% whereas the unshelled category also shot up from 24 – 40%. After discussing with farmers whose samples registered dangerously high levels of aflatoxin contamination, we understood that some of them added water to soften the shell for ease of shelling. Groundnut powder had the highest proportion of highly contaminated samples - 73% registering levels above the EU acceptance. Approximately 25% of all market samples of powdered groundnut had contamination levels above 100ppb. It was sad to observe that 43% of all roasted nuts in local shops would not meet the EU safety standards and peanut butter in super markets had contamination levels ranging between 5.3 to as high as 543.6 ppb. This implies that some of the worst peanuts find their way into the peanut butter industry as well. Though some ready to use foods had acceptable low levels of contamination, there were some with levels as high as 57.8 ppb levels considered unsafe for human consumption – yet these are considered as special formulas for convalescent people

***Table 8: Aflatoxin results by sample collection source of samples under storage for 8-11 months***

| Groundnuts sample source | Samples (n) | Concentration in ppb | Proportion within EU Limits ≤4ppb | Proportion exceeding Limits ≥4ppb |
|---|---|---|---|---|
| Farm house | 213 | 0.0 – 2197 | 57 | 43 |
| Local market | 152 | 0.0 – 1643 | 51 | 49 |
| Local Shops | 12 | 0.9 – 1316 | 42 | 58 |
| Super market | 15 | 0.0 – 543.6 | 27 | 63 |
| Warehouse | 17 | 5.3 – 804 | 59 | 41 |
| Others | 11 | 2.8 – 471 | 55 | 45 |

Forty three percent of all samples in farmers households, 49% from local markets, 58 – 63% from shops and supermarkets, and 41% from warehouses, had aflatoxin levels above the EU safe limit. Similar results have been reported by ICRISAT in India (Waliyar et al 2003). The drought prone districts Machinga, Salima, Nkhotakhota also registered high proportions of contamination (44 – 86% of samples) above EU safety limits after 11 months storage.




The proportion of samples qualifying for the European Union export market declined by approximately 30% after 11 months of storage from 77% - 54%. The proportion of samples deemed unsafe for human consumption i.e (≥20ppb) increased by 62% from about 8% - 21%. Ironically, Kasungu, Ncheu and Salima are also important groundnut production districts of Malawi – hence high contamination lots in these districts also implies high levels of toxin exposure to the inhabitants of these districts. Post-harvest contamination of groundnuts is thus a serious problem under smallholder conditions in Malawi.

Chikwawa, Kasungu, Ncheu and Salima had the highest proportions above EU acceptance.

***Figure 10: Aflatoxin in groundnut samples under different storage regimes***

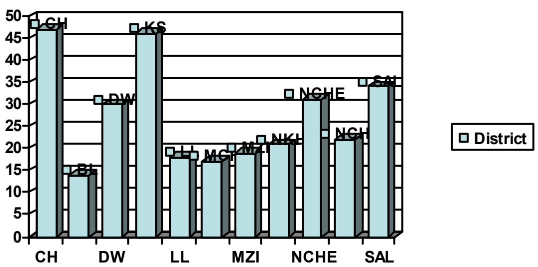
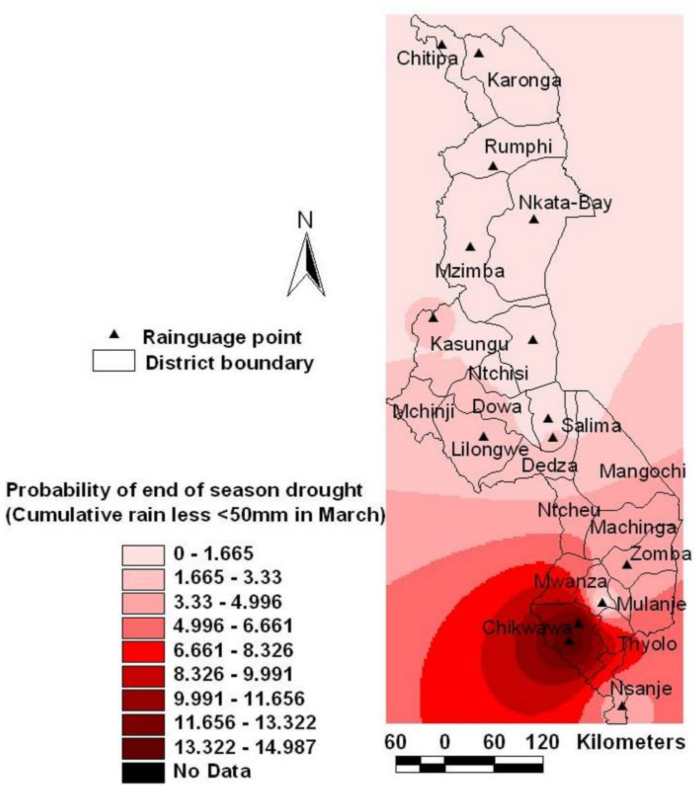



***Figure 11 Aflatoxin proportion above EU acceptance by district*** *(CH=Chikwawa), BL=Blantyre, DW=Dowa, KS=Kasungu, LL=Lilongwe, MCH=Mchinji, MZI=Mzimba, NKH=Nkhotakhota, NCHE=Ncheu, NCH=Nchisi, SAL=Salima)*

**Comparison of aflatoxin in maize over time**

A comparison of average aflatoxin levels relative to time of storage indicated that there was a build up in levels as the crop was stored over a longer period of time. The contamination trend was similar to groundnuts in that samples stored longer had higher levels of aflatoxin contamination – the exception being Mzimba, Ncheu, and Phalombe. These districts received late rains increasing chances for post-harvest contamination as a result of poor handling by farmers.

***Figure 12: Probability of Pre-harvest Contamination.***




In maize, the greatest source of contamination seems to be a result of post harvest handling. Malt flour which is prepared by soaking in water to pre-fement the flour seems to have the highest contamination level with values from 0 – 1335ppb, followed by bran flour 0 – 805ppb. During periods of hunger many family households survive on bran flour so this can be a significant source of contamination for maize. Grain held by farmers and vendors also had contamination levels ranging from 0 - 800ppb. It is worth to note that 60% of all malted grain had levels above the EU safety limit while 80% of all bran flour had levels of contamination above the EU acceptance .

## GIS based Risk map for pre-harvest contamination

The variations in contamination levels across district are partly because of altitude and rainfall pattern. Chikwawa had registered the highest groundnut mean contamination across the surveyed districts. Other districts with significant levels of contamination are Kasungu, Salima, Ncheu, and Ntchisi. It is worth noting that these are the same districts with high cases of cancer as reported by Kamuzu Central Hospital in Lilongwe. Chikwawa had the highest mean because of dry spells as clearly indicated in the probability of early termination of rains Figure 12. Pre-harvest contamination is mostly induced by early termination of rains. The impact of this is mostly felt in the dry short season districts. Chikwawa for example has approximately 15% probability of receiving less than 50 mm of rainfall in March leading to end of season drought and thus higher chance of pre-harvest contamination. Other areas include Ncheu, Machinga, Nsanje

## Aflatoxin contamination levels by variety

It was observed that there were variations in aflatoxin contamination across varieties. In groundnuts most of the short and medium duration varieties were more affected than long season varieties. Chitala, JL 24 and Baka were identified as the most susceptible varieties. The majority of farmers growing these short to medium duration varieties were from low altitude low rainfall areas (Chikwawa and Salima) but also areas which experience drought in the mid of the season like Kasungu. Some of the long season groundnut varieties with low contamination were Nsinjiro, Chalimbana, Chitembana, Chalimbana 2005 and CG 7. (Table 9). These varieties are large seeded confectionary market types normally planted in the high potential groundnut production zones. They are therefore not exposed to drought induced aflatoxin contamination. It is worth mentioning that none of the currently released varieties is resistant to aflatoxin contamination. Since genetic resistance is an important aflatoxin management component, development of resistant varieties should be given due importance.

***Table 9: Distribution of aflatoxin by variety in groundnuts***

| **Variety** | **Number of samples** | **0-4** | **4.1-10** | **10.1-20** | **20.1-100** | **>100** |
|---|---|---|---|---|---|---|
| Other gnut varieties | 16 | 93.8 | 6.3 | 0 | 0 | 0.0 |
| Baka | 28 | 64.3 | 21.4 | 3.6 | 3.6 | 7.1 |
| CG 7 | 472 | 75.8 | 12.1 | 2.8 | 4 | 5.3 |
| Chalimbana | 302 | 77.2 | 14.9 | 2.3 | 0.7 | 5.0 |
| Chalimbana 2005 | 58 | 79.3 | 10.3 | 3.4 | 3.4 | 3.4 |
| Chitala | 6 | 33.3 | 33.3 | 0 | 33.3 | 0.0 |
| Chitembana | 6 | 83.3 | 16.7 | 0 | 0 | 0.0 |
| Gambia | 12 | 75 | 16.7 | 0 | 0 | 8.3 |
| JL 24 | 43 | 74.4 | 11.6 | 0 | 7 | 7.0 |
| Kalisere | 22 | 77.3 | 4.5 | 0 | 9.1 | 9.1 |
| Groundnut local | 113 | 77 | 13.3 | 1.8 | 1.8 | 6.2 |
| Malimba | 6 | 83.3 | 0 | 0 | 0 | 16.7 |
| Nsinjiro | 96 | 83.3 | 10.4 | 1 | 2.1 | 3.1 |
| RG1 | 4 | 100 | 0 | 0 | 0 | 0.0 |
| Tchailosi | 5 | 80 | 0 | 0 | 0 | 20.0 |

AfB1 levels in maize indicated that Pannar 77, SC 403 and ZM 621, an OPV maize variety, were most affected whereas SC 627 and MH 18 were observed to be the least contaminated by aflatoxin (Table 10).

***Table 10: Distribution of aflatoxin by variety in Maize***

| | | Proportion of varieties within a specified aflatoxin range (ppb) | | | | |
|---|---|---|---|---|---|---|
| **Variety** | **Number of samples** | **0-4** | **4.1-10** | **10.1-20** | **20.1-100** | **>100** |
| DK 8033 | 42 | 83.3 | 11.9 | 2.4 | 0 | 2.4 |
| DK 8071 | 6 | 83.3 | 0 | 0 | 0 | 16.7 |
| Other hybrids | 29 | 82.8 | 13.8 | 0 | 3.4 | 0.0 |
| Local | 249 | 84.8 | 10.4 | 2 | 0.8 | 1.6 |
| MH 12 | 9 | 87.9 | 0 | 0 | 0 | 0.0 |
| Pannar 77 | 6 | 50.0 | 33.3 | 0 | 0 | 16.7 |
| SC 403 | 43 | 67.4 | 18.6 | 7 | 4.7 | 2.3 |
| SC 627 | 24 | 91.7 | 4.2 | 4.2 | 0 | 0.0 |
| ZM 621 | 9 | 42.9 | 14.3 | 14.3 | 0 | 14.3 |
| MH 18 | 91 | 87.9 | 11 | 1.1 | 0 | 0.0 |

Generally maize varieties which did not have a complete sheath cover were more exposed to contamination. Varieties with hard vitreous endosperm are generally less prone to mycotoxin contamination as exemplified by majority of the farmer's local varieties generally known to have hard vitreous endosperm and hybrids like MH 12 and MH 18.

## Volumes rejected and pathways taken by rejects

During sample collection period among traders, no case was reported of groundnut that had been rejected because of poor quality. This shows that although traders and farmers are aware of aflatoxin and its effects on health, there are no stringent measures to control aflatoxin between buyers and farmers. Only those organizations targeting the EU Market like NASFAM considers issues of quality serious. Some traders had their own grading but sub-standard facilities preferring to buy cheap grain from farmers and sorting out the bad ones themselves.

**Volumes rejected due to aflatoxin contamination**

On average 7.5kg of nuts was rejected per farmer. On further examining the rejects, we discovered that 69.4% of interviewed groundnut farmers had rejects of less than 5kg. Further analysis indicated that about 15% of farmers had lost up 10kg of groundnut as a result of aflatoxin contamination. The highest volume of rejected groundnut was 340 kg. However, interview with traders indicated that they were only rejecting rotten nuts, which were infested by fungus. Most of the traders were seen drying the nuts which they bought from farmers soaked in an attempt to ease shelling and compensate for defective weighing scales.

**Ranges of groundnut rejects due to aflatoxin from the 2007/08 sample survey**

| Amount rejected (kg) | Frequency | Percent |
|---|---|---|
| 0.1-5 | 393 | 69.4 |
| 5.1-10 | 82 | 14.5 |
| 10.1-20 | 46 | 8.1 |
| 20.1-50 | 40 | 7.1 |
| >50 | 5 | .9 |
| **Total** | **566** | **100.0** |

**Pathways taken by grade outs**

One of the objectives of the study was to identify pathways taken by groundnut grade outs including those affected by aflatoxin. It was discovered that farmers threw away only groundnut that was literally rotten as reported by 48.2% of respondents. Otherwise the rest of groundnut is used as groundnut flour, seed and given to livestock as feed. Bearing in mind that groundnut is not easy to produce in Chikwawa, the majority of farmers use inferior shriveled nuts to make groundnut flour. The practice is also common in Ntcheu, Salima, Ntchisi, Kasungu and Lilongwe (Table 11).

***Table 11: Pathways taken by groundnut grade outs***

| | **Pathways taken by groundnut grade outs** | | | | |
|---|---|---|---|---|---|
| **District** | **Fed to livestock** | **Thrown away[1]** | **Consumed as groundnut flour** | **Used as seed** | **Left in the field** |
| Nkhotakota | 7.7% | 61.5% | 30.8% | .0% | .0% |
| Salima | .0% | 40.0% | 60.0% | .0% | .0% |
| Dowa | 10.5% | 47.4% | 36.8% | .0% | 5.3% |
| Ntchisi | 14.3% | 42.9% | 42.9% | .0% | .0% |
| Kasungu | 4.0% | 52.0% | 42.0% | 2.0% | .0% |
| Mzimba | 7.7% | 69.6% | 25.3% | .0% | .0% |
| Mchinji | 6.7% | 51.1% | 40.0% | 1.1% | .0% |
| Phalombe | .0% | 66.7% | 33.3% | .0% | .0% |
| Chikwawa | .0% | 21.4% | 71.4% | 7.1% | .0% |
| Ntcheu | 2.9% | 28.6% | 68.6% | .0% | .0% |
| Lilongwe | 1.6% | 38.8% | 55.0% | 4.7% | .0% |
| Total | 4.8% | 48.2% | 44.9% | 1.7% | .2% |

[1] *Farmers only threw away rotten nuts. Broken, shriveled nuts are ground into groundnut flour.*

## Sensitization Workshops for Policy Makers, NARES and Private Sector

***Stakeholder and Project Start-up Workshop***

A one day workshop was arranged and conducted at the ICRISAT Conference Room at Chitedze Agricultural Research Station, Lilongwe, Malawi on 5 December, 2008. Involved in the workshop were 22 participants representing various aflatoxin stakeholder groups including research and extension, farmer representatives, processors and traders from the private and public sector.

Participants to the Stakeholder's start up workshop held at the ICRISAT Malawi Conference Room

The Principal Investigator Dr. E Monyo reviewed background information to the project and rationale, justifying the need to determine and document the status of aflatoxin contamination in Malawi. He also emphasized the linkages between the Aflatoxin

Project and the on-going Groundnut Breeding Project for East and Southern Africa also funded by the McKnight Foundation CCRP. An overview on research progress and current knowledge on aflatoxins was presented by Dr. F Waliyar, ICRISAT Director for West and Central Africa and an authority in Aflatoxin Research at ICRISAT. Experiences, from the medical fraternity in Malawi on aflatoxin effects on human health were presented by Dr. F Madinda, a surgeon from the Kamuzu Central Hospital. Presentations were also delivered on the impact of aflatoxins on trade by NASFAM and Tambala Food Processors representing the private sector. One of the main achievements of the Workshop was the opportunity for sharing information from the key stakeholders, and resulting in improved understanding of the aflatoxin problem. A second achievement of the workshop was the coming together of key stakeholders in Malawi, particularly the interest shown by the Medical fraternity, to discuss strategies for documenting the magnitude of the aflatoxin problem and its implication on human health in Malawi.

### *Project Steering Committee Meeting*

Parallel to the ongoing McKnight Foundation funded project, UNIDO initiated a one year study on Capacity Building for Aflatoxin Management and Control in Groundnut and Paprika in February 2009. Some of the activities of this study were similar to what we were doing so we decided where possible we should join hands. We agreed the best way of getting the ‘buy in’ and attention of the policy makers was to create a steering committee to guide and advise on the project which composed of policy makers. This committee established in September 2009 has The Permanent Secretary of the Ministry of Agriculture and Food Security (Dr Andrew Daudi) as its chair and draws memberships from Ministry of Industry and Trade, Malawi Export Promotion Council, Malawi Bureau of Standards, Department of Agricultural Research Services (DARS), Farmer’s World, NASFAM, and ICRISAT. The committee met at Chitedze Research Station on 24th September, 2009 to review progress, plan outstanding issues and recommends the way forward. Among major outcomes from this meeting was the agreement by UNIDO to equip the DARS Laboratory with state of the art equipment for Aflatoxin determination. This is expected to support the national efforts to regain the groundnuts export market it has lost due to inability to properly determine the composition of contamination in the crop before export.

### *End of Project Reporting Workshop*

Due to delays in procuring of laboratory chemicals and reagents for *A.Flavus and A.Parasiticus*, the project could not be completed at the planned end of project date 31st August, 2009. The last batch of reagents was finally received in October, 2009 so analysis was completed in December, 2009, and final write up in January 2010. A one day reporting workshop was held on 21st January, 2010 at Lilongwe. To show the keen interest The Government of Malawi has in the project The Perrmanent Secretary Ministry of Agriculture and Food Security Dr Andrew Daudi attended and contributed to discussion of the findings. The Workshop was attended by 25 stakeholders who included representatives from The Ministry of Health, Malawi Bureau of Standards, Malawi Exports Promotions Council, Private Sector (Mulli Brothers, Tambala Foods, Export Trading Company), Department of Research Services (DARS-Malawi) NASFAM and ICRISAT. We also had representatives from Communities of Practice for the Post-harvest value chain technologies project (From Sokoine University) and from the groundnut breeding project Naliendele Research Station in Tanzania. The major agreements from this workshop was the need to develop stronger links with


Participants to the End of Project Workshop held at the Pacific Hotel - Lilongwe Malawi the Ministry of Health to document the effects of contamination on the human population, strengthen the Capacity of the Malawi Bureau of Standard in monitoring locally processed foods to ensure compliance, capacity building for routine testing, capacity building of consumers and knowledge of farmers in reducing contamination levels.

## Training Workshops to sensitize NARES on Aflatoxin and its management

A 4 day training of frontline staff workshop was organized for two major groundnuts producing districts – Lilongwe and Kasungu from 30$^{th}$ June – 10$^{th}$ July with a session for each district. A total of 27 NARES from different Agricultural Extension Planning Areas, District Health Offices and NASFAM Field Officers attended. The training involved presentations on health risks of aflatoxin to human, the groundnuts production chain, critical points for intervention to manage and control aflatoxin contamination and aflatoxin as a trade barrier. The presentations were followed by group discussions on the topics and individual assignments to gauge the understanding of the trainees. We learned that the topic on risk management analysis needed more time and effort to be clearly understood and implemented at farm level. The participants finally developed an action plan tackling three main issues: Lack of awareness, Training materials and knowledge of management tactics. It was obvious more such training are required if the problem of aflatoxin is to be known, understood and action taken.

## Conclusions, lessons learned and further research

The occurrence of aflatoxin in Malawi is not crop specific as evidenced by presence in the two target crops maize and groundnuts. Groundnuts from farmer's households registered the highest level of 3871 ppb. The dangerously high levels of contamination are indicative of the fact that farmers sell the best nuts and leave for themselves the inferior nuts for consuming slowly in their homesteads.

The study also discovered that only those nuts, which were completely rotten, were thrown away. However, shriveled nuts, groundnut splits and bruised nuts were ground into groundnut powder popularly used to prepare groundnut based relish and sources. Groundnut remains the cheapest most easily available source of protein among most Malawians.

Aflatoxins were further rampant in districts that experience dry spells. Some of the districts that registered highest levels of aflatoxin were Chikwawa, Kasungu, Salima and Ntcheu. Districts, which receive high rainfall, also recorded high levels of aflatoxin contamination particularly in maize. This was true in Phalombe and Mzimba. This finding suggests need for different strategies for tackling the aflatoxin problem. Genetic resistance can contribute significantly to the issues of pre-harvest contamination in the dry areas whereas storage may play a significant role in the high rainfall zones. Genetic resistance should therefore be seriously considered as a component in the overall management of the aflatoxin contamination problem. Since groundnut and maize forms important diets in Malawi, it is clear that farmers are at risk of being exposed to aflatoxin. The study further indicated that most farmers shell their nuts manually, an activity that is tedious and labour intensive. It would be necessary to promote mechanical shelling to dissuade farmers from soaking the nuts to make the pods soft.

Best quality nuts at harvest come from the Central and North: Mchinji, Lilongwe, Dowa and Ntchisi. These are also the areas known for excess production accounting for the nuts that could be held under storage for up to 11 months. In these areas, storage becomes a problem – leading to highest contamination later in the year. Though there is high inoculum load of *A.Flavus* in the soil in Lilongwe and Dowa, conditions for pod cracking and fungal penetration are not optimal – until harvest when the rains have ended. Thus high soil inoculum load in Lilongwe and Dowa is likely to cause infection in seasons of drought, or if harvesting is overly delayed, or if a wrong variety which matures before end of rains is planted

Areas with highest grain contamination are: Chikwawa, Salima, Mzimba, Kasungu, Ntcheu and Mulanje. Areas with highest soil contamination are: Chikwawa, Lilongwe, Salima, Ntcheu, Kasungu. Chikwawa, Salima, Ntcheu and Kasungu have high *A.Flavus* load and are exposed to drought induced pre-harvest contamination. Mzimba and Mulanje have low *A.Flavus* load but are predisposed to late season rains which create conditions for post-harvest contamination.

***What next?***

We now know something about Aflatoxin occurrence and distribution and the extent of soil contaminatin by the aflatoxin causing fungi *A.Flavus/A.Parasiticus* as a result of this study. However, we do not know how this has affected the health of population in Malawi we only have anecdotal speculations. There is need to establish whether contamination in food translates to elevated aflatoxin load in affected individuals. We also need to establish whether elevated aflatoxin load in the population is related to diseases. In other words, does aflatoxin in food products translates into aflatoxin load in humans and does it have any relationships to the aflatoxin health related diseases eg HCC, esophageal cancer, congenital malformations etc currently observed in Malawi?

On Aflatoxin and Human Nutrition: we need to establish whether the state of human nutrition is at risk in Malawi as a result of aflatoxin contamination of foods. For example it might be important to know if any relationship exists between dietary aflatoxin and HIV/AIDS.

On Aflatoxin and agriculture: More studies are needed to ascertain the source of dietary contamination and its management. There is need to ensure that the general public is knowledgeable about aflatoxin and its effects on health. To this end there is need to rigorously disseminate available aflatoxin reducing technologies while building capacity of front line staff and farmers through farmer friendly integrated aflatoxin management packages; that include host plant resistance

On Aflatoxin and Policy: There is need to strengthen efforts to ensure that policy is well informed of the pandemic and its effects on the health of the population. For example there is need to have regulations for aflatoxin contamination on locally traded commodities in Malawi. There is good monitoring of commodities being exported but no such rigor on locally processed groundnut products for local consumption. There is also a need to work with policy to establish and enforce a national code of safety for aflatoxin in Malawi.

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