On-farm Management of Aflatoxin Contamination of Groundnut in West Africa

A Synthesis Report

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Abstract

This report summarizes results from on-farm management of aflatoxin contamination of groundnut activities conducted by ICRISAT and IER in Mali, with funding support from CFC. A number of technologies to minimize aflatoxin contamination were tested on-farm with participation of the farmers in two regions of Mali. The technologies included tolerant varieties, soil amendment using farm yard manure, crop residues and lime as well as best-bet harvesting and drying techniques. Applying these technologies resulted in aflatoxin reduction ranging from 70-84%. More than 50% of the farmers applying the technologies are producing groundnut with tolerable levels of aflatoxin contamination (i.e. < 10 ppb). The technologies are being scaled-out in Nigeria and Senegal.

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On-farm Management of Aflatoxin Contamination of Groundnut in West Africa

Executive summary

Groundnuts are prone to infestation by two closely related fungal species, *Aspergillus flavus* and *A. parasiticus*. Both fungal species produce a highly toxic group of mycotoxins known as aflatoxins. Health effects in humans and livestock due to consumption of aflatoxin-contaminated foods include impaired growth, liver and other cancers, immuno-suppression, synergisms and death. These toxins can contaminate an array of crops including maize, groundnuts, spices and tree nuts.

ICRISAT and partners have developed several technologies that can reduce risks of aflatoxin contamination. These include genetic resistance and integrated crop management practices, agronomic practices, biological control and biotechnological interventions. This paper summarizes results from on-farm trials conducted in Mali during 2003-05 under a project supported by the Common Fund for Commodities (CFC). Some of the key achievements are as follows:

- Eight resistant/tolerant cultivars were evaluated by 10 farmers in five villages of Kolokani under their own management practices. The tolerant varieties recorded significantly lower levels of aflatoxin compared to the susceptible check.
- A number of agronomic practices that minimize risk of pre-harvest infection by Aspergillus flavus were tested in two major groundnut growing areas in Mali (Kolokani and Kayes). These technologies included the application of lime, farmyard manure (FYM), crop residues (CR) and their combinations using aflatoxin resistant (55-437) and susceptible (JL 24) cultivars. The application of lime and FYM 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%.
- Several best harvesting and drying techniques such as avoiding damage to pods, harvesting at right maturity, proper drying of pods were also demonstrated in Kolokani and Kayes. The aflatoxin reduction under these practices varied from 69% to 88% at Kolokani, and 63% to 84% at Kayes.

The above management techniques can significantly contribute to healthy groundnut production and need to be promoted widely. A number of information pathways were used to increase awareness about the importance of aflatoxin contamination in groundnut and other products. These include information brochures in various languages (French, English and Hausa), training workshops/seminars, radio and television programs, end of crop season meetings, farmer-to-farmer visits.

Introduction

Groundnut (*Arachis hypogaea* L.) is one of the major sources for protein, livelihood for the rural poor and foreign exchange earnings for many West African countries. It generates 60%, 42% and 21% of rural cash earnings among groundnut producers in Senegal, Niger and Nigeria respectively, and accounts for about 70% of rural employment in Senegal (Ndjeunga et al. 2006). However, during the last four decades, West Africa lost its position in world groundnut production and export shares. Groundnut production share declined from 23% to 15% whereas export share declined from 55% to 20%. However, since 1984, groundnut production in West Africa has been increasing by about 6% annually, mainly due to expansion of groundnut production area. Senegal and Nigeria are among the world's largest groundnut producers (Ntare et al. 2005).
Low productivity, aflatoxin regulations, stricter grades and standards have limited the competitiveness of West African groundnut in domestic, regional and international markets. Relative prices of groundnut oils are higher in the international markets, making these products less competitive compared to palm oil, cotton oil and others. To regain its competitiveness, groundnut productivity and production need to be increased significantly, technologies to reduce aflatoxin contamination must be promoted, and grades and standards met.

Aflatoxins are natural toxic chemical substances produced by *Aspergillus flavus* and *A. parasiticus*. These toxins can contaminate an array of crops including maize, groundnuts and tree nuts. Health consequences related to consumption of aflatoxin-contaminated foods include impaired growth in children, liver cancer, immuno-suppression and synergism with hepatitis B and C viruses. In April 2004, one of the largest aflatoxicosis outbreaks occurred in rural Kenya, resulting in 317 cases and 125 deaths; Aflatoxin-contaminated homegrown maize was the

Infected groundnuts

source of the outbreak (Lewis et al. 2005). In West Africa many individuals are not only malnourished but are also chronically exposed to high levels of aflatoxin through their diets (Gong et al. 2002). Due to deleterious health hazards, aflatoxin contamination significantly restricts the volume of groundnut exports from sub-Saharan Africa (Freeman et al. 1999). International trade restriction is particularly serious, because of the European Union's (EU) imposition of a new aflatoxin regulation, which is stricter than that suggested by the Codex Alimentarius Commission (Ntare et al. 2005). The potential seriousness of the export-restricting effect of aflatoxin contamination in the groundnut sectors in many African countries has been documented in a number of studies (Otsuki et al. 2001). The impact analysis of the European Union's new harmonized aflatoxin limits on exports from Africa indicated that 1 percent lower maximum allowable level of aflatoxin contamination will decrease groundnut trade by 1.3 percent. The results of the study suggest that the implementation of the new (and more stringent) EU aflatoxin regulations will impact adversely on African exports of even cereals, dried fruits, and nuts to Europe. More specifically, the study suggests that even though the new EU standard would decrease health risk by roughly 1.4 deaths per billion a year, it will result in a $670 million (or 64 percent) reduction in African exports, in contrast to a regulation based on an international standard suggested by Codex guidelines.

Implementing programs to reduce the levels of aflatoxin contamination will generate social benefits. Boakye-Yiadom (2003) used an economic surplus model that incorporates trade, as well as, domestic production and consumption to assess the potential benefits from research into the aflatoxin-reducing program on high quality edible groundnut exports in Senegal. Several scenarios (from a 30% increase to a 60% increase in high quality groundnut) of program-effectiveness were examined. The results support that besides enhancing farmers' welfare, the adoption of the aflatoxin-reducing program is expected to yield an overall net-gain ranging between $0.56 to 4.25 million. This study does not account for benefits accruing from improved health, nutrition and livestock.

ICRISAT has developed promising technologies based on agronomic and cultural practices that can minimize the risk of aflatoxin contamination in groundnut and its products (Waliyar et al. 2005 and 2006). The technologies need to be demonstrated on-farm to realize their impact.

Objectives

The overall goal is to reduce aflatoxin contamination to improve health and incomes of groundnut farmers and consumers through the promotion of pre- and post-harvest technologies that minimize contamination, and information dissemination to increase awareness.

Approach and methods

Analytical framework: *Aspergillus flavus* infection of groundnut occurs under pre- and post-harvest handling and storage conditions (Mehan et al. 1991). Apart from biological and physical factors, farmers' practices that lead to contamination include: absence of sorting before marketing, use of damaged and shriveled kernels as seed, delayed harvesting after physiological maturity, retention of high quantities of moisture in pods, inadequate protection from rain, pest and disease attacks. Therefore aflatoxin management should start in farmers' fields with proper crop management and handling, post-harvest storage, followed by marketing and processing conditions.

Several approaches have been recognized to minimize aflatoxin-contamination in agricultural commodities. These comprise breeding for resistance to fungal contamination, good agricultural production, processing, handling and storage practices. However, there has been little success in the development of resistant varieties of groundnut that are resistant to aflatoxins (Waliyar et al. 1994). Other agronomic approaches such as avoiding moisture stress, minimizing insect infestation and reducing the inoculum potential of the causal fungi have been suggested and these may not be appropriate under smallholder agricultural systems prevalent in most parts of West Africa.

Implementing good agricultural practices such as appropriate drying techniques, drying the produce to $<10\%$ moisture, maintaining proper storage facilities and limiting exposure of grains and oilseeds to moisture during transport and marketing would minimize the problem of contamination by aflatoxins. Indeed, segregating contaminated, moldy, discolored, small shriveled or insect-infested seeds from sound kernels has been particularly useful in minimizing the level of aflatoxin contamination in Senegal.

Methodology: The trials/demonstrations were initially conducted in selected villages of Kolokani and Kayes in Mali and later extended to Nigeria and Senegal. Farmers were given a package of selected technologies identified through on-station experiments and compared with farmers' management practices in their own fields. Aflatoxin content was measured in a bulk sample from each plot of each treatment by Enzyme Linked Immunosorbent Assay (ELISA) technique developed by ICRISAT. Each farmer was taken as a replicate. Field days were conducted to expose improved practices to other farmers in villages.

Harvesting techniques such as avoiding damage to pods during harvest, crop harvest at right maturity, proper drying of pods and good storage practices were also evaluated/demonstrated.

A number of information pathways were used to increase awareness about the importance of aflatoxin contamination in groundnut and other products. These include information brochures in various languages (French, English and Hausa), training workshops/seminars, broadcast and telecast of the relevant programs.

Selection of pilot sites and setting up demonstration plots

Kolokani and Kayes in Mali represent the major groundnut growing regions of Mali. Several of ICRISAT's on-farm experiments and socioeconomic studies have been conducted for many years at Kolokani, and the groundnut program of the Institut d'Economie Rurale (IER) is based at Kayes. In these locations, groundnut is grown extensively under rainfed conditions with limited or no external inputs and are prone to end-of-season drought. Groundnut based cropping systems constitute an important source of livelihood for farmers in these areas as groundnut pods provide the much needed cash income and the haulms are a valuable source of fodder for livestock.

Participation in the trials/demonstrations was open to all interested farmers within a village. Besides scientists and farmers, the local extension agents and NGOs were also involved. Field demonstrations were conducted on an individual basis. At the end of the crop season a meeting was held between the participating farmers and extension officials to discuss progress and get feedback. These meetings provided a forum for reviewing trial management and facilitated ongoing assessment of technologies being tested. The farmers managed the trials by carrying out all field operations from land preparation to sowing, weeding and harvesting. Visits were organized for surrounding farmers to promote the flow of information and knowledge between the farmers and scientists.

Training and information dissemination

Training is a key element to build capacity and strengthen the knowledge of farmers, partners and scientists in order to promote awareness about the risks of aflatoxin contamination. We used various tools such as farmer field days, brochures and flyers, workshops, exchange visits and field trips to strengthen and build human resources in the targeted villages/areas.

Collection and analysis of data

Periodic follow-up trips were conducted to supervise project activities, collect data, and provide technical support and advice to farmers. Groundnut pod samples from the harvested crop were taken to the laboratory for determination of aflatoxin content.

Results and discussion

Participatory evaluation of tolerant varieties

Past research has identified and developed groundnut varieties that are tolerant to *Aspergillus flavus* invasion and subsequent aflatoxin contamination (Waliyar et al. 1994). The first task was to expose groundnut farmers to these varieties through participatory on farm trials/demonstrations.

Five varieties identified from on-station screening trials were tested in on-farm trials along with resistant, susceptible and local checks. Ten farmers (two each from five villages) in Kolokani, Mali, conducted the trial. The tolerant varieties showed significantly lower levels of *A. flavus* infection and aflatoxin contamination compared to the susceptible and local susceptible checks (Table 1). ICG 6101,

Table 1. Aspergillus flavus infection (%), aflatoxin content (μg/kg) and pod yield (t/ha) under farmer management in Kolokani district of Mali. Figures are mean of ten farmers in five villages (2004 and 2005 rainy seasons).

	2004			2005		
Variety/ year	A. flavus infection (%)	Aflatoxin content (μg/kg)	Pod yield (t/ha)	A. flavus infection (%)	Aflatoxin content (μg/kg)	Pod yield (t/ha)
ICG 6101	1.90	0.86	0.82	6.20	4.62	1.05
ICG 7	1.60	0.36	0.92	5.10	2.62	1.03
ICG 6222	4.10	1.86	0.82	7.70	4.86	0.79
ICGV 88274	8.41	5.87	0.72	10.00	7.79	0.86
ICGV 93093	8.97	6.71	0.85	11.20	3.99	1.11
55-347-S	1.80	1.02	0.93	9.10	3.77	1.31
Fleur 11-R	52.10	92.49	0.94	57.00	114.53	1.00
Local	25.00	16.95	0.87	18.10	27.72	1.31
SE ±	1.175	1.920	0.064	1.221	10813	0.076
CV (%)	29	36	23	25	27	23

ICG 7 recorded low aflatoxin content <1 μg/kg compared to 1.02 for the resistant check 55-437-S, and 92.49 μg/kg for the susceptible check Fleur 11 (Table 2). The yields were reasonable considering that no additional inputs were added. The results confirm the tolerance of the selected varieties to aflatoxin contamination and can play a significant role in the integrated management of the aflatoxin problem.

Table 2. Effect of soil amendments on aflatoxin contamination in on-station trials.

Treatment	% reduction
Lime (L)	72
Manure (FYM)	42
Crop residues (CR)	28
L + FYM	84
L + CR	82
FYM + CR	53
L + FYM + CR	83

Integrated management

Effect of agronomic and cultural practices

Pre-harvest

As end-of-season drought conditions favor aflatoxin contamination, several management practices have been developed to improve water retention after cessation of rains (Craufurd et al. 2005). Results of the on-station trials showed that various soil amendments could significantly reduce aflatoxin contamination in groundnut (Table 2).

These treatments were tested in on-farm trials at Kolokani and Kayes in Mali during the 2003 and 2005 crop seasons. In each district, farmers evaluated the cultural practices in various combinations using resistant (55-437) and susceptible (JL 24) varieties. The cultural treatments involved a combination of application of farmyard manure (FYM), lime and crop residues (CR) at sowing and 50 days after sowing. Other than lime (a purchased input), FYM and CR were farmers' resources.

The treatments included application of FYM (2.5 t/ha) before planting, lime as source of calcium at 45-50 days after sowing, CR at 50 days after planting. Five farmers in Kolokani and 8 in Kayes were selected to conduct the trials. Results presented in Table 3 indicate that all treatments significantly

A field affected by drought

reduced aflatoxin contamination especially in the susceptible variety JL 24. No significant differences were observed in the resistant variety (55-437) at Kayes. Application of lime was the most effective, and it reduced contamination by 73% and 85% at Kolokani and Kayes respectively. However, the pod yield was not significant and it indicates that the technology may face difficulties in adoption. Lack of sufficient quantities of CR and FYM are major constraints.

Table 3. Level of aflatoxin contamination and pod yield under various agronomic practices in Kayes and Kolokani (2003-2005).				
	Aflatoxin content (μg/kg)		Pod yield (t/ha)	
Treatment/variety	55-437	JL24	55-437	JL24
Kolokani* (2004)				
400 kg/ha lime 50 dap	1.90	52.34	1.16	1.06
2.5 t/ha FYM	2.07	64.07	1.27	1.09
2.5 t/ha CR	3.28	126.59	1.14	1.03
L + CR	2.76	79.53	1.24	0.96
FYM + CR	4.20	90.64	1.39	1.18
No treatment	6.21	190.84	1.00	1.07
SE ±	1.22	0.87		
Kayes** (2003 and 2004)				
400 kg/ha lime 50 dap	6.00	12.10	1.98	2.06
2.5 t/ha FYM	8.20	34.80	2.05	1.99
2.5 t/ha CR	9.20	61.45	1.84	1.80
L + CR	6.80	12.10	2.08	2.08
FYM + CR	7.50	17.50	2.05	2.01
No treatment	8.00	82.32	2.05	2.11
SE ±	4.73	0.13		
* trials by five farmers				
** trials by eight farmers				

Post-harvest

Soon after crop maturity, proper harvesting, handling and storage are essential to reduce the risk of contamination. Good drying requires plenty of air circulation. Poorly dried groundnuts enhance fungal growth and aflatoxin contamination. Groundnuts need to be harvested at the right time. Delays in harvesting results in over maturity which leads to mold infestation and subsequent aflatoxin contamination.

Two on-farm trials in each of the four villages (Tioribougou, Mambabougou, Somon and Kolokani) were conducted to demonstrate the best harvesting and drying techniques. This essentially involves lifting the plants, laying them with foliage directly on the ground in a circle with pods placed towards the inner part of the circle. Layers are built up gradually decreasing the inner part of the circle. The pods are then removed at the farmer's convenience. In Kayes, demonstrations were done with 10 farmers. In Kolokani, the reduction of contamination on a tolerant variety ranged from 48-100% and 69-88% on the susceptible variety compared to the traditional random heaping by the farmers (Table 4). Results for Kayes are presented in Table 5.

Best-bet post-harvest drying

Table 4. The effects of the drying method on aflatoxin contamination (μg/kg) in Kolokani (2004).

	55-437		47-10	
Farmer	Traditional method	Improved method	Traditional method	Improved method
Bagui	1.45	0.58 (60)	17.94	2.22 (88)
Mory	3.24	1.45 (56)	13.73	1.78 (87)
Seba	1.014	0.00 (100)	15.93	4.97 (69)
Demba	1.50	0.78 (48)	14.61	3.89 (74)
SE ±		0.776		
CV (%)		29		

Figures in parenthesis indicate % reduction over the traditional method.

Table 5. The effects of the drying method on aflatoxin contamination (µg/kg) in Kayes (2004).

	55-437		47-10	
Farmer	Traditional method	Improved method (% reduction)	Traditional method	Improved method (% reduction)
Bagui	1.45	0.58 (60)	17.94	2.22 (88)
Madou	10.32	5.21 (50)	71.31	20.02 (72)
Savadogo	8.08	3.03 (63)	60.08	18.01 (70)
Yaya	5.70	2.17 (62)	58.01	21.53 (63)
Mamadou	11.65	8.96 (23)	79.52	28.31 (64)
Coumba	9.90	2.32 (77)	59.62	15.73 (74)
Djenaba	6.03	3.25 (46)	74.48	27.01 (64)
Kande	8.01	1.67 (79)	44.86	14.28 (68)
Seydou	5.78	0.31 (95)	12.32	1.96 (84)
SE ±		2.999		
CV (%)		43		

Effects of the timing of pod removal on aflatoxin contamination

An on-farm experiment was initiated to evaluate the effects of harvesting methods on *A. flavus* invasion and aflatoxin contamination using eight varieties that were selected by farmers in Kolokani. Two resistant checks (J 11 and 55-437) were included. The treatments were: removal of pods immediately after lifting, one week and two weeks after, picking pods remaining in the soil (gleaning the pods). These were compared to the traditional practice.

Differences among varieties were highly significant. With farmers' practice of removing pods nearly one month after harvest of the crop, the aflatoxin content ranged from 77 to 342 µg/kg compared to 9 µg/kg for 55-437 and 6 µg/kg for J11. Removing pods immediately after lifting reduced aflatoxin contamination by 60% and levels were 30% for removing pods two weeks after. Pods left in the soil (gleaned pods) had the highest aflatoxin contamination, which ranged from 99 to 413 µg/kg in susceptible varieties compared to 7-11 µg/kg for resistant cultivars (Table 6).

Table 6. The effects of timing of pod removal on aflatoxin levels in Kolokani* (2003-2004).				
Time for pod removal	Aflatoxin content (μg/kg)			
	Resistant cultivars		Susceptible cultivars	
	55-437	J 11	JL 24	Fleur 11
0 week	4.5	3.6	90.5	117.7
1 week	6.3	5.7	152.4	199.5
2 weeks	7.4	6.1	244.4	295.2
Farmers' practice	8.7	7.1	316.3	342.2
*averaged over five farmer trials.				

Monitoring aflatoxin contamination in farmers' produce

In addition to on-farm trials/demonstrations, we also monitored for aflatoxin contamination in groundnut from farmers' produce and markets in the districts of Kolokani, Kayes, Kita and Bamako in Mali. Results in Table 7 show a significant reduction in aflatoxin contamination in samples from farmers who participated

Groundnuts in markets

in the trials/demonstrations (Fig. 1). This is an indication of adoption of improved management practices that reduced aflatoxin contamination level in groundnut in Mali. The high levels of aflatoxin contamination in market samples are of concern and indicate that post-harvest handling and storage are significant predisposing factors.

Table 7. Levels of aflatoxin contamination in the groundnut growing districts of Mali.

Location	Number of samples	Aflatoxin range (μg/kg)	% with 10 μg/kg	Participation in trials?
Farmers				
Kolokani	56	0.12-75	72	Yes
Kayes	20	6-1597	50	Yes
Kita	80	4-1152	45	Yes
Dioila	30	1.4-927	7	No
Markets				
Kolokani	9	88-612	0	NA
Kita	22	30-1648	0	NA
Bamako (kernels)	291	2-2666	14	NA
Bamako (paste)	69	5-2914	0.01	NA
NA : not applicable				

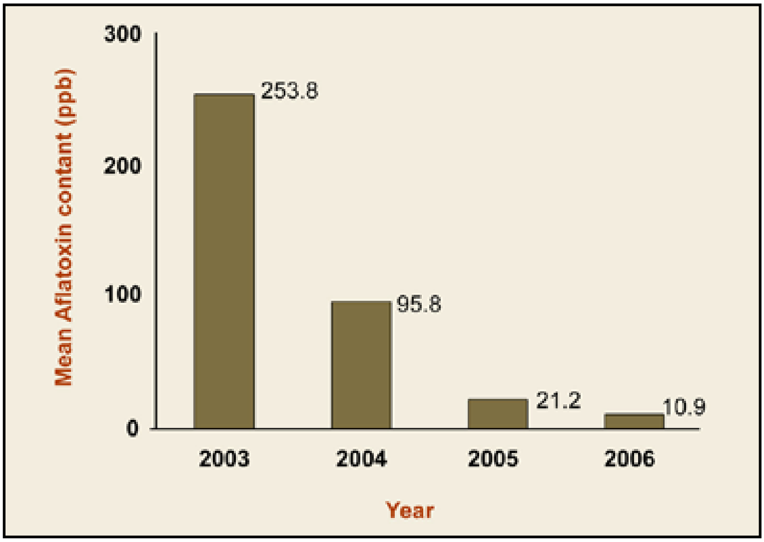

Figure 1. Trend in aflatoxin levels from 20 farmers' produce in 4 villages of Kolokani, Mali, 2003-2006.

Scaling out

We have successfully developed and tested integrated management technologies to prevent pre-harvest aflatoxin contamination at the farmer level in Mali. However, large scale dissemination of these technical packages, along with intensive sensitization campaigns across the commodity chain remains a major challenge. Awareness about aflatoxin contamination is improving and efforts were made to continue dissemination technology packages on the control of aflatoxin contamination at the production level.

On-farm trials/demonstrations of the best-bet harvesting and drying techniques were conducted in Nigeria for a second year and in Senegal for the first time. In Nigeria, the recommended method of drying the pods facing the sun reduced aflatoxin contamination by as high as 97% compared to the farmers' method of windrow drying. Aflatoxin content in seed ranged from 3.73 to 9.00 mg/kg under the recommended method compared to 6.00 to 337.00 mg/kg under the traditional method. These results are consistent with those obtained in the previous crop season. This simple management technique can significantly contribute to healthy groundnut production and needs to be promoted vigorously.

Farmers' awareness and perceptions of groundnut quality

Although no systematic awareness surveys were conducted in the study villages interacting with the groundnut growers, both women and men revealed that farmers' knowledge about aflatoxin is very low. The reason for such a situation is that nowhere in the production and marketing process are they ever asked to check or verify for aflatoxin contamination. None of the marketing channels where they dispose their groundnuts has any restriction on the sale of aflatoxin-contaminated products.

Farmers are normally more concerned about good quality seed material and good marketable produce. The indicators for good quality material include: fully developed, bold, big and spotless pods, clear color, good taste of kernels with high shelling percentage. Small shriveled kernels that taste bitter, have fungal growth, are rotten or sprouted and have bad odor are often discarded. However, small quantities of such inferior quality gleans (immature and shriveled seeds), broken shelled and other deformed kernels and pods are sold along with the rest of the good quality material or used in preparation of source for family consumption.

It is clear that farmers are not aware of the aflatoxin issue, and so do not perceive aflatoxin contamination as a problem in their groundnut production systems. They are oblivious of the fact that their current production and post-harvest practices are likely to increase the chances of aflatoxin contamination. They do not perceive any economic risks in producing a groundnut crop that

Brochures in local (Bambara) and French languages in Mali (above) and in English and Hausa in Nigeria (below)

may carry aflatoxin contamination since groundnut prices are neither influenced due to contamination nor are there any market restrictions on its sale. They also do not have information on health risks associated with the consumption of aflatoxin contaminated products including groundnut.

Enhancing awareness

In order to increase awareness about the dangers associated with aflatoxin contamination, field days were organized for more than 600 stakeholders, ie, farmers, extension agents, processors and traders. Awareness on the problem of aflatoxin was further enhanced through brochures in local (Bambara) and French languages in Mali and in Hausa in Nigeria. In Nigeria, a one-day workshop was held for extension workers and local government officials from the major groundnut growing states to increase awareness about the dangers of aflatoxin and how to minimize it. Over 100 participants attended the workshop.

In Niger, a workshop was organized for researchers, extension workers, producers, traders and processors to sensitize them to the aflatoxin problems and its management. Sixty participants attended and the workshop was widely covered by local radios.

Lessons learned

- The results demonstrate that simple crop management techniques can significantly reduce aflatoxin contamination at the production level. However, technological adoption will not take place unless a series of interventions take place that give the necessary incentives to farmers and other stakeholders.
- Farmers work under several socioeconomic constraints, which are likely to become their primary concern before they are prepared for any changes to their current management practices. Introduction of new technologies entail certain conditions for adoption. Technologies that are labor intensive or that have higher financial implications to the farmer or are more input intensive are less likely to be accepted. New technologies must be simple cost effective (incur low or no costs) and must be easy to adopt.
- Though farmers pay considerable attention to the selection of seed from their own produce, lack of awareness about identification of contamination in general prevents them from using aflatoxin-free seeds. Interventions need to ensure that farmers use seeds free from contamination, irrespective of the sources of supply. There is a need to build coalitions of interest for providing incentives and necessary structures that support contamination-free production and delivery for the entire food and feed chain.

- Institutional arrangements need to be explored to bring about common norms among all the stakeholders in the supply chain. Specific policy measures including legislation are required to enforce prevention of trade in aflatoxin contaminated products.
- Mass awareness campaigns are required to educate farmers, traders, processors and the consumers of groundnuts and groundnut products regarding the ill-effects of aflatoxin contamination. This may imply developing alternative marketing approaches such that the whole supply chain is intimately integrated into a single system.
- Providing incentives to farmers, health concerns, building up consumer demands for aflatoxin-free groundnuts, trade responsiveness and appropriate action research for technological change should be the operational focus of interventions.
- Effective aflatoxin control requires awareness among all stakeholders from production, through processing, to marketing and eventual consumption and consequent actions.
- Management of the risks associated with aflatoxin contamination can be controlled with an integrated system, and should involve strategies for advocacy (awareness), prevention, integrated management, policy support, and appropriate institutions linking producers to markets with quality assurance perspectives.
- Several aspects of aflatoxin R&D need further attention. These include strategies to reduce impact on trade, biological control especially adapted to specific ecologies, development of resistant cultivars using traditional and biotechnological approaches, and impact of aflatoxin management options and/or nutritional improvement on children's health in high-risk zones.
- Quality control requires appropriate legislations, regulations and standards. Compliance entails surveillance and laboratory analysis.
- The results from this study need to be scaled-out to larger geographical areas to include appropriate mechanisms and linkages to leverage changes in policy and institutions to effectively address the marketing constraints of groundnut.
- Consolidate efforts by major stakeholders in the field of aflatoxin research, with the aim to make a significant impact on reduction in contamination in high-risk commodities and improving access to markets that have been lost.

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