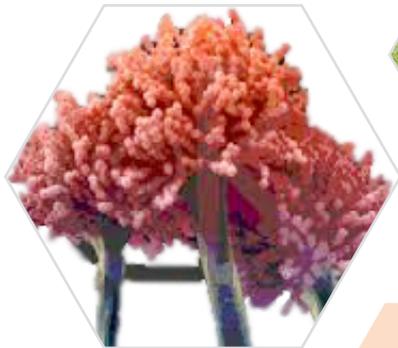


# Aflatoxin Timeline





# Aflatoxin Timeline

## What is Aflatoxin?



- Aflatoxin was discovered in the 1960s. Regulatory limits were enforced in 1980.
- Aflatoxin is a poisonous substance produced by mould fungi (*Aspergillus flavus* and *A. parasiticus*) that can grow on poorly managed agricultural crops, particularly groundnuts.
- If eaten in sufficient quantities, aflatoxin can cause serious sicknesses that can lead to liver and several other cancers.
- Groundnuts for sale and export should be free from aflatoxin.
- Therefore appropriate crop management is essential at pre- and post-harvest times.
- Aflatoxin is carcinogenic and can cause liver and other cancers in humans.
- It increases incidents of hepatitis viruses B and C.
- It lowers the body's normal immune response to invasion by foreign substances.
- It impairs growth in children, notably in Africa, and causes childhood cirrhosis in India.
- In poultry and livestock, aflatoxin can cause feed refusal, loss of weight, reduced egg production, and contamination of milk.

## Effects of aflatoxin



Aflatoxins are carcinogenic. FAO has declared that **25%** of all crops in the world are affected by aflatoxins. Countries in Africa have lost their export markets as a result. It affects the absorption of other nutrients thereby causing malnutrition.



<http://www.icrisat.org/aflatoxin-timeline>



**The Food and Agriculture Organization (FAO) has declared that 25% of all crops in the world are affected by aflatoxins. Predominantly, these toxins affect:**

- Cereals and millets (maize, sorghum, pearl millet, rice, wheat)
- Oilseeds (groundnut, soybean, rapeseed, sunflower, cotton)
- Spices (chillies, black pepper, coriander, turmeric, ginger)
- Tree nuts (almond, pistachio, walnut, cashewnut, hazelnut, Brazil nut, tiger nut, coconut)
- Pulses (pigeonpea, horse gram, green gram, mung bean, lentil, cowpea, haricot bean)
- Figs, meats, dairy products and fruit juices (apple, guava)

**The Center for Disease Control has estimated that more than 4.5 billion people in developing countries are chronically exposed to aflatoxins in their diets.**

**Together with its donors and partners, ICRISAT has made contributions and scientific achievements towards finding solutions to aflatoxin contamination in Asia and sub-Saharan Africa.**

# 1970s

## ICRISAT starts aflatoxin research

Many agricultural commodities are vulnerable to attack by a group of fungi that produce toxic metabolites called mycotoxins. Among these mycotoxins, aflatoxins have assumed significance due to their harmful effects on human beings, poultry and livestock and their implications for international trade. Worldwide attention began to be paid to aflatoxin contamination when peanut meal from Brazil fed to poultry killed thousands of birds in the United Kingdom. After examination it was found that the meal was highly contaminated with aflatoxin. This was the first time attention was drawn to this contaminant. Regulatory measures were put in place across several countries along with levels of acceptable contamination in parts per billion (ppb). ICRISAT began initiating research on aflatoxins by identifying sources of resistance and development of methodologies for screening.

# 1980s

## ICRISAT develops a few breeding lines with partial resistance

ICRISAT's focus turned to the following:

### Integrated Management

- Technologies for pre-harvest, post-harvest and storage
- Identification of high-yielding resistant genotypes
  - \* Developing robust screening methods
  - \* Markers for resistance, e.g. lipoxygenase genes

### Assessment of risk to health of humans and livestock

#### Socioeconomic issues

- Public awareness

- Management options to reduce contamination
- Implications on international trade

### Breeding for resistance

- Conventional breeding
- Non-conventional approaches to develop resistant cultivars
- Antifungal genes (chitinase)

### Utilization of biological control agents

- Examples: Trichoderma, Pseudomonads

# 1987-2007

## Addressing regional priorities in West and Central Africa

Projects were undertaken on improving groundnut breeding systems for drought tolerance and disease tolerance in West and Central Africa. This included several projects addressing regional priorities identified by Conseil Ouest et Centre Africain pour la Recherche et le Développement Agricoles/West and Central African Council for Agricultural Research and Development (CORAF/WECARD), and implemented by national agricultural research organizations in collaboration with ICRISAT.

### Impact

- Delivery of groundnut varieties resistant to drought and aflatoxin
- Enhanced stakeholder knowledge to manage aflatoxin

# 2000s

## Strategic plan for aflatoxin research developed

ICRISAT developed a strategic plan for aflatoxin research that included genetic enhancement and management approaches. In terms of genetic enhancement, the development of cultivars with enhanced resistance would provide an effective complementary approach to control aflatoxins in groundnut.

## cELISA aflatoxin detection kit developed in-house

Since aflatoxin contamination is invisible in commodities, the key is detection. In the face of high testing costs constraining the development of new resistant varieties and integrated management technologies that were unaffordable to farmers in developing countries, scientists at ICRISAT devised a fast, simple and affordable test kit for aflatoxin detection. The kit uses a competitive enzyme-linked immunosorbent assay (cELISA) which cuts the cost of testing crops from US\$ 25 to \$1 per sample.

The results obtained using cELISA are comparable with that of highly sensitive HPLC results. The kit can be used in even the most remote rural farms to monitor grains and nuts and improve storage techniques to avoid serious contamination. Its advantage is that most of the required chemicals are locally available in developing countries and it allows the analyses of up to 200 samples per day.

The National Smallholder Farmers' Association of Malawi (NASFAM) successfully used the technology, in conjunction with HPLC, as part of a broader effort to regain its once-lucrative European groundnut export market. The kit was also promoted with partners in Mali, Niger and Nigeria.

The test provided a unique opportunity for ICRISAT and its partners to conduct field studies to select breeding populations, to develop pre- and post-harvest management technologies and to discover dietary sources of aflatoxin, thereby stimulating interventions that enhance safety of food and human health, trade, and ultimately farmers' income.

**For more information:** [ICRISAT Aflatoxin testing kit](#)

**NASFAM CEO speaks:** Video <https://www.youtube.com/watch?v=VnpWjF5Jgtc>

### Aflatoxin kills! Videos in several languages

[Aflatoxin Kills!! Control it!](#) (English subtites)

[Aflatoxin Kills!! Control it!](#) (french subtitles)

[Aflatoxin Kills!! Control it!](#) (Hausa)

[Aflatoxin Kills!! Control it!](#) (Fulfulde)

[Aflatoxin Kills!! Control it!](#) (Oulof)

[Aflatoxin Kills!! Control it!](#) (Moore)

[Aflatoxin Kills!! Control it!](#) (Bambara)



## Indian private poultry feed company uses ELISA technique, annual turnover jumps to \$4 million

Vimala Feeds Private Limited, a large poultry feed factory near Hyderabad, India, was forced to buy groundnut cake from growers hundreds of kilometers away because of high aflatoxin levels in the groundnut cake purchased from local farmers. The only alternative was to analyze each packet of cake for aflatoxin through thin layer chromatography (TLC), an expensive and time consuming process. Transporting the groundnut cake over long distances was cheaper.

ICRISAT's ELISA package changed everything. ELISA tests cost about a dollar, while TLC costs three times that amount. The end result was that Vimala Feeds spent less on transport and could process its feed production faster. Moreover, neighboring farmers were able to sell their groundnut cake to Vimala Feeds instead of watching the cash fly off to farmers in other states.

## Advanced immunological ELISA technique developed at ICRISAT benefits Malawi groundnut exports to UK

The National Smallholder Farmers' Association of Malawi (NASFAM) and ICRISAT established a collaboration for testing the groundnut produced by the farmers. Based on the level of aflatoxin contamination, NASFAM graded groundnut lots into permissible (20 µg/kg) amounts. Graded groundnut lots found favorable markets for regional and global export, benefiting the farmers. The aflatoxin-testing laboratory in Malawi contributed to the revival of groundnut exports to Europe and South Africa from that country.

## Meeting on strategies to reduce aflatoxin in foods and feeds

A 2-day scientific meeting on "Strategies for reducing aflatoxin levels in groundnut-based foods and feeds in India - a step towards improving health of human and livestock" was held at ICRISAT-Patancheru, 26-27 July, 2000.

The meeting gave an opportunity to the main partners of a Project funded by the Department for International Development/Natural Resources Institute (NRI), UK, to address the research and development aspects of the problem of aflatoxins in groundnut. Participants included experts from the University of Reading, UK, Acharya N G Ranga Agricultural University, National Research Centre for Groundnut, and ICRISAT with representatives from non-governmental organizations and development agencies such as Man and Ecology (AME) and the Society for Transformation Agriculture and Alternatives in Development (STAAD) as well as from Janaki Feeds, Hyderabad.

## Government of Andhra Pradesh funds setting up of aflatoxin testing laboratory

The Government of Andhra Pradesh in India funded the setting up of the aflatoxin laboratory as well as other laboratories in the state, through the Agri-Science Park@ICRISAT.

## ICRISAT helps set up aflatoxin monitoring laboratories in India, Mozambique, Kenya, Mali and Malawi

# 2001-2005

## Ghana studies confirm aflatoxin's role in suppressing immunity

- Research showed that the aflatoxin exposure in Ghana is enough to suppress immunity – so fears that this toxin is a factor in infectious diseases were confirmed.
- Gender studies in Uganda show that women farmers and women homemakers have no knowledge of aflatoxin contamination in food – so need is identified for extensive outreach and education
- Trained 900 professionals in Ghana to handle problems of aflatoxin contamination

For more information: <http://www.oecd.org/derec/unitedstates/36079702.pdf>

**Funded by:** United States Agency for International Development (USAID)

**Partners:** ICRISAT; University of Georgia (USA); Institut d'économie rurale (IER, Mali)

Research undertaken through the Peanut Collaborative Research Support Program (CRSP)

# 2003-2005

## 70-84% dip in aflatoxin contamination in groundnut from on-farm management practices in Mali

A number of technologies such as tolerant varieties, soil amendment using farmyard manure (FYM), crop residues and lime and best bet harvesting and drying techniques were tested on farm in two regions of Mali to minimize aflatoxin contamination by *A. flavus*.

- 8 resistant/tolerant cultivars evaluated by 10 farmers in 5 villages of Kolokani under their own management practices recorded significantly lower levels of aflatoxin compared to the susceptible check.
- In Kolokani and Kayes, application of lime and farmyard manure significantly reduced aflatoxin contamination, especially in the susceptible cultivar. The application of lime alone reduced aflatoxin by 79% and the application of FYM reduced the aflatoxin content by 74%.
- Harvesting and drying techniques such as avoiding damage to pods, harvesting at right maturity, proper drying of pods demonstrated led to 69-88% aflatoxin reduction in Kolokani and 63-84% in Kayes.
- Together, these technologies contributed to healthy groundnut production – aflatoxin reduction ranged from 70-84%.
- The technologies were scaled out in Nigeria and Senegal.

For more information: [On-farm management of aflatoxin contamination of groundnut in West Africa: A synthesis report](#)

**Project:** On-farm management of aflatoxin contamination of groundnut in West Africa

**Funded by:** Common Fund for Commodities (CFC) of the UN

# 2003-2007

## Developed sustainable seed systems in Mali, Niger, Nigeria and Senegal

### Impacts

- Scaling-up of measures to control aflatoxin contamination along the groundnut value chain
- Agronomic practices such as application of lime 50 days after planting reduced aflatoxin contamination in grains by 70-95%
- Improved harvesting and drying techniques reduced aflatoxin contamination to tolerable levels (<10 ppb)
- Awareness on the problem of aflatoxin was further enhanced through brochures in local languages (Hausa, Bambara) and French
- Extensive training provided to national research organizations, farmer associations and other stakeholders
- Socioeconomic surveys and market studies carried out

**Research on** - Development of sustainable groundnut seed systems in West Africa – Groundnut Seed Project (GSP), in Mali, Niger, Nigeria, Senegal

**Funded by:** Common Fund for Commodities (CFC) of the UN

# 2005-2006

## 6 advanced breeding lines with low aflatoxin risk identified

In the groundnut growing belt of Andhra Pradesh, high-yielding, short-duration groundnut advanced breeding lines with resistance to in vitro seed colonization (IVSC) to *Aspergillus flavus* were tested in farmers' fields from 2003 to 2006 with an objective to identify superior agronomic performance coupled with low aflatoxin risk lines. Six lines with low aflatoxin risk (up to 73% reduction in pre-harvest aflatoxin contamination) such as ICGVs 91341, 93305, 91278, 91328, 94379 and 94434 were identified. This exercise was part of a project to improve the livelihoods of poor farmers through better access to aflatoxin reducing strategies. Among the issues addressed were lack of awareness of aflatoxin or aflatoxin-reducing technologies among farmers and processors; reluctance to adopt technologies if they increase costs or, equally importantly, drudgery; and lack of incentive mechanisms in the market to encourage the production of aflatoxin-free produce.

Aflatoxin awareness programs involving farmers, NGOs, oil millers and traders, were organized through field days in the villages. Flyers, newspaper articles in the local language, radio broadcasts and TV programs were used to manage and reduce contamination.

**For more information:** <http://r4d.dfid.gov.uk/Project/3972/>

**Project:** Safer and better groundnut for Southern India

**Funded by:** Department for International Development (DFID), UK

**Partners:** ICRISAT; Acharya NG Ranga Agricultural University; Plant Environment Laboratory, Department of Agriculture, University of Reading; Society for Transformation Agriculture and Alternatives in Development (STAAD) (Hyderabad, India NGO)

# 2006-2009

## Research highlights the scarcity of historical data on aflatoxin

The project on aflatoxin risk early warning system aimed to improve nutrition, health and income in West African smallholder farms in Mali, Ghana, Niger through the development of a groundnut aflatoxin risk prediction and mapping system. It highlighted the scarcity of historical aflatoxin data, which could quantify the actual role of environmental drivers on contamination patterns in smallholder conditions. Extension activities significantly raised public awareness on aflatoxin and its harmful effects.

**Project:** An aflatoxin risk early warning system to improve nutrition, health and income in West African smallholder farms in Mali, Ghana, Niger

**Funded by:** Canadian International Development Agency (CIDA)

**Partners:** ICRISAT; University of Sherbrooke, UoS; Cartel, University of Florida; Institut d'économie rurale (IER, Mali); Savanna Agricultural Research Institute, AGRHYMET, Niger.

# 2006-2010

## Improving groundnut varieties for yield and adaptation, health and nutrition in Malawi and Tanzania

Activities centered around strengthening existing work on foliar disease resistance breeding in Malawi; building capacity with the Tanzanian national agricultural research organizations to select resistant lines, engaging farming communities in the breeding and selection process and piloting local groundnut seed initiatives.

### Outcomes

- Identified a number of germplasm lines with good resistance to groundnut rosette disease, rust and aflatoxin for further hybridization activities in Phase II
- Sampled aflatoxin levels in blood of inhabitants of two districts in Malawi with high levels of aflatoxin to establish levels of human potential for aflatoxin contamination
- Farmer-preferred groundnut lines have been identified – in Malawi most farmers preferred varieties, ICGV-SMs 99722 and 99551; while in Tanzania the varieties preferred were ICGV-SMs 01731, 02724 and 02715
- Two field days were conducted in Malawi engaging 797 stakeholders to raise awareness on aflatoxin
- A field day was conducted in Tanzania engaging 100 stakeholders.

**For more information:** <http://ccrp.org/projects/groundnut-breeding-ii>

**Project :** Groundnut varieties improvement for yield and adaptation, human health, and nutrition

**Funded by:** McKnight Foundation Collaborative Crops Research Program (CCRP)

# 2006-2011

## Aflatoxin biomarker detection kit (ELISA) invented and produced to detect aflatoxin-albumin from human serum

Aflatoxin B<sub>1</sub> (AFB<sub>1</sub>) is a frequent contaminant in several foods (e.g. groundnut, maize, chillies, etc.). Human exposure to it occurs through dietary intake of aflatoxin contaminated food. AFB<sub>1</sub> heightens the risk of liver cirrhosis and hepatocellular carcinoma, particularly in individuals affected with hepatitis B virus. When aflatoxin enters the body through contaminated food, it is metabolized into aflatoxin epoxide which tends to bind with the lysine amino acid of the protein albumin and forms aflatoxin-albumin adduct. Therefore measuring aflatoxin-albumin biomarker helps to quantify aflatoxin exposure.

As part of its aflatoxin management strategy, ICRISAT produced polyclonal antibody to detect aflatoxin-albumin biomarker in blood using a simple indirect competitive (IC)-ELISA for quantitative estimation of AFB<sub>1</sub>-lys adducts in human serum albumin.

IC-ELISA was validated by testing 250 blood samples that include 85 HBV positive samples from unidentified subjects from the Apollo Health City, Hyderabad, and 165 blood samples collected from ICRISAT campus, Hyderabad.

**For details, read:** [Development of a simple enzyme-linked immunosorbent assay for quantitative estimation of aflatoxin B<sub>1</sub> albumin adduct in humans](#)



# 2007

## International training course on aflatoxin management



# 2007-2009

## Assessing pre- and post-harvest contamination in groundnuts

Malawi's status in the 1970s as a major groundnut exporter was eroded by aflatoxin outbreaks.

### Outcomes

- High incidences of contamination observed
- AFB<sub>1</sub> contamination levels in food found to be a significant problem and they are likely to indicate AFB<sub>1</sub> exposure in the public
- Better aflatoxin management practices called for, such as proper drying of groundnuts and storing on raised pallets.

**For more information:** [Occurrence and distribution of aflatoxin contamination in groundnuts \(\*Arachis hypogaea\* L\) and population density of Aflatoxigenic \*Aspergilli\* in Malawi](#)

**Project:** Assessing occurrence and distribution of aflatoxins in Malawi

**Funded by:** McKnight Foundation Collaborative Crops Research Program (CCRP)

**Partners:** ICRISAT; National Smallholder Farmers' Association of Malawi (NASFAM)

# 2008-2011

## Introgression lines developed show poor resistance against aflatoxin contamination

Several research activities were undertaken, such as advanced generation of crosses, analysis of variance for *A. flavus* infection and contamination, etc as part of a Department of Biotechnology (DBT) Project – India.

### Impact

- Development of many introgression lines of diverse nature by using synthetics with the cultivated genotypes
- Majority of the lines showed poor resistance against aflatoxin contamination.

# 2008-2013

## 7 groundnut accessions identified as potential sources to understand resistant mechanism

Screening and identification of stable and reliable resistance sources to pre-harvest aflatoxin contamination in ICRISAT's groundnut mini core germplasm accessions at ICRISAT-Niger

- Field studies were conducted during 2008 and 2009
- 180 accessions screened in 2008
- 34 superior accessions were selected and screened during 2010 and 2011; eight accessions had  $<1 \mu\text{g}/\text{kg}$
- 7 best accessions (ICGs 13,603, 1415, 14,630, 3584, 5195, 6703 and 6888), over six years (2008–2013) consistently accumulated very low levels of aflatoxin ( $<4 \mu\text{g}/\text{kg}$ )
- These accessions could be potential sources for understanding the resistant mechanisms and can be further used in developing resistant cultivars or introgressing resistance in popular released varieties.

### For more information:

[Resistance to pre-harvest aflatoxin contamination in ICRISAT's groundnut mini core collection](#)

**Funded by:** Partially funded by the CGIAR Research Program on Grain Legumes

# 2009-2011

## Mali: High aflatoxin contamination in groundnut growing areas and value chains

- Investigations carried out for aflatoxin contamination in the groundnut value chains at various points and durations across Mali
- Management options aimed at mitigating aflatoxin content of groundnut at pre-and post-harvest stages were evaluated on-farm using strategies developed by ICRISAT.

### Outcomes

- High levels of aflatoxin contamination were found in major groundnut growing areas as well as in farmers' storage systems and markets in different agro-ecological zones
- A total of 5,162 and 5,300 samples were analyzed in the first and second year in which aflatoxin content ranged from 0 to 3,135  $\mu\text{g}/\text{kg}$  with a grand mean of  $>164 \mu\text{g}/\text{kg}$  within the two years
- Thus this situation poses critical health risks to all consumers in Mali and impedes export.

**Research on:** Exploring the scope of cost-effective aflatoxin risk reduction strategies in maize and groundnut value chains so as to improve market access of the poor in Africa



# 2010-2014

## Improving groundnut varieties

- A system for growing groundnuts in fungus contaminated soil in large containers has been established to allow lines to be screened for aflatoxin resistance under drought stress
- Multisector collaboration established
- Participatory research developed improved varieties.

**Project:** Groundnut varieties improvement for yield and adaptation, human health, and nutrition (Phase 2) in Malawi & Tanzania

**Funded by:** McKnight Foundation Collaborative Crops Research Program (CCRP)

**Partners:** ICRISAT; Department of Research & Development, Tanzania; Kamuzu Central Hospital, Malawi; Sokoine University, Tanzania



# 2012-2014

## Innovative communications to build awareness of aflatoxins in Malawi and Tanzania

Innovative Communication Media and Methods for More Effective Aflatoxin Mitigation in Groundnut (ICMM), a communication project on aflatoxin mitigation funded by the McKnight Foundation assessed the role of communication in influencing the process of change that leads from awareness to understanding, to desirable, sustainable action to reduce aflatoxin exposure in these countries. The project used an informal Learning Alliance Approach and also tested the effectiveness of leaflets, radio and video in increasing awareness and understanding on aflatoxin mitigation and management. The result was increased understanding of mould so as to decrease exposure to aflatoxin and improve the health and incomes of the various stakeholders along the groundnut value chain.



### Activities

- 6,000 aflatoxin awareness flyers distributed to agricultural extension departments of nine districts, farmers, school students and village authorities in Tanzania
- 3,000 posters on groundnut varieties and aflatoxin awareness distributed to stakeholders in Tanzania
- Aflatoxin educational video, aflatoxin awareness flyer, a radio program on aflatoxin control – produced in Malawi
- New national programs that are being established in Malawi and Tanzania to intensify aflatoxin mitigation action – e.g. under the umbrella of the *Partnership for Aflatoxin Control in Africa* in which both ICRISAT and NARI participate and other donor projects – are affirming the importance of multi-stakeholder processes
- Radio program on aflatoxin on August 23, 2013 tested in Malawi
- A Learning Alliance meeting held in Malawi where stakeholders shared information, ideas, experiences as well as commitment and action to tackle the problems of aflatoxin contamination.

### For more information:

[Communication project on aflatoxin mitigation begins in Malawi](#)

[Radio program on Aflatoxin tested in Malawi](#)

[Creating a new narrative for aflatoxin communication in Malawi](#)

**Project:** Innovative Communication Media and Methods (ICMM) project in Malawi, Tanzania

**Funded by:** McKnight Foundation

**Partners:** ICRISAT; Naliendele Agricultural Research Institute (NARI), LIMAS, Danish Management, Malawi Ministry of Trade & Industry, Ministry of Agriculture, Rural Oriented Sustainable Development Organization (ROSDO), Small-scale Industries Development Organization (SIDO)

**CGIAR Research Program:** Grain Legumes

# 2012-2015

## Mitigation of aflatoxin in groundnuts in Zambia

A 3-year comprehensive analysis of aflatoxin contamination in peanut butter was conducted in Zambia, sub-Saharan Africa. The study analyzed 954 containers of 24 local and imported peanut butter brands collected from shops in Chipata, Mambwe, Petauke, Katete, and Nyimba districts and also in Lusaka from 2012 to 2014. Results showed that in 2013, 80% of the brands were contaminated with AFB<sub>1</sub> levels >20 µg/kg and ranged up to 10,740 µg/kg. Compared with this data, 53% of the brands in 2014 had aflatoxin B<sub>1</sub> levels >20 µg/kg and ranged up to 1,000 µg/kg.

An aflatoxin testing laboratory in Zambia is currently operational and provides service to stakeholders. As a result of the work in Zambia on peanut butter, peanut butter processors are now testing their products. One company has started labelling its product as 'tested for aflatoxins and safe for consumption' and the Zambia Bureau of Standards is in the process of establishing a National Standards for aflatoxin in peanut butter.

### Outcomes

- Scale of the aflatoxin problem in maize and groundnut value chains quantified
- Biocontrol of aflatoxin contamination deployed
- Technical capacity of national partners, extension services, and farmers enhanced
- Awareness of stakeholders on aflatoxin raised.

**For more information:** [Mitigation of aflatoxin in maize and groundnuts in Zambia](#)

**Project:** Feed the Future project on Aflatoxin mitigation in Zambia

**Funded by:** United States Agency for International Development (USAID) – Zambia

**CGIAR Research Programs:** Grain Legumes & Agriculture for Nutrition and Health (A4NH)

## Tracking *Aspergillus flavus* toxigenic strain AF 11- 4 in groundnut crop soils using SCAR marker-based PCR diagnostic assay

Sequence characterized amplified region (SCAR) markers are one of the most accurate tools of identifying a selective microbe and tracking its populations in a particular environment, adding substantially new information and knowledge to the domain of the subject. Success was achieved for the first time in developing aflatoxin biosynthetic gene cluster-derived SCAR marker to differentiate a particular toxigenic strain from another. This will help in understanding the population biology of a particular toxigenic strain (AF 11-4) in groundnut crop soils, which is very important for developing field screening techniques to identify resistant sources to *A. flavus*.

**Funded by:** Science and Engineering Research Board, Department of Science and Technology, Government of India

**CGIAR Research Program:** Grain Legumes



For video: [https://www.youtube.com/watch?time\\_continue=93&v=E9TGINcbdlw](https://www.youtube.com/watch?time_continue=93&v=E9TGINcbdlw)



For video: <https://www.youtube.com/watch?v=g1uXfOctq4Y>

# 2013-2014

## Women in Mali trained to make nutritious and healthy equinut

ICRISAT, together with the Institut d'Economie Rurale (IER), helped farmers produce quality groundnut, free of aflatoxin, to enhance household consumption as part of a project with the Aga Khan Foundation in Mali. ICRISAT supported groups of women to produce improved aflatoxin-free groundnut varieties to be used to make a biofortified version of the local dish di-dégué, developed into a product known as Equinut. Di-dégué is a food recipe based on existing local products in the food habits of people in rural areas of Mali. This led to developing five varieties of groundnut resistant to contamination by aflatoxin fungi and integrated management practices introduced in groundnut-growing areas in rural districts of Kita (Kayes region) and those of Mopti and Djenné (Mopti region).

**For more information:** [EQUINUT: a high-energy weapon fighting malnutrition Nourishing communities through holistic farming](#)

## Rebuilding Nigeria's groundnut pyramids

More than 700,000 hectares of groundnut worth US\$250 million were destroyed in Nigeria by rosette in 1975. Additional epidemics affected the region in 1983, 1985 and 1988. These persistent onslaughts forced millions of farmers to switch to cereal crops and cowpea.

As part of the Nigerian Government-funded project "Rebuilding the groundnut pyramids: boosting farmers' income through new groundnut varieties, cropping systems and processing technologies in Nigeria" implemented in 15 states, a workshop was held at ICRISAT-Kano, Nigeria to enable farmers to grow improved varieties of groundnuts with more resistance to diseases, higher export market demand, and better aflatoxin management to prevent contamination. A revival of the vibrant groundnut industry would help generate employment opportunities and improve the livelihoods of millions of Nigeria's smallholder farmers.

Organized by ICRISAT-Kano, the Kano State Agricultural and Rural Development Authority (KNARDA), and the Kano State Ministry for Local Government and Women Farmer Advancement Network (WOFAN), the workshop sought to enable farmers to produce seeds of improved varieties in the dry season (January-May).



*Participants of the workshop on quality groundnut seed production held at ICRISAT-Kano, Nigeria.*



*This groundnut pyramid in Kano is a testimony to the fact that Nigeria was once a major groundnut exporter.*

## CAAS-ICRISAT joint laboratory for aflatoxin management

A joint Chinese Academy of Agricultural Sciences (CAAS)-ICRISAT laboratory for groundnut aflatoxin management was inaugurated at the Oil Crops Research Institute (OCRI) of CAAS, Wuhan, China. The collaboration facilitates the producing of drought-tolerant and aflatoxin-free groundnuts as part of the CGIAR Research Programs on Grain Legumes and Agriculture for Nutrition and Health (A4NH).

As part of capacity building activities, a three-day international workshop on “Management of groundnut diseases” was organized on 12-14 May 2014 by ICRISAT and the Chinese Academy of Agricultural Sciences (CAAS) in Hanoi, Vietnam in which groundnut researchers devised strategies to combat regionally important soilborne diseases and aflatoxins.



# 2013-2015

## Good Agricultural Practices in Anantapur district reduce aflatoxin in groundnut; raise yields and fetch additional net incomes

More than 90% of the 1000 farmers surveyed in India do not know about the ill-effects of aflatoxin contamination and management options available. This was the results of a survey ICRISAT conducted in the important groundnut growing states of India such as Andhra Pradesh, Gujarat, Karnataka and Tamil Nadu. One of the reasons for poor adoption of aflatoxin management interventions is lack of awareness among the farming community about this menace.

Other important interventions included identification of “Good Agricultural Practices” (GAPs) which significantly reduce pre- and post-harvest aflatoxin contamination. Tremendous progress was made in this area. Several technologies were identified, packaged and tested on-farm, such as soil amendments (eg. farmyard manure, lime, and gypsum), moisture conservation techniques, pod drying methods and storage methods.

Recently in Anantapur district of Andhra Pradesh state in India, the largest groundnut growing district in the country (approximately 0.5 million ha every year), 89 result demonstrations (2013-15) were conducted in farmers’ fields showcasing a set of GAPs and compared with farmers’ practices. The GAPs included application of farmyard manure, gypsum, protective irrigation at around 90 days after sowing and pod drying on tarpaulins to avoid contact with the soil after harvesting.

- The results clearly showed 62-94% reduction in aflatoxin contamination in groundnut
- Yield increased around 30% in addition to a reduction in aflatoxin contamination
- This fetched an additional net income of around \$25 per acre.
- This package of GAPs is ready to scale-up

**Project:** Integrated pre and post-harvest management strategies to mitigate aflatoxin contamination

**Partners:** AF Ecology Centre, Anantapur, Andhra Pradesh, India; ICAR-Directorate of Groundnut Research, Junagadh, Gujarat; Acharya N.G. Ranga Agricultural University, Hyderabad; University of Agricultural Sciences, Raichur, Karnataka; Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu.

**CGIAR Research Program:** Agriculture for Nutrition and Health (A4NH)

# 2013-2017

## Genomics interventions to reduce pre-harvest aflatoxin contamination in groundnut in India, Niger and Senegal

The primary aim of the project is to associate molecular variation with resistance to pre-harvest aflatoxin contamination on a genome-wide scale.

### Outcomes

- Aflatoxin which presents itself under heat and drought stress could be prevented by irrigation. However, irrigation is not available in areas that suffer the most from contamination.
- There is evidence that wild species can be used to broaden the genetic base of cultivated peanut for complex traits including disease resistance and drought tolerance.

**For more information:** [Translational Genomics to Reduce Pre-Harvest Aflatoxin Contamination of Peanut](#)

**Partners:** ICRISAT; University of Georgia, USA; Institut Sénégalaise de Recherches Agricoles/Centre National de Recherche Agronomique (ISRA/CNRA); United States Department of Agriculture- Agriculture Research Service (USDA-ARS)

# Aflatoxin mitigation for nutrition, safety and market competitiveness in Tanzania

## Assess levels of aflatoxin contamination of sunflower oil press cake and its feeds value chain

Baseline study in 2013 in Kongwa and Kiteto revealed low productivity of legumes (groundnuts, bambara nuts) and cereals (sorghum, pearl millet and maize); farmers obtained <50% of potential yield. Very high levels of aflatoxin were found in oilseeds and subterranean crops (up to 4000 ppb) including bambara nut and groundnut, especially after long storage period. Poor grading practices (14%) and poor knowledge on aflatoxin (19%) were observed. All market samples had higher than the 20 ppb threshold for aflatoxin in food products. Sunflower cake was found safe with no samples having >20 ppb aflatoxins. Following the study, training sessions were conducted in post-harvest crop handling methods for lead farmers in the 2014-2015 cropping season:

- 80% of the trained farmers adopted better drying methods, such as the Mandela cork for groundnuts.
- Maize and other grains: Drying on polythene sheets after initial drying in the field limited exposure
- Six-fold increase in awareness (with 92%) was observed among farmers using the handling methods.

## Improving food availability by reducing post-harvest losses

- A key farmer leader per village was trained on post-harvest management of grains
- Mothers from Mlali, Moleti, Chetigo and Laikala were trained on post-harvest crop management, utilization of locally available cereals and legumes combinations to make complementary food and on practising good hygiene.

## Capacity of aflatoxin diagnosis deployed in Morogoro to test samples from Kongwa and Kiteto

Five technicians from ARI-Hombolo and Sokoine University of Agriculture (SUA) were trained to use the aflatoxin detection capacity established in SUA. It is currently used for testing aflatoxin from crop samples and testing aflatoxin biomarker in urine samples as part of nutrition activity. ICRISAT to continue to provide technical backstopping to SUA, including support to use the lateral flow device in the field testing of the samples as part of mitigation at household level.

## Intervention alternatives to improve child growth and minimize exposure

Mothers with 5-6 month-old children were recruited (100 each in 2014-2015 and 2015-2016) to study the impact of safe cereal-legume based complementary food and hygiene on their growth. The gender inclusive baseline was conducted along with the collection of crop samples, urine samples for aflatoxin testing and anthropometric data to understand the undernutrition status of the children. The results showed very poor dietary diversity; >30% children were stunted; > 20% children were underweight; and > 10% children were wasted.

- Complementary food recipes for children below 5 years were developed using maize, finger millet, pigeonpea and soyabean.
- Mothers were trained intensively for 21 days on post-harvest crop handling, preparation and adequate feeding of children and hygiene.
- Follow up data collection and feeding trials were continued for 3 months to understand the impact of intervention on stunting.
- Data revealed significant reduction in underweight, stunting and wasting status
- The nutrition team participated in the Nane Agricultural show to exhibit complementary food recipes, train on recipe formulation and how to improve child growth.

**Project:** Intensification of maize-legume based systems in the semi-arid areas of Tanzania (Kongwa and Kiteto districts) to increase farm productivity and improves farming natural resource base

**Funded by:** USAID through IITA

**Partners:**

*Implementing partners*

Agricultural Research Institute – Hombolo (ARI-Hombolo)

World Agroforestry Centre (ICRAF)

International Maize and Wheat Improvement Centre (CIMMYT)

Sokoine University of Agriculture (SUA)

University of Dodoma

**Associate partners:**

NAFAKA - Staple Value Chains

University of Dodoma

District Agricultural Offices of Kiteto and Kongwa

Community leaders in target villages of Kiteto and Kongwa

Tuboreshe Chaluka- A USAID-funded nutrition project

Pasture Research Institute Kongwa

# 2014

## Nigerian NARS trained in aflatoxin



# 2014-17

## Determining the aflatoxigenic *Aspergillus* species in African countries

The aim of this work is to isolate *Aspergillus flavus* and *Aspergillus parasiticus* mainly from peanut growing areas, and determine the genetic diversity of the aflatoxin synthesis cluster in the isolates, in order to feed that information back into the design of RNAi molecular constructs.

- Soil samples collected from important groundnut growing agroecologies; isolated fungi, identified isolates, transferred hyphal tip isolates for long term storage and characterization
- Groundnut samples collected from farmers storage and markets; isolated fungi, identified isolates, transferred hyphal tip isolates for long term storage and characterization
- Isolates being screened for aflatoxin production
- 441 isolates of *flavus* have been sent to USDA-NPRL for DNA isolation



**Project :** Genetic diversity of Aflatoxigenic *Aspergillus* species in African countries (RNAi silencing of aflatoxin synthesis)

**Funded by:** USAID through Peanut and Mycotoxin Innovation Lab (PMIL)

**Partners :** USDA-ARS NPRL (National Peanut Research Lab-Georgia, USA)

**CGIAR Research Program:** Agriculture for Nutrition and Health (A4NH)

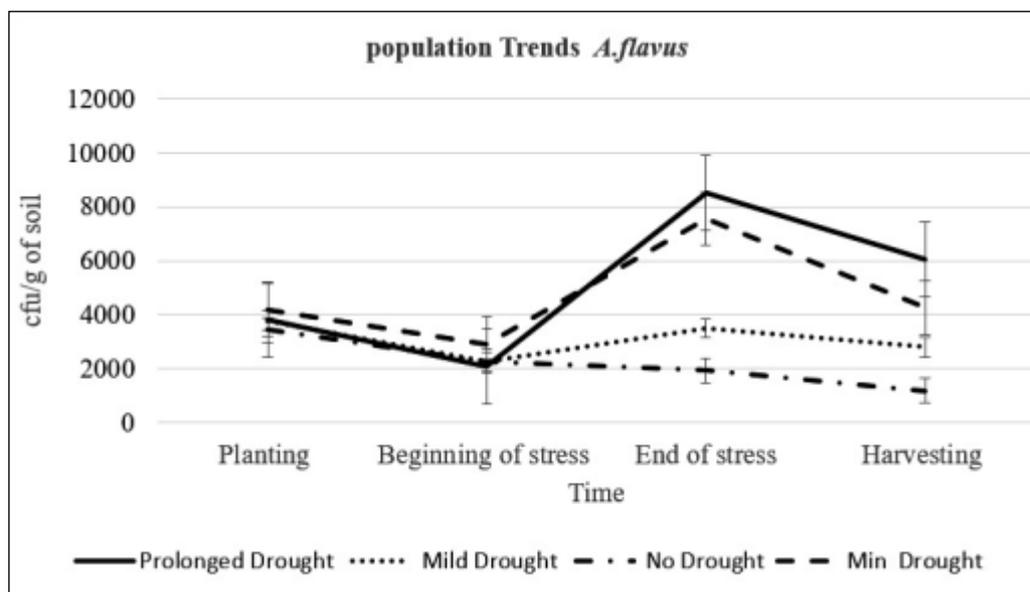
## Addressing aflatoxin management within the peanut value chain in Malawi, Mozambique and Zambia

The ability of farmers to produce high-yielding, high quality peanuts with low aflatoxin levels is still quite low. Improved cultivars are available, but the lack of an effective seed program limits availability. Limited marketing due to high aflatoxin contamination levels further reduces farmer incentive to implement current production recommendations and limits commercial processing and marketing. The project addresses a wide range of production, post-harvest handling, and processing issues relative to peanut in Malawi, Zambia, and Mozambique that can impact aflatoxin contamination levels, yield, and profitability.

The broad, interdisciplinary research and technology approach starts with cultivar selection and production through the entire value chain including post-harvest storage, processing, and marketing, taking advantage of improved germplasm already available, in country aflatoxin testing equipment and technicians already in place, key production, processing, marketing, and technology transfer partners.

### Progress

- The crop rotation trial at Chitedze is currently in the third season while the trial at Mwimba research station in Malawi is in the second season
- Harvest date trials
- Moisture stress experiment to determine the effect of different moisture stress levels, during plant maturation on aflatoxin contamination. The trial was planted on 22 October 2015 and harvested 10 February 2016.



Population densities of *A. flavus* in treatments under different moisture stress.

**Project:** Aflatoxin management interventions, education, and analysis at various steps within the peanut value chain in Malawi, Mozambique and Zambia

**Funded by:** USAID through Peanut and Mycotoxin Innovation Lab (PMIL)

**Partners:** North Carolina State University; University of Zambia; Lilongwe University of Agriculture and Natural Resources; Department of Agriculture Research Services (Malawi), IIAM (Mozambique)

**CGIAR Research Program:** Grain Legumes

# 2014-18

## New varieties and management systems to improve productivity, food security and safety and market competitiveness

Groundnut covers about 316,000 ha and serves more than 300,000 households in Tanzania and Malawi. The potential area for the crops is however 780,000 ha, indicative of the opportunity to double production by expanding crop area and productivity. The main challenges include biotic (diseases/pests and aflatoxin contamination), abiotic (drought), socio-economic, and institutional challenges. The project aims to improve production and productivity of groundnuts as a grain legume that delivers nutrition, food security and improved incomes of smallholder farmers. The activities involve development of resilient and nutritious genotypes, testing and promotion of sustainable intensification production systems and strengthening aflatoxin management from households to markets through evidence, diagnosis and knowledge dissemination.



### Progress

- New genetic resources generated to expand the portfolio of breeding lines
  - \* Generated 39 families of breeding lines developed from released popular varieties with enhanced Fe, Zn and Oleic acid; to be advanced
  - \* Generated 70 families with a drought tolerance background using 7 genotypes identified for earliness as a drought escape trait
- Select agro-ecologies characterized identifying the major cropping systems to better understand the deployment of crops species in a way that will influence the adoption of groundnuts
- Conducted farmer participatory agro-ecological intensification trials (legume-legume and legume cereal); farmer preferred combinations identified and will be promoted in targeted agro-ecologies of Malawi and Tanzania.
- 3500 farmers trained to be engaged in multi-pronged aflatoxin management.

**Project:** New varieties and management systems to improve productivity, food security and safety and market competitiveness

**Funded by:** McKnight Foundation

**Partners:** International Crops Research Institute for the Semi-Arid Tropics (ICRISAT); National Smallholder Farmers' Association of Malawi (NASFAM) – Malawi; Kamuzu Central Hospital (KCH), Ministry of Health-Malawi; Department of Agriculture, Ekwendeni Mission Hospital-Malawi; Department of Research and Training (DRT) of the Ministry of Agriculture and Food Security – Tanzania and Sokoine University of Agriculture (SUA)-Tanzania.

**CGIAR Research Program:** Grain Legumes

# 2015-2018

## Increasing groundnut productivity of smallholder farmers in Ghana, Mali and Nigeria

The target areas for this project are 74 administrative units (21 in Ghana, 22 in Mali, and 31 in Nigeria).

The project aims to enhance farmers' knowledge of improved groundnut production technologies; seed production and marketing; diffuse improved aflatoxin management technologies; and farmers' access to small scale processing technologies.

To date the following activities have been carried out:

- 674 demonstrations established on integrated crop management practices and aflatoxin management
- 6534 farmers took part in field days
- 263 facilitators were trained (Training of trainers)
- 9000 value chain actors were sensitized on the impact of aflatoxin on human nutrition and health
- 215 researchers trained
- 3515 trained on post-harvest storage technologies to manage aflatoxin
- Seeds produced: 24.35 tons of breeder seed; 51.44 tons of foundation seed and 526.85 tons of certified seed.

**Funded by:** United States Agency for International Development (USAID) in Feed the Future Initiative (FtF)

**Coordinated by:** International Crops Research Institute for Semi-Arid Tropics (ICRISAT)

**CGIAR Research Programs:** Grain Legumes and Agriculture for Health and Nutrition (A4NH)



# 2016

## Aflatoxin detection laboratories set up at 2 NARS centers in Nigeria

Towards creating awareness about aflatoxin, its prevention and detection in the groundnut and sorghum value chain programme of the Federal Government of Nigeria, ICRISAT helped set up two aflatoxin detection and quantification laboratories – at the Institute for Agricultural Research (IAR)/Ahmadu Bello University (ABU) Zaria, and the Federal University of Agriculture (FUAM), Makurdi. These will serve as aflatoxin detection centers in groundnut, sorghum and other grains and food, facilitating aflatoxin related research and learning by students, academic staff and other researchers, while ensuring that the food is safer for consumption and export.



Nigeria was once the world's leading groundnut exporters in the 1960s with the crop accounting for about 70% of the country's total export earnings. Since then, efforts have been ongoing to revive the groundnut pyramids of Kano.

## First portable low-cost device developed for rapid detection of aflatoxins

A new improved method to detect aflatoxin in groundnuts, developed by ICRISAT, can save lives and open export markets for African and Asian countries. The device is faster, the first ever to be mobile as well as having a low cost for undertaking the tests.

The aflatoxin detection test is simple to perform and can detect contamination at levels of 10 parts per billion (ppb) in less than 15 minutes. The compact mobile device is based on the lateral flow immunoassay test (popularly known as the strip test as used in a glucometer). If aflatoxin is present in the sample, then one pink line appears on the strip, whereas if the sample doesn't have any aflatoxin, two pink lines appear on the strip.

No technical knowledge or training is required to use the kit. For example, it can be used by traders to check for contamination before concluding a sale. The rapid detection is useful for public health authorities to be able to identify suspected samples in cases of an outbreak of aflatoxin poisoning. It is expected that the kit can be made available for less than US\$ 2.

Efforts are in progress to develop a mobile sample extraction kit so that the entire process can be carried out in the field. It is expected to be ready in the next two months. The kit was developed by Dr S Anitha, Special Project Scientist, ICRISAT-Malawi.



For video: <https://www.youtube.com/>

**Funded by:** The McKnight Foundation, Africa Rising, CGIAR Research Program on Grain Legumes, and CGIAR Research Program on Agriculture for Nutrition and Health (A4NH)

**Partners:** ICRISAT, NASFAM, Kamuzu Central Hospital, Nkhoma Hospital and Ministry of Agriculture and Water Development

## Nutrition studies reveal aflatoxin effect on nutrient absorption in children

A baseline study carried out in 2015 revealed the presence of aflatoxin biomarker AFM<sub>1</sub> in the urine samples of study group children indicating that more than 60% of them were exposed to aflatoxin contamination.

Following the baseline survey, a study group of 50 children each, in the 2 districts of Mzimba and Balaka in Northern and Central Malawi respectively, and 70 children from 5 villages of the Dodoma Region in Tanzania, were selected, to test the impact of nutritious food, hygienic practices and controlling aflatoxin contamination, on malnutrition and stunting among children.



The project addresses issues pertaining to quantity of aflatoxin that results in stunting among children; effect of different levels of hygiene on health and stunting; and nutrient levels in crops and its impact on stunting. Studies are planned on each of these components through different intervention groups. Bioavailability studies will also be carried out.

**Watch video:** <http://wp.me/p75LkR-49C>

**Project:** Malawi Seed Industry Development Project – Phase II

**Investor:** Irish Aid

**Partners:** Kamuzu Central Hospital (KCH), Malawi; Sokoine University of Agriculture (SUA), Tanzania

**CGIAR Research Program:** Agriculture for Nutrition and Health (A4NH)

## 2016-2017

### Evaluating aflatoxin contamination in the soils of Malawi

The project is evaluating the prevalence of aflatoxin contamination in the soils of the target districts, as well as in maize and groundnuts stored at the household level (immediately after harvest and again just before planting of the next season), and at key points in the value chains of each crop. This also involves training on pre- and post-crop handling to mitigate aflatoxin levels to the UBALE staff, Ministry of Agriculture staff (AEDOs) and lead farmers.

**Funded by:** USAID-funded project on United in building and advancing life expectations (UBALE) through Catholic Relief Services (CRS)

**CGIAR Research Program:** Agriculture for Nutrition and Health (A4NH)

# 2016-2019

## Aflatoxin control in farmers' fields, post-harvest handling, and off-farm value chain

ICRISAT is investigating whether raising awareness in marketing associations on the constraints that aflatoxin poses to marketability, results in improved practices for aflatoxin control, and better prices for aflatoxin-free products. This research provides an important bridge between USAID's FtF agenda and its Food for Peace activities, including opportunities for the work in Malawi to inform practice elsewhere around the world. The research will build on the baseline aflatoxin levels determined as part of the capacity building work, and take place during the 2018/2019 season.

**Funded by:** USAID-funded project on United in building and advancing life expectations (UBALE) through Catholic Relief Services (CRS)

**CGIAR Research Program:** Agriculture for Nutrition and Health (A4NH)

## Genomics project on groundnut aflatoxin research launched

A new research project "Identification of markers and genomic regions associated with aflatoxin resistance in groundnut" was launched to identify the genomic regions and genes associated with aflatoxin resistance in groundnut using a combination of genomics approaches. One of the main objectives of the new project is to validate the identified genes and develop diagnostic markers so that they can be deployed in molecular breeding for developing superior lines with enhanced aflatoxin resistance in addition to other desired agronomic and productivity traits.

**Project:** Identification of markers and genomic regions associated with aflatoxin resistance in groundnut

**Investor:** Mars Inc., USA

**Partner:** ICRISAT

**CGIAR Research Program:** Grain Legumes

## Key publications

[The association between exposure to aflatoxin, mutation in TP53, infection with hepatitis B virus, and occurrence of liver disease in a selected population in Hyderabad, India](#)

[Although drought intensity increases aflatoxin contamination, drought tolerance does not lead to less aflatoxin contamination](#)

[Effect of storage conditions on quality and aflatoxin contamination of peanuts \(\*Arachis hypogaea\* L.\)](#)

[Aflatoxin contamination of food commodities and their management.](#)

[Prevalence and potential for aflatoxin contamination in groundnuts and peanut butter from farmers and traders in Nairobi and Nyanza provinces of Kenya.](#)

[Occurrence of \*Aspergillus\* species and aflatoxin contamination in raw and roasted peanuts from formal and informal markets in Eldoret and Kericho towns, Kenya.](#)

[Peanut contamination by \*Aspergillus flavus\* and aflatoxin B1 in granaries of villages and markets of Mali, West Africa.](#)

[Reducing aflatoxins in groundnuts through integrated management and biocontrol.](#)

[ELISA: An inexpensive and highly precise tool for estimation of aflatoxins.](#)

[Assessing occurrence and distribution of aflatoxins in Malawi.](#)

[Incidence of aflatoxin in peanuts \(\*Arachis hypogaea\* Linnaeus\) from markets in Western, Nyanza and Nairobi Provinces of Kenya and related market traits.](#)

[Occurrence and distribution of aflatoxin contamination in groundnut \(\*Arachis hypogaea\* L\) and population density of Aflatoxigenic \*Aspergilli\*.](#)

[Importance of mycotoxins in food and feed in India.](#)

[Effect of irrigation interval, planting date, and cultivar on \*Aspergillus flavus\* and aflatoxin contamination of peanut in a sandy soil of Niger.](#)

[Aflatoxin B1 contamination of groundnut \(\*Arachis hypogaea\* L.\) in eastern Zambia.](#)

[Resistance to preharvest aflatoxin in ICRISATs minicore collection.](#)

[Understanding and managing aflatoxin contamination in the groundnut value chain in Nigeria.](#)

[Uncommon occurrence ratios of aflatoxin B1, B2, G1, and G2 in maize and groundnuts from Malawi.](#)

[A Case for Regular Aflatoxin Monitoring in Peanut Butter in Sub-Saharan Africa: Lessons from a 3-Year Survey in Zambia.](#)

[Knowledge, attitude, and practices concerning presence of molds in foods among members of the general public in Malawi.](#)

[Aflatoxins: Finding solutions for improved food safety.](#)

We believe all **people** have a **right** to **nutritious food** and a **better livelihood**.

ICRISAT works in agricultural research for development across the drylands of Africa and Asia, making farming profitable for smallholder farmers while reducing malnutrition and environmental degradation.

We work across the entire value chain from developing new varieties to agri-business and linking farmers to markets.

**ICRISAT-India  
(Headquarters)**  
Patancheru, Telangana, India  
icrisat@cgiar.org

**ICRISAT-India Liaison Office**  
New Delhi, India

**ICRISAT-Mali  
(Regional hub WCA)**  
Bamako, Mali  
icrisat-w-mali@cgiar.org

**ICRISAT-Niger**  
Niamey, Niger  
icrisatniger@cgiar.org

**ICRISAT-Nigeria**  
Kano, Nigeria  
icrisat-kano@cgiar.org

**ICRISAT-Kenya  
(Regional hub ESA)**  
Nairobi, Kenya  
icrisat-nairobi@cgiar.org

**ICRISAT-Ethiopia**  
Addis Ababa, Ethiopia  
icrisat-addis@cgiar.org

**ICRISAT-Malawi**  
Lilongwe, Malawi  
icrisat-malawi@cgiar.org

**ICRISAT-Mozambique**  
Maputo, Mozambique  
icrisatmoz@panintra.com

**ICRISAT-Zimbabwe**  
Bulawayo, Zimbabwe  
icrisatzw@cgiar.org

ICRISAT appreciates the support of CGIAR investors to help overcome poverty, malnutrition and environmental degradation in the harshest dryland regions of the world. See <http://www.icrisat.org/icrisat-donors.htm> for full list of donors.



About ICRISAT: [www.icrisat.org](http://www.icrisat.org)



ICRISAT's scientific information: [EXPLOREit.icrisat.org](http://EXPLOREit.icrisat.org)

