Assessment of *Aspergillus flavus* Infection and Aflatoxin Contamination in Groundnut in Southern Vietnam

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Abstract

Groundnut is an important food and cash crop in Vietnam with a high export potential. Limited studies of foods in the country have indicated that aflatoxin contamination is a problem in groundnut and maize. Vietnam considers the aflatoxin problem in groundnut to be of great importance, especially in view of Vietnam's expanding trade in this commodity, and the increasing use of groundnut cake as animal feed. Systematic surveys were conducted to assess *Aspergillus flavus* infection and aflatoxin contamination in groundnuts from farmers' fields and markets/oil mills in the major groundnut-growing areas of southern Vietnam. Results indicated that preharvest aflatoxin contamination is not likely to be a serious problem in adequately irrigated groundnuts. However, groundnuts grown under residual moisture or limited irrigation can be contaminated under conducive environmental conditions prevailing in the winter-spring season as evidenced by moderate to high aflatoxin levels found in some samples. Soilborne diseases such as stem/pod rot and bacterial wilt prevalent in many parts of southern Vietnam are likely to encourage *A. flavus* invasion of pod/seed in the field. It is emphasized that the aflatoxin problem should be viewed holistically as contamination can be pre- and postharvest with many factors influencing, e.g., the crop rotation, soil moisture, soilborne pests and diseases, crop produce drying and storage conditions. A brochure on "Aflatoxin contamination problems in groundnuts and groundnut products" was prepared (in English and Vietnamese) and distributed to many farmers, traders, and extension and research workers to enhance awareness of the aflatoxin problem and management options.

Collaborating Institutes and Staff

Activities	(i) Survey for *Aspergillus flavus* seed infection and aflatoxin contamination in groundnut in southern Vietnam
	(ii) Enhancement of awareness of aflatoxin contamination problems
Collaborating institutions	International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru 502 324, Andhra Pradesh, India
	Oil Plant Institute (OPI), Ho Chi Minh City, Vietnam
Location	Long An and Tay Ninh Provinces (Southern Vietnam)
Period	2-29 March 1996
Collaborating staff	
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Preface

At the request of Dr Phan Lieu, Director, Oil Plant Institute (OPI), and Dr Pham Van Bien, Director, Institute of Agricultural Science (IAS) of South Vietnam, Ho Chi Minh City, Vietnam, Dr CLL Gowda, Coordinator, Cereals and Legumes Asia Network (CLAN), deputed Dr VK Mehan to visit OPI and IAS for developing collaborative research plans on aflatoxin contamination problems in groundnut in southern Vietnam. Dr Mehan visited the institutions concerned from 21 to 23 July 1995 to plan joint research activities. The following areas of collaborative research/activities were identified: (1) assessment of aflatoxin contamination risks in various regions (2) development of aflatoxin management packages (3) enhancement of awareness of the aflatoxin problem among farmers, marketing personnel, and processors.

It was envisaged that this collaborative research project should serve as an excellent opportunity to elucidate aflatoxin contamination risks in various rice-based groundnut production systems in southern Vietnam, and to increase awareness of the aflatoxin problem. It was also projected that joint surveys on aflatoxin contamination would prove useful to train the national staff in sampling procedures and aflatoxin determination. This report documents the results of a survey and awareness activities carried out during March 1996. These activities were carried out under the ICRISAT's Integrated Systems Project 4 (ISP 4), and received financial support from the ISP 4 and OPI.

Introduction

Groundnut is an important food and cash crop in Vietnam with a high export potential. The area under groundnut is almost equally distributed between northern (125 000 ha of rainfed crop) and southern (125 000 ha of irrigated or partially irrigated crop) Vietnam. In southern Vietnam, groundnut is sown throughout the year but it is mainly cultivated in the winter-spring and summer seasons. A third crop is also grown in the rainy season, but on a limited scale under rainfed conditions.

A few studies in Vietnam have shown considerable levels of aflatoxin (40-500 $\mu g\ kg^{-1}$) in groundnuts and groundnut products, and have highlighted the occurrence of aflatoxicosis in poultry and livestock (Hao 1993, 1995, To and An 1994). Vietnam will soon be entering into an agreement with some Japanese companies for the supply of peanut butter with a guarantee for aflatoxin-free butter. Some recent consignments of groundnuts exported to Australia have been rejected because of high levels of aflatoxin contamination. This has resulted in increasing the attention of various Vietnamese research institutions to this important problem. Prevention or control of aflatoxin contamination in groundnut is considered to be of great importance, particularly in view of Vietnam's expanding trade in this commodity, and the increasing use of groundnut cake as animal feed. There is now an increased emphasis on the surveillance and monitoring of groundnuts for aflatoxin levels, and several institutes are keen to initiate research on the development of appropriate aflatoxin management technologies.

In 1996, the Oil Plant Institute (OPI), in collaboration with ICRISAT, initiated research on the aflatoxin problem in groundnut in southern Vietnam.

Objectives

(a) to assess the extent of *Aspergillus flavus* seed infection and aflatoxin contamination in groundnuts from farmers' fields in rice-based production systems, and from markets in southern Vietnam.

(b) to increase awareness of aflatoxin contamination problems in groundnuts and groundnut products among farmers, agricultural extension workers, and the groundnut processing industry personnel.

Materials and Methods

Survey of Groundnuts for *A. flavus* Infection and Aflatoxin Contamination

Collection of groundnut samples

Groundnut samples were collected using a participatory approach that involved farmers. In each of the villages visited, comprehensive discussions were held with farmers on production systems, varieties grown, number of irrigations, and major pest and disease problems. Several national scientists and extension workers were involved in sample collections and discussions with farmers.

One hundred-thirty-six samples of groundnut pods were obtained from farmers in the major groundnut-growing villages in Cu Chi, Duc Hoa, Go Dau, and Trang Bang districts. Samples were from the 1995/96 winter-spring season crop. In each village, samples were collected from 10 to 20 farmers following a groundnut-groundnut-rice or groundnut-rice-rice cropping system. Samples were collected from the freshly harvested crop or from plants/pods being dried in farmers' houses.

Approximately 1.5 kg pod samples (mature pods) were collected from each farmer for examining seed infection by the aflatoxin-producing fungus *Aspergillus flavus*, and for determining the levels of aflatoxin. Pod samples were collected in brown paper bags, and brought to the Oil Plant Institute; they were sun-dried to a seed moisture content of 8-9%. The pods were hand-shelled, and seeds tested for fungal infection and for aflatoxin contamination.

Eleven samples of groundnuts were also obtained from several markets and an oil factory (Nhat Thinh Oil Factory, District 6, Ho Chi Minh City) in and around Ho Chi Minh City.

Examination of seeds for infection by *A. flavus* and other fungi

One hundred seeds from each sample were tested for infection by *A. flavus* and other fungi. The seeds were surface-sterilized by soaking for two and a half minutes in a 0.1% aqueous solution of mercuric chloride, rinsed in two changes of sterile distilled water, and then plated onto Czapek-Dox agar medium supplemented with rose bengal and streptomycin sulphate in 9 cm diameter petri plates for isolation of fungi. The plates were incubated at 25 °C in the dark, and colonies of fungi growing from seeds were recorded after 5-7 days.

Aflatoxin analyses

One hundred samples from farmers' fields, markets and an oil factory were analyzed for aflatoxins. These samples were selected based on their origin (cropping systems, districts) and levels of *A. flavus* infection. A 20-g sample of seed from each pod sample was tested for aflatoxin content using the BF method (AOAC 1980). The 20-g sample was taken from the thoroughly mixed and ground seed (about 1 kg) from each pod sample.

Background information on cropping systems, disease constraints, and harvesting and drying practices

Cultural practices

In each village, groundnut-groundnut-rice and/or groundnut-rice-rice cropping systems are predominantly followed. Few farmers practise a groundnut-fallow/vegetable cropping system. Groundnut is irrigated in both the winter-spring (November-February) and summer-autumn (March-May/June) seasons. Rice is irrigated in the summer-autumn season, while it is rainfed in the rainy season (July-November).

Only spanish varieties/landraces (Ly, Giay, Khia Ly, Local; mostly in mixtures) that mature in 90 days are grown. Number of irrigations to the winter-spring season crop varies from 0 to 15. Most farmers give four to seven irrigations; some give eight to 15, some 1-3 irrigations, while some others grow the crop without any irrigation (particularly in groundnut-rice-rice cropping system).

High inputs (fertilizers, herbicides, several sprays of insecticides and fungicides) are commonly used.

Disease constraints

Collar rot, damping-off, bacterial wilt, and stem rot diseases are important constraints to groundnut production. Pod rots are also considered as one of the major constraints affecting yield and quality. In many areas, there is a substantial pod loss (from peg and pod rots - *Sclerotium rolfsii* is suspected to be involved) in the soil at the time of harvest. Considerable number of groundnut samples from farmers' fields showed moderate to high percentages of pods rotted (including severely and moderately rotted pods), particularly from Cu Chi and Duc Hoa districts; pod rot levels ranged from 0-30%. *Sclerotium rolfsii* is mainly implicated in these pod rots. Some ectoparasitic nematodes (*Tylenchorhynchus* sp, *Macroposthonia* sp, and a lesion nematode) are involved in causing brownish-black lesions on pod surfaces (slightly damaged pods) in some areas.

Harvesting, drying, and storage

The harvested plants are generally dried in random windrows in the field only for half a day or one day, and then the pods are sun-dried on a concrete floor in farmers' houses for 4-5 days. Some farmers stack groundnut plants in stores for several days before pods are plucked and dried in the sun. Dried pods are stored in jute bags for periods ranging from 1 to 5 months.

Full details of farmers visited, cropping systems, farmers' perceptions regarding groundnut yield and constraints to production are given in Appendix 1, and percentages of seed infected by *A. flavus* and other fungi are given in Appendix 2.

Results

Aspergillus flavus seed infection in samples

One hundred and forty-seven samples of groundnuts from farmers' fields and markets/oil mills were examined for seed infection by *A. flavus*. Seed infection levels ranged from 0 to 12% in samples from farmers, and from 3 to 35% in samples from markets and an oil mill (Table 1). Overall, no marked differences were found among four districts for *A. flavus* infection in samples (51.5% samples from Go Dau, 55.5% from Trang Bang, 57.5% from Cu Chi, and 57.6% from Duc Hoa districts showed *A. flavus* infection). But locational differences were found for *A. flavus* seed infection; much lower percentages of samples (30-45%) from Hiep Thanh (Go Dau district), Trung Lap Ha (Cu Chi district), and An Tinh (Duc Hoa district) villages were infected with *A. flavus* than those from other villages (60-80%).

In general, *A. flavus* infection levels were low in samples from farmers in all villages. Only 9 (2 from Bau Don, 5 from Loc Hung, 1 from Trung Lap Ha, and 1 from Duc Lap Thuong) of the 136 samples tested had 4-12% seed infected by *A. flavus*; two of these had 9-12% seed infected. Levels of infection by *A. niger* and other fungi were also high in these samples (Table 1).

Samples from fields with groundnut-groundnut-rice cropping system tended to show slightly higher levels of *A. flavus* infection than those from fields with groundnut-rice-rice cropping system. In An Tinh village, levels of *A. flavus* infection were similar (1-3%) in samples from both the cropping systems. Levels of *A. flavus* infection were low (mostly 1-2%) in samples obtained from various villages of Cu Chi and Duc Hoa districts

Samples from fields receiving no or limited irrigations (1-3) had, generally, higher levels of *A. flavus* infection than samples from fields receiving five or more irrigations.

Surprisingly, a few samples collected from intensively irrigated fields (10 irrigations) also showed *A. flavus* infection (1-5%).

Most of the samples obtained from markets in and around Ho Chi Minh City had high levels of *A. flavus* infection (13-35%) (Table 1). All market samples also showed substantial infection by *Penicillium* species. Samples from an oil factory had 5-11% seed infected by *A. flavus*.

Aflatoxin contamination in samples

Of the 89 samples of farmers' groundnuts tested, only 7 were contaminated with aflatoxin B_1 (5-125 $\mu g\ kg^{-1}$). Four of these samples contained moderate to high aflatoxin levels (31.2-125 $\mu g\ kg^{-1}$), and the other three low levels (5-12 $\mu g\ kg^{-1}$). Four of these contaminated samples were from Loc Hung village, and one each from Bau Don, Trung Lap Ha, and Phuoc Thanh villages. The two samples that contained high levels of aflatoxin (125 $\mu g\ kg^{-1}$) had relatively higher percentages of seed infected by *A. flavus* (9-12%) (samples 8 and 51: Figure 1). The other five samples with low to moderate levels of aflatoxin (5-62 $\mu g\ kg^{-1}$) had low to moderate *A. flavus* infection (2-5%) (samples 40 and 49: Figure 1).

Two samples of seed from slightly and moderately damaged pods were found contaminated with high aflatoxin levels (112-160 $\mu g\ kg^{-1}$).

Of the 11 market/oil mill samples analyzed, five (45.4%) contained aflatoxin B_1; levels of aflatoxin ranged from 20 to 112.2 $\mu g\ kg^{-1}$. Samples from Banh Thanh and Ben Thanh markets (MS7, MS9, MS10, and MS11) with high levels of *A. flavus* infection (14-35%) (Figure 2) had high levels of aflatoxin (50-112.2 $\mu g\ kg^{-1}$). One sample (MS11) also contained substantial amount of aflatoxin B_2. Aflatoxin levels in samples from an oil factory ranged from 0 to 20.6 $\mu g\ kg^{-1}$. None of the samples collected from Duc Thanh market (showing 3% *A. flavus* infection) was contaminated with aflatoxin.

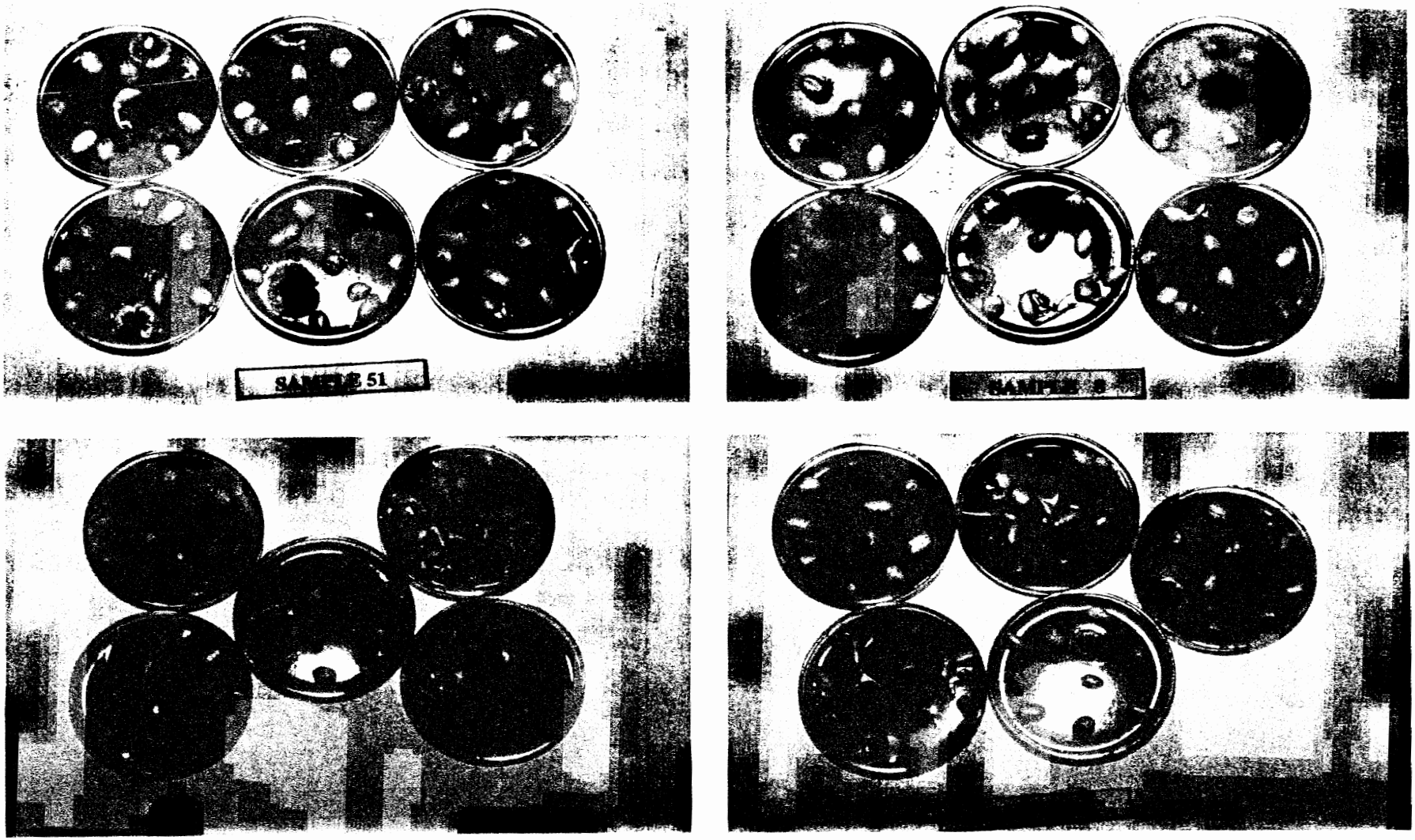

Figure 1. Groundnut seed samples from farmers' fields showing infection by ***Aspergillus flavus*** (green sporulating), *A. niger* (black sporulating), and other fungi: samples 40, 49, and 51 from Loc Hung village (Trang Bang district); sample 8 from Bau Don village (Go Dau district).

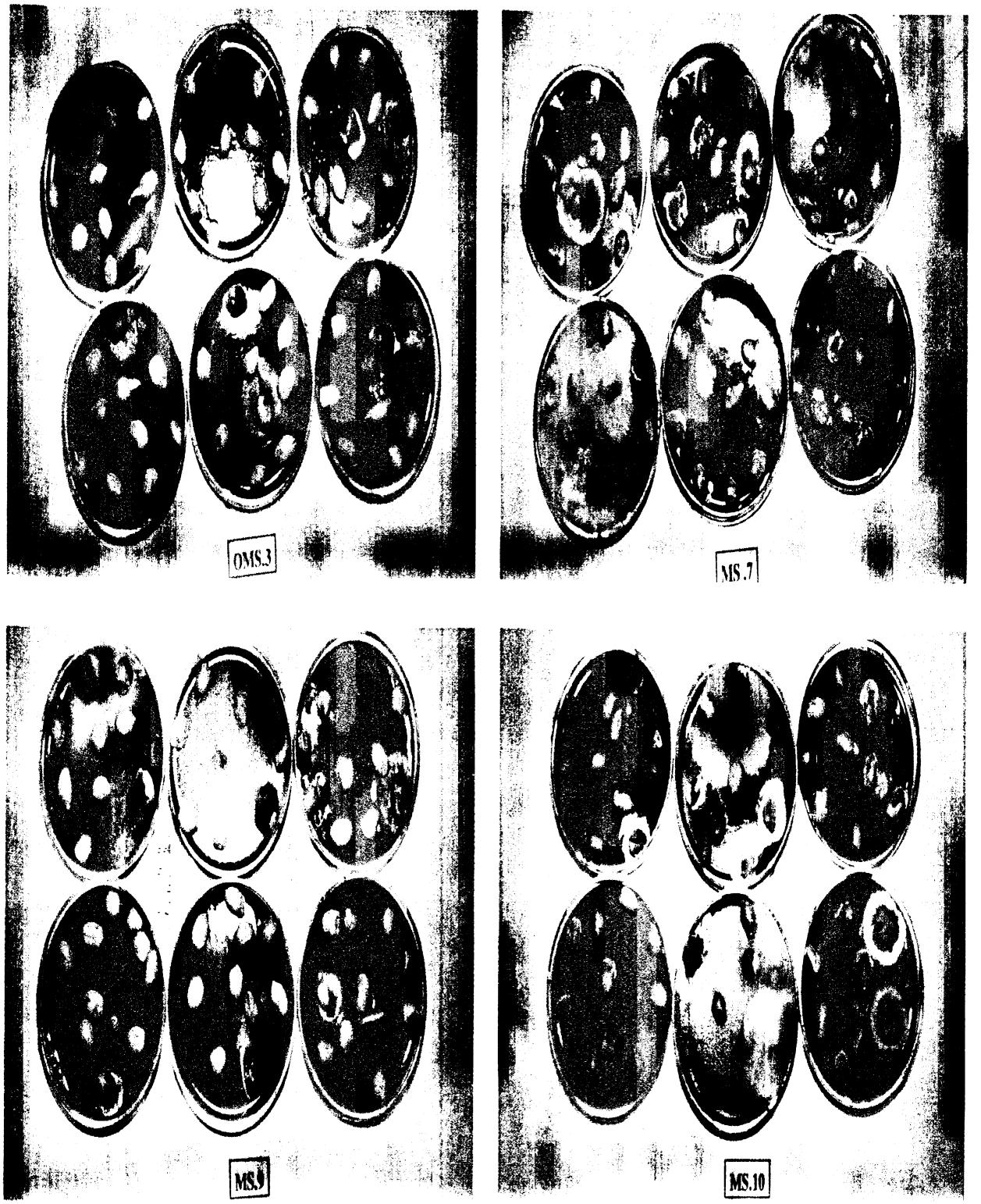

Figure 2. Groundnut seed samples from an oil mill and markets in Ho Chi Minh City showing infection by *Aspergillus flavus*, *A. niger*, and *Penicillium* species (blue sporulating): sample OMS. 3 from an oil mill; sample MS. 7 from Banh Thanh market; sample MS. 9 from Banh Thanh market; and sample MS. 10 from Benh Thanh market.

Aflatoxin awareness

To increase awareness of the aflatoxin contamination problem in groundnuts and groundnut products among groundnut farmers, extension workers, and processors, two activities were carried out:

(a) preparation and distribution of a pamphlet in Vietnamese titled "Aflatoxin contamination problems in groundnuts and groundnut products". (An English version was prepared earlier at ICRISAT.) (Given in Appendix 3)

(b) dissemination of information on the groundnut aflatoxin problem and its management through lectures to plant protection specialists and extension workers.

During our visits to various villages, farmers were informed about the importance and the need to adopt certain cultural and decontamination practices for aflatoxin management. To increase awareness of the aflatoxin problem, traders, oil millers, processors, and farmers were given a brochure (in Vietnamese) on "Aflatoxin contamination problems in groundnuts and groundnut products". The need for each farmer/trader to share the information in the brcchure with family members and colleagues, as widely as possible, was stressed.

Dr V K Mehan gave a lecture on "The Groundnut aflatoxin problem and its management" at the Department of Agriculture, Ho Chi Minh City. This was attended by many scientists and extension workers from various institutions - the Oil Plants Institute, the Postharvest Technology Institute, the Department of Plant Protection, the Department of Science and Technology, the Department of Agriculture, and the Agricultural University No. 1. It was proposed to form groups of extension workers and agricultural and veterinary researchers at the province level for increasing awareness of the aflatoxin problem among farmers and groundnut industry personnel.

Conclusions

- Preharvest aflatoxin contamination is not likely to be serious in irrigated groundnuts in southern Vietnam. However, groundnuts grown under no or limited irrigation can be contaminated under conducive environmental conditions prevailing in the winter-spring season as evidenced by moderate to high aflatoxin levels found in some samples.

- Although *A. flavus* infection levels were low (1-3%) in most samples, these are significant as only apparently healthy seeds were used for fungal infection and aflatoxin analysis. Groundnuts infected by *A. flavus* before harvest can lead to

aflatoxin contamination in storage under favorable environmental conditions.

- Soilborne diseases (e.g., stem rot/pod rot, bacterial wilt) prevalent in many areas are likely to encourage *A. flavus* invasion of pod/seed in the field. This is discernible from the moderate levels of *A. flavus* infection found in some samples from even extensively irrigated fields. Infected seeds often get into the saleable yield as fungal pod rots and pod damage by nematodes are common in most areas in sandy loam soils.

- High levels of aflatoxin found in various market samples indicate that the postharvest aflatoxin problem is important.

- We were successful in increasing awareness of the aflatoxin problems through distribution of the brochure, and interactions with many farmers, traders, plant protection specialists, and extension workers in various districts.

The aflatoxin problem must be viewed holistically as contamination can be pre- and postharvest with many factors influencing, e.g., the crop rotation, soil moisture, soilborne diseases and pests, field drying and storage conditions.

Future Plans

OPI will focus on the following:

- assessment of aflatoxin contamination of groundnuts (a) in farmers' fields in selected areas during winter-spring and rainy seasons (b) in storage (in farmers' warehouses, oil mills, and warehouses of processors) over a period of time;

- development and evaluation of appropriate cultural practices, and storage technologies to reduce *A. flavus* infection and aflatoxin contamination; and

- preparation of a detailed brochure on aflatoxin management options at all levels - production, marketing, storage, and processing.

Acknowledgements

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and encouragement to conduct the collaborative research through the project ISP4. We are also grateful to Dr Phan Lieu for providing useful logistic support. The excellent assistance provided by Ms Lien Hoa (Agronomist), Mr Tung (Researcher, Plant Protection), and Mr Nguyen Van Long (Vice Chief, Department of Planning and Transfer of Technology), OPI, in sample collections and active interactions with farmers, and Ms Oanh and Ms Phuong (Chemists) for aflatoxin analysis, is gratefully acknowledged.

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Table 1. Seed infection by *Aspergillus flavus* and other fungi, and aflatoxin levels in groundnut samples collected from farmers and markets in various groundnut-growing areas of southern Vietnam.

District/ village	CS[1]	No. of irrigations[2]	No. of samples		Percentage seed infected by						Aflatoxin B_1 (µg kg^{-1})	
					A. flavus		*A. niger*		Other fungi			
			Tested	Infected	Range	Mean	Range	Mean	Range	Mean	Range	Mean
Go Dau/	G-G-R	5-8	8	2	0-2	0.4	0-4	1.2	1-6	3.0	0-0	0.0
Bau Don	G-G-R	1-3	2	2	1-5	3.0	2-3	2.5	7	7.0	0-0	0.0
	G-R-R	7	1	1	2	2.0	2	2.0	3	3.0	0-0	0.0
	G-R-R	4	2	2	1-9	5.0	2-16	9.0	3-6	4.5	125	125
	G-R-R	3	2	2	2	2.0	2-3	2.5	7-11	9.0	0-0	0.0
Go Dau/ Phuoc Dong	G-G-R	5-7	6	3	0-2	0.7	0-4	2.7	0-10	3.1	0-0	0.0
	G-G-R	2-4	4	3	0-3	2.0	1-5	3.0	1-3	2.2	0-0	0.0
Go Dau/ Hiep Thanh	G-G-R	5-10	8	2	0-2	0.5	0-5	1.7	0-6	2.1	0-0	0.0
	G-G-R	3-4	2	1	0-2	1.0	0-5	2.5	0-7	3.5	0-0	0.0
Trang Bang/ Loc Hung	G-G-R	7-10	3	0	0	0.0	2-3	2.3	1-3	2.0	0-0	0.0
	G-G-R	1-3	5	5	2-4	3.0	1-11	8.6	0-7	2.6	5-31	12
	G-G-R	0	1	1	3	3.0	6	6.0	3	3.0	0	0
	G-F-R	2	2	2	1-12	6.5	5-19	12.0	4-6	5.0	125	125
	G-R-R	6	2	0	0	0	0-2	1.0	0	0.0	0	0
	G-R-R	1-4	5	4	0-3	1.6	1-5	3.2	2-7	4.6	0-0	0
	G-R-R	0	2	2	4	4.0	2	2.0	4	4.0	62.5	62.5
Trang Bang/ An Tinh	G-G-R	5-10	5	1	0-2	0.4	0-2	0.8	0-3	1.0	0-0	0
	G-G-R	2-4	5	4	0-3	1.2	2-5	3.0	1-10	4.2	0-0	0
	G-R-R	6-10	2	1	0-1	0.5	0-1	0.5	3	3.0	0-0	0
	G-R-R	1-4	8	2	0-3	1.0	0-5	1.6	0-5	2.0	0-0	0

continued

Table 1 continued

District/ village	CS[1]	No. of irrigations[2]	No. of samples		Percentage seed infected by						Aflatoxin B_1 ($\mu g\ kg^{-1}$)	
					A. flavus		*A. niger*		Other fungi			
			Tested	Infected	Range	Mean	Range	Mean	Range	Mean	Range	Mean
Cu Chi/												
Trung Lap Ha	G-G-R	15	1	0	0	0.0	0	0.0	0	0.0	0-0	0
	G-G-R	6-10	3	1	0-5	1.6	1-2	1.3	2-6	3.3	0-5	2.5
	G-G-R	2-4	3	0	0	0.0	0-2	1.7	0-3	1.3	0-0	0
	G-G-R	0	1	1	2	2.0	7	7.0	3	3.0		
	G-R-R	10-15	2	1	0-1	0.5	1-2	1.5	0-4	2.0	0-0	0
	G-R-R	2	1	1	2	2.0	5	5.0	4	4.0	0	0
Cu Chi/												
Phuoc Hiep	G-R-R	2-3	4	3	0-2	1.2	2-3	2.2	2-5	3.5	0-0	0
	G-R-R	0	6	5	0-2	1.3	0-4	1.6	0-6	2.3	0-0	0
Cu Chi/												
Phuoc Thanh	G-R-R	5-10	3	0	0	0.0	0-2	1.0	0-4	1.6	0	0
	G-R-R	0	3	3	2-4	3.0	3-4	3.3	0-5	2.6	0-12	4
Duc Hoa/												
Hoa KhanhDong	G-R-R	5	4	2	0-2	0.7	0-5	2.2	0-7	4.0	0-0	0
	G-R-R	2-4	9	6	0-3	1.4	0-4	1.7	0-5	2.9	0-0	0
Duc Hoa/												
Duc Lap Thuong	G-G-R	5-10	6	4	0-4	1.3	0-6	1.8	0-4	1.8	0-0	0
	G-G-R	3-4	4	2	0-2	0.7	0-5	2.0	0-5	2.2	0-0	0
Duc Hoa/												
Duc Hoa Thuong	G-G-R	5-6	2	0	0	0.0	1-5	3.0	0-2	1.0	0-0	0
	G-G-R	3-4	8	5	0-3	1.0	0-4	2.1	0-7	3.1	0-0	0

continued

Table 1 continued

District/ village	CS[1]	No. of irrigations[2]	No. of samples		Percentage seed infected by						Aflatoxin B_1 (µg kg^{-1})	
					A. flavus		*A. niger*		Other fungi			
			Tested	Infected	Range	Mean	Range	Mean	Range	Mean	Range	Mean
Samples from an oil mill/markets												
Oil mill	-		3	3	5-11	7.7	4-8	6.3	4-6	5.0	0-20.6	6.9
Duc Thanh Market	-		3	3	3	3.0	9-12	10.0	3-7	4.7	0-0	0
Banh Thanh Market	-		2	2	4-28	16.0	3-8	5.5	5-19	12.0	0-80	40
Ben Thanh Market	-		3	3	11-35	20.7	6-7	6.7	7-18	11.0	50-112	74

[1]Cropping system : G = Groundnut; R = Rice
[2]Number of irrigations given to the crop
[3]AF = *Aspergillus flavus*; AN = *A. niger*; Other fungi include *Fusarium* spp, *Macrophomina phaseolina*, *Penicillium* spp, *Rhizopus* spp, *Rhizoctonia solani*, and *Sclerotium rolfsii*.
[4]OMS = Oil mill sample; MS = market sample

Appendix 1. Groundnut samples obtained from farmers in various villages in four districts of southern Vietnam, March 1996: Farmers' perceptions regarding groundnut yield and yield constraints.

District/ village	Farmer's name	Sample No.	CS[1]	No. of irrigations	Yield (t ha^{-1})	Plant mortality (at 60-75 DAS)	Damping off (%) (at 25-30 DAS)
Go Dau/ Bau Don	Vo Van Thiem	1	G-G-R	8	3.5	-	-
	Truong Van Coi	2	G-R-R	7	2.5	30(SR,CR)	10
	Phuong My Le	3	G-G-R	7	2.5	20(BW,SR,CR)	-
	Phan Van Ben	4	G-G-R	7	3.0	-	-
	Phan Van Rung	5	G-G-R	7	2.5	20(SR,CR,BW)	-
	Phan Van Ngon	6	G-G-R	8	2.5	10(SR,BW)	-
	Nguyen Van Tien	7	G-G-R	5	2.0	5-10(BW)	-
	Le Van Ngo	8	G-R-R	4	3.0	5-8(SR,BW)	5
	Le Van Teo	9	G-G-R	6	2-2.5	20-25(BW,CR)	-
	Vo Thi Phi	10	G-G-R	1	3-3.5	-	-
	Nghi Van Nho	11	G-R-R	4	3.0	5	5
	Vo Thi Cho	12	G-G-R	3	2.5-3	-	-
	Vo Van Duoe	13	G-R-R	3	2.5	-	5
	Vo Van Bon	14	G-R-R	3	3.0	20-30(SR,CR)	5
	Vo Thi Xen	15	G-G-R	6	2.5	15-20(SR,BW,CR)	-
Go Dau/ Phuoc Dong	Nguyen Van Sen	16	G-G-R	6	3.0	15(BW,CR)	10
	Vo Van Hai	17	G-G-R	7	3.0	-	-
	Nguyen Van Lu	18	G-G-R	6	3.0	10-15(BW)	-
	Pham Van Ne	19	G-G-R	6	3.0	6-8(BW)	-
	Le Van Xung	20	G-G-R	3	2.5	-	-
	Dang Van Giau	21	G-G-R	2	2.5	-	-
	Le Van Xung	22	G-G-R	6	2.0	50-60(BW)	-
	Nguyen Van Thoi	23	G-G-R	4	2.5-3.0	10(BW,SR)	-
	Nguyen Van Ri	24	G-G-R	5	2.5	-	-
	Nguyen Van Xung	25	G-G-R	2	3.0	5(BW)	-
Go Dau/ Hiep Thanh	Nguyen Van Hong	26	G-G-R	3	3.0	10(BW,CR)	-
	Tran Van Thanh	27	G-G-R	6	2-2.5	-	5
	Nguyen Thi Ngan	28	G-G-R	4	2.0	-	-
	Tran Van Cong	29	G-G-R	10	2.0	5(BW,CR)	-
	Nguyen Van Ngoa	30	G-G-R	5	2.2	10(BW,CR)	5
	Che Van Tam	31	G-G-R	9	2.0	5(BW)	8
	Ho Van Tai	32	G-G-R	5	2.5	5-8(BW)	-
	Tran Hoa Loc	33	G-G-R	7	2.5	5(BW,CR)	-
	Ha Thi Thuq	34	G-G-R	6	2.5	-	-
	Hiep Thanh	35	G-G-R	6	2.0	10(BW,CR)	-

continued

Appendix 1 continued

District/ village	Farmer's name	Sample No.	CS[1]	No. of irrigations	Yield (t ha^{-1})	Plant mortality (at 60-75 DAS)	Damping off (%) (at 25-30 DAS)
Trang Bang/							
Loc Hung	Cao Hoang Trong	36	G-G-R	7	2.0	-	-
	Trader	37	G-G-R	-	-	-	-
	Le Van Sap	38	G-G-R	10	2.3	15(BW,SR,CR)	12-15
	Le Van Nhanh	39	G-R-R	0	2.5	12(SR,CR)	12
	Phan Van Chau	40	G-R-R	2	3.0	15(SR,CR)	-
	Tit Cung	41	G-G-R	10	1.4	25(BW,SR,CR)	25
	Tran Van Nhin	42	G-G-R	3	2.2	10(CR,BW)	-
	Nguyen Thanh Duc	43	G-R-R	1	2.0	20(SR)	20
	Cao Van Houng	44	G-R-R	2	2.0	25(SR,CR)	25-30
	Cao Van Xop	45	G-R-R	2	2.0	30(SR,CR)	25-30
	Le Van Tam	46	G-R	0	1.0	30(SR,CR)	30
	Le Van Huu	47	G-R-R	6	2.5	20(SR,CR)	30
	Vo Thi Loan	48	G-F-R	2	1.2	10(SR,CR)	25-30
	Le Van Tao	49	G-G-R	2	2.0	8(SR,CR)	10
	Tran Van Pham	50	G-G-R	2	2.4	20(SR,CR)	5
	-	51	G-F-R	2	2.4	15(SR,CR)	20
	Nguyen Van Vu	52	G-G-R	4	2.2	5(CR,BW)	5
	Pham Van Rieng	53	G-G-R	1	1.2	8(BW,SR)	8
	Tran Thi Ganh	54	G-R-R	6	1.5	-	-
	Tran Thi Kiem	55	G-R-R	4	2.4	-	-
	-	56	G-R-R	0	1.5	-	-
Trang Bang/							
An Tinh	Tran Van Thuon	57	G-R-R	1	2.5	-	-
	Nguyen Van Go	58	G-R-R	10	2.2	-	-
	Nguyen Van Tum	59	G-G-R	6	2.6	5(BW,CR)	5
	Ngo Thi Hanh	60	G-G-R	3	2.6	5(SR,CR)	-
	Pham Van Nua	61	G-R-R	4	1.5	-	-
	Duong Tan Ngoa	62	G-G-R	6	2.0	15(CR,BW,SR)	10-15
	Tran Huu Phuoc	63	G-G-R	10	2.4	8(BW,CR)	-
	Nguyen Thanh Hao	64	G-G-R	6	2.7	5(CR,BW)	5
	Buu Minh Chon	65	G-G-M	5	2.5	10(CR,BW)	5
	Nguyen Khac Ve	66	G-G-R	2	2.5	-	-
	Nguyen Van Nhon	67	G-R-R	6	1.8	15(SR,CR)	20
	Nguyen Van Thieu	68	G-R-R	3	2.2	10(SR,CR)	10
	Nguyen Thi Can	69	G-R-R	3	2.6	-	-
	Nguyen Van Cuoc	70	G-R-R	3	3.0	25(SR,CR)	-

continued

Appendix 1 continued

District/ village	Farmer's name	Sample No.	CS[1]	No. of irrigations	Yield (t ha^{-1})	Plant mortality (at 60-75 DAS)	Damping off (%) (at 25-30 DAS)
Trang Bang/							
An Tinh	Nguyen Van Lo	71	G-R-R	4	2.0	15(SR)	-
	Nguyen Van Ly	72	G-R-R	3	2.0	20(SR)	-
	Tran Van Hy	73	G-G-R	7	2.8	15(SR)	-
	Nguyen Van Bang	74	G-G-R-R	4	2.5	15(SR,CR)	30
	Nguyen Thi Nam	75	G-G-R-R	3	2.5	20(SR,CR)	15
		76	G-G-R-R	3	2.5	20(SR,CR)	10
Cu Chi/							
Trang Lap Ha	Nguyen Van Huyen	77	G-R-R	15	2.0	10(SR,CR)	20
	Cao Thi Trien	78	G-G-R	0	2.2	8(CR,BW)	-
	Mai Van Chau	79	G-G-R-R	15	1.5	25(SR,CR)	15-20
	Vo Thi Tren	80	G-R-V	8	2.2	8(SR,CR)	5
	Von Van Na	81	G-G-R	10	2.8	8(BW)	-
	Vo Van Ban	82	G-G-G	6	2.5	10(SR,CR)	10-12
Cu Chi/							
Trung Lap Ha	Nguyen Thi Cuon	83	G-G-R	10	2.5	15(CR,SR)	-
	Nguyen Van Thanh	84	G-G-R	4	2.2	5(SR,CR)	-
	Le Thi Mubi	85	G-G-R	4	3.0	8(CR,SR)	10-15
	Nguyen Van Tren	86	G-G-R	4	2.2	15(CR,SR,BW)	-
	Nguyen Van Moi	87	G-R-R	2	2.5	15(SR,CR)	15-20
Cu Chi/							
Phuoc Hiep	Van Cong Ron	88	G-R-R	3	2.5	-	-
	Nguyen Thi Do	89	G-R-R	2	2.5	20(SR,CR)	-
	Tran Van Hon	90	G-R-R	2	2.5	-	12-15
	Le Van Lam	91	G-R-R	0	3	-	-
	Pham Thi Thuy	92	G-R-R	3	2.5	-	-
	Ho Thanh Binh	93	G-R-R	0	2.5	-	-
	La Xuan Hung	94	G-R-R	0	3.0	-	-
	Nguyen Van Oanh	95	G-R-R	0	3.0	10(SR,CR)	-
	Pham Van Bua	96	G-R-R	0	3.5	-	
	Nguyen Thi Ri	97	G-R-R	0	2.5	10(SR)	8
Cu Chi/							
Phuoc Thanh	Nguyen Van Su	98	G-R-R	0	3.5	-	-
	Lam Van Lam	99	G-R-R	10	3.0	-	5
	Le Thi Duyen	100	G-R-R	6	2.4	-	-
	Do Van Tuan	101	G-R-R	5	3.6	-	-
	Nguyen Van Hen	102	G-R-R	0	3.0	-	-
	-	103	G-R-R	0	2.5	-	-

continued

Appendix 3 continued

District/ village	Farmer's name	Sample No.	CS[1]	No. of irrigations	Yield (t ha^{-1})	Plant mortality (at 60-75 DAS)	Damping off (%) (at 25-30 DAS)
Duc Hoa/							
Hoa Khanh	Vuong Van Tan	104	G-R-R	5	2.0	40(SR,CR,BW)	10
Dong	Le Dinh Co	105	G-R-R	3	1.0	50(SR,CR,BW)	-
	Ho Van Se	106	G-R-R	3	2.0	15(SR,CR)	15-20
	Ho Thi Ma	107	G-R-R	2	2.0	10(SR,CR,BW)	5
	Nguyen Van Khanh	108	G-R-R	4	2.5	20(SR,CR,BW)	8
	Nguyen Van Ben	109	G-G-R	4	1.8	40(SR,CR)	-
	Vo Thi Gam	110	G-R-R	2	2.0	10(SR,CR)	-
	Le Tan Phuong	111	G-G-R	5	3.0	15(SR,CR,BW)	-
	Bay Thau	112	G-R-R	5	2.0	25(SR,CR,BW)	-
	Le Van Nguyen	113	G-G-R	5	2.0	15(SR,CR,BW)	-
	Tran Van Tau	114	G-R-R	4	1.5	20(SR,CR)	-
	Nhanh	115	G-G-R	2	2.0	15(SR,BW)	-
	Le Van Bao	116	G-R-R	3	2.0	15(SR,CR, BW)	-
Duc Hoa/							
Duc Lap	Tran Thi Ngham	117	G-G-R	10	3.0	15(SR,CR,BW)	-
Thuong	Nguyen Thanh Choi	118	G-G-R	10	2.5	15(SR,CR)	-
	Nguyen Van Cong	119	G-G-R	7	2.0	15(CR,BW,SR)	-
	Le Van Ouan	120	G-G-R	6	2.8	10(SR,CR)	-
	Vo Van Ngoan	121	G-G-R	6	2.4	15(CR,BW)	-
	Ho Thi Xa	122	G-G-R	4	2.5	15(BW,CR,SR)	-
	Nguyen Thi Sau	123	G-G-R	4	2.5	-	-
	Le Dinhh Viet	124	G-G-R	3	2.6	-	-
	Nguyen Van Ky	125	G-G-R	4	2.5	25(SR,CR,BW)	-
	Tran Van Loi	126	G-G-R	5	2.5	15-20(SR,CR,BW)	-
Duc Hoa/							
Duc Hoa	Nguyen Van Tong	127	G-G-R	4	3.0	10(SR,CR)	-
Thuong	Nguyen Van Phuc	128	G-G-R	3	3.0	8(CR,BW)	-
	Tran Van Dinh	129	G-G-R	3	2.5	10(CR,BW)	-
	Dao Van Cong	130	G-G-R	4	3.3	-	-
	Nguyen E	131	G-G-R	3	2.5	2(CR)	-
	Nguyen Van Thao	132	G-G-R	5	1.5	15(CR,SR,BW)	-
	Le Van Son	133	G-G-R	3	1.7	25(CR,SR,BW)	25
	Tran Thanh Duc	134	G-G-R	4	3.0	5	-
	Nguyen Van Chat	135	G-G-R	6	2.5	8-10(CR,BW)	-
	Tran Thi Sluong	136	G-G-R	3	2.5	-	-

[1] CS = Cropping system; G = Groundnut; R = Rice

- not indicated by farmer; SR = stem rot; CR = collar rot; BW = bacterial wilt

Appendix 2. Seed infection by fungal species in groundnut samples from farmers and markets in various groundnut-growing areas of southern Vietnam, March 1996.

District/ village	S. No.	CS[1]	No. of irrigations[2]	Percentage seed infected by AF[3]	AN	AF+AN	FS	MP	PS	RH	RS	SR
Go Dau/	1	G-G-R	8	0	1	0	1	3	0	1	0	1
Bau Don	2	G-R-R	7	2	2	1	0	2	0	0	0	1
	3	G-G-R	7	0	0	0	0	2	0	1	0	1
	4	G-G-R	7	0	1	0	0	1	0	0	0	0
	5	G-G-R	7	1	1	0	0	1	0	0	0	2
	6	G-G-R	8	0	2	0	0	1	0	0	0	1
	7	G-G-R	5	2	4	1	0	4	0	0	0	1
	8	G-R-R	4	9	16	5	1	1	0	3	0	1
	9	G-G-R	6	0	0	0	0	1	0	0	0	0
	10	G-G-R	1	5	3	2	1	2	3	1	0	0
	11	G-R-R	4	1	2	0	0	2	0	1	0	0
	12	G-G-R	3	1	2	0	0	3	0	2	1	1
	13	G-R-R	3	2	3	1	1	6	0	2	0	2
	14	G-R-R	3	2	2	0	1	2	0	2	0	2
	15	G-G-R	6	0	1	0	0	2	0	0	0	0
Go Dau/	16	G-G-R	6	1	3	1	0	2	0	0	0	0
Phuoc Dong	17	G-G-R	7	0	4	0	0	0	0	0	0	0
	18	G-G-R	6	2	4	1	1	5	0	1	1	2
	19	G-G-R	6	0	0	0	0	1	0	2	0	0
	20	G-G-R	3	2	3	0	0	1	0	0	0	0
	21	G-G-R	2	3	5	2	0	3	0	0	0	0
	22	G-G-R	6	1	2	0	0	2	0	0	0	0
	23	G-G-R	4	0	1	0	0	2	0	0	0	0
	24	G-G-R	5	0	3	0	0	2	0	0	0	0
	25	G-G-R	2	3	3	1	1	2	0	0	0	0
Go Dau/												
Hiep Thanh	26	G-G-R	3	0	0	0	0	0	0	0	0	0
	27	G-G-R	6	0	0	0	0	0	0	0	0	0
	28	G-G-R	4	2	5	0	2	3	0	1	0	1
	29	G-G-R	10	2	5	0	1	1	0	0	0	2
	30	G-G-R	5	0	0	0	0	0	0	0	0	0
	31	G-G-R	9	0	1	0	1	2	0	1	1	1
	32	G-G-R	5	0	0	0	0	1	0	0	0	0
	33	G-G-R	7	0	2	0	0	0	0	0	0	0
	34	G-G-R	6	2	5	2	0	1	0	0	0	1
	35	G-G-R	6	0	1	0	0	2	0	0	1	1

continued

Appendix 2 continued

District/ village	S. No.	CS[1]	No. of irrigations[2]	Percentage seed infected by AF[3]	AN	AF+AN	FS	MP	PS	RH	RS	SR
Trang Bang/												
Loc Hung	36	G-G-R	7	0	3	0	0	2	0	0	0	1
	37[a]	G-G-R	-	4	7	2	2	8	0	1	2	2
	38	G-G-R	10	0	2	0	0	0	0	1	0	1
	39	G-R-R	0	4	2	1	0	2	0	0	0	2
	40	G-R-R	2	2	5	0	0	1	0	1	0	1
	41	G-G-R	10	0	2	0	0	1	0	0	0	0
	42	G-G-R	3	2	4	1	0	2	0	0	0	0
	43	G-R-R	1	3	5	2	0	2	0	2	0	2
	44	G-R-R	2	1	2	1	0	3	0	1	1	2
	45	G-R-R	2	2	1	0	0	2	0	0	0	0
	46	G-R	0	3	6	2	0	3	0	0	0	0
	47	G-R-R	6	0	0	0	0	0	0	0	0	0
	48	G-F-R	2	1	5	0	0	3	0	1	0	0
	49	G-G-R	2	4	9	1	1	3	0	2	0	1
	50	G-G-R	2	2	1	0	0	0	1	0	0	0
	51	G-F-R	2	12	19	7	1	2	0	2	0	1
	52	G-G-R	4	4	11	3	0	1	0	1	0	1
	53	G-G-R	1	3	1	0	0	0	0	0	0	0
	54	G-R-R	6	0	2	0	0	0	0	0	0	0
	55	G-R-R	4	0	3	0	0	2	0	1	0	2
	56	G-R-R	0	3	2	1	0	1	0	0	0	0
Trang Bang/												
An Tinh	57	G-R-R	1	3	5	1	0	3	0	0	1	1
	58	G-R-R	10	1	1	0	0	1	0	0	0	2
	59	G-G-R	6	0	2	0	1	2	0	0	0	0
	60	G-G-R	3	1	2	0	0	1	0	0	0	0
	61	G-R-R	4	2	2	1	0	0	0	0	0	0
	62	G-G-R	6	2	2	1	0	0	0	0	0	2
	63	G-G-R	10	0	0	0	0	0	0	0	0	0
	64	G-G-R	6	0	0	0	0	0	0	0	0	0
	65	G-G-M	5	0	0	0	0	0	0	0	0	0
	66	G-G-R	2	3	4	1	2	8	0	0	0	0
	67	G-R-R	6	0	0	0	0	1	0	0	0	2
	68	G-R-R	3	0	0	0	0	1	0	0	1	1
	69	G-R-R	3	1	1	0	0	0	0	0	0	0
	70	G-R-R	3	0	0	0	0	0	0	0	0	0

continued

Appendix 2 continued

District/ village	S. No.	CS[1]	No. of irrigations[2]	Percentage seed infected by AF[3]	AN	AF+AN	FS	MP	PS	RH	RS	SR
Trang Bang/												
An Tinh	71	G-R-R	4	0	0	0	0	0	0	0	0	0
	72	G-R-R	3	0	3	0	1	3	0	1	0	0
	73	G-G-R	7	0	5	0	1	1	0	0	0	0
	74	G-G-R-R	4	0	2	0	0	0	0	1	0	1
	75	G-G-R-R	3	1	2	0	0	2	0	0	0	2
	76	G-G-R-R	3	1	5	1	1	3	0	0	0	1
Cu Chi/												
Trung Lap Ha	77	G-R-R	15	1	2	0	0	0	0	2	0	2
	78	G-G-R	0	2	7	1	0	3	0	0	0	0
	79	G-G-R-R	15	0	0	0	0	0	0	0	0	0
	80	G-R-V	8	0	1	0	0	0	0	0	0	0
	81	G-G-R	10	0	1	0	1	0	0	0	0	1
	82	G-G-G	6	0	1	0	0	2	0	0	0	0
	83	G-G-R	10	5	2	1	1	3	0	0	0	2
	84	G-G-R	4	0	0	0	0	0	0	0	0	0
	85	G-G-R	4	0	2	0	0	1	0	1	0	1
	86	G-G-R	4	0	1	0	0	2	0	0	0	0
	87	G-R-R	2	2	5	1	0	4	0	0	0	0
Cu Chi/												
Phuoc Hiep	88	G-R-R	3	0	2	0	0	4	0	0	0	1
	89	G-R-R	2	2	2	0	0	3	0	0	0	0
	90	G-R-R	2	2	2	0	1	1	0	0	0	0
	91	G-R-R	0	2	3	1	1	4	0	0	0	1
	92	G-R-R	3	1	3	0	1	3	0	0	0	0
	93	G-R-R	0	1	0	0	0	0	0	0	0	0
	94	G-R-R	0	2	1	0	0	1	0	0	0	1
	95	G-R-R	0	1	1	1	0	3	0	0	1	1
	96	G-R-R	0	0	1	0	0	0	0	0	0	0
	97	G-R-R	0	2	4	0	0	1	0	0	0	0
Cu Chi/												
Phuoc Thanh	98	G-R-R	0	4	3	2	1	3	0	0	0	1
	99	G-R-R	10	0	1	0	1	2	0	0	0	1
	100	G-R-R	6	0	2	0	0	0	0	0	0	1
	101	G-R-R	5	0	0	0	0	0	0	0	0	0
	102	G-R-R	0	2	4	0	0	2	0	0	0	1
	103	G-R-R	0	2	3	0	0	0	0	0	0	0

continued

Appendix 2 continued

District/ village	S. No.	CS[1]	No. of irrigations[2]	Percentage seed infected by AF[3]	AN	AF+AN	FS	MP	PS	RH	RS	SR
Duc Hoa/												
Hoa Khanh	104	G-R-R	5	2	3	0	1	3	0	0	0	2
Dong	105	G-R-R	3	2	1	0	1	0	1	0	2	1
	106	G-R-R	3	1	1	0	0	3	0	0	0	1
	107	G-R-R	2	2	3	0	0	1	0	0	0	0
	108	G-R-R	4	0	2	0	1	0	0	1		
	109	G-R-R	4	2	2	0	0	3	0	0	1	1
	110	G-R-R	2	3	2	0	0	3	0	0	0	1
	111	G-R-R	5	0	5	0	0	3	0	0	0	0
	112	G-R-R	5	1	1	0	0	4	0	0	0	3
	113	G-G-R	5	0	0	0	0	0	0	0	0	0
	114	G-R-R	4	0	0	0	0	0	0	0	0	0
	115	G-G-R	2	3	4	1	0	5	0	0	0	0
	116	G-R-R	3	0	0	0	0	0	0	0	0	0
Duc Hoa/												
Duc Lap	117	G-G-R	10	1	1	0	0	0	0	0	0	1
Thuong	118	G-G-R	10	4	6	2	0	1	0	0	0	2
	119	G-G-R	7	0	0	0	0	0	0	0	0	0
	120	G-G-R	6	1	2	1	0	2	0	0	0	2
	121	G-G-R	6	2	2	0	0	2	0	0	0	1
	122	G-G-R	4	0	0	0	0	0	0	0	0	0
	123	G-G-R	4	2	2	0	0	4	0	0	0	0
	124	G-G-R	3	1	1	0	0	0	0	0	0	0
	125	G-G-R	4	0	5	0	1	3	0	0	0	1
	126	G-G-R	5	0	0	0	0	0	0	0	0	0
Duc Hoa/												
Duc Hoa	127	G-G-R	4	1	1	0	1	0	0	0	0	1
Thuong	128	G-G-R	3	1	4	1	0	4	0	0	0	1
	129	G-G-R	3	2	1	1	1	3	0	0	0	3
	130	G-G-R	4	0	4	0	0	2	0	0	0	0
	131	G-G-R	3	3	2	1	1	2	0	0	0	2
	132	G-G-R	5	0	5	0	0	0	0	0	0	0
	133	G-G-R	3	0	0	0	0	0	0	0	0	0
	134	G-G-R	4	1	3	0	0	2	0	0	0	0
	135	G-G-R	6	0	1	0	0	2	0	0	0	0
	136	G-G-R	3	0	2	0	0	1	0	0	0	1

continued

Appendix 2 continued

District/ village	S. No.	CS[1]	No. of irrigations[2]	Percentage seed infected by AF[3]	AN	AF+AN	FS	MP	PS	RH	RS	SR
Ho Chi Minh City	OMS1	-	-	5	8	2	0	1	1	2	0	1
	OMS2	-	-	11	7	2	0	1	1	3	0	1
	OMS3	-	-	7	4	1	0	0	1	1	0	0
Duc Thanh Market	MS4	-	-	3	9	1	0	1	2	3	0	1
	MS5	-	-	3	11	0	0	0	1	2	0	0
	MS6	-	-	3	12	4	0	0	1	1	0	0
Banh Thanh Market	MS7	-	-	28	3	1	1	1	17	0	0	0
	MS8	-	-	4	8	2	0	0	1	3	0	0
Ben Thanh Market	MS9	-	-	13	7	4	1	0	4	2	0	1
	MS10	-	-	35	7	4	0	0	18	0	0	0
	MS11	-	-	14	6	4	0	2	3	3	0	0

[1]Cropping system : G = Groundnut; R = Rice

[2]Number of irrigations given to the crop

[3]AF = *Aspergillus flavus*; AN = *A. niger*; AF+AN = *A. flavus* + *A. niger* (occurring together); FS = *Fusarium* spp; MP = *Macrophomina phaseolina*; PS = *Penicillium* spp; RH = *Rhizopus* spp; RS = *Rhizoctonia solani*; SR = *Sclerotium rolfsii*

* seed sample from a trader (at the shelling plant in Loc Hung village of Trang Bang district).

[4]OMS = Oil mill sample; MS = market sample

Aflatoxin Contamination Problems in Groundnut and Groundnut Products

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Why worry ?

Aflatoxin contamination is groundnut's most serious quality problem because it affects

- utilization of groundnuts
- trade in groundnuts and groundnut products
- human and animal health

Most developed countries place limits on the levels of aflatoxins permissible in groundnuts and groundnut products; they allow 0 to 20 parts per billion (0-20 μg kg^{-1}) aflatoxin in material for human consumption. Groundnut-exporting countries lose foreign exchange if their export consignments (e.g., groundnuts, groundnut cake, peanut butter) are found to be contaminated with aflatoxins.

In Vietnam groundnut is an important crop with high export potential. It is therefore crucial that producers and the groundnut industry become fully aware of the dangers of aflatoxin contamination.

What are aflatoxins ?

Aflatoxins are highly toxic, cancer-causing substances produced by the fungus *Aspergillus flavus*, which often infects groundnuts. The yellowish-green spores of *A. flavus* are commonly found in the air and soils of tropical and warm temperate regions, e.g., Vietnam, Thailand, the Philippines. The fungus can infect groundnuts, and subsequently produce aflatoxin, during several stages:

- crop development
- postharvest drying
- storage

Effects of aflatoxins

Consumption of aflatoxin-contaminated products adversely affects human and animal health. High levels of aflatoxins in the diet can cause liver cancer in humans and animals. Aflatoxin consumption can aggravate the effects of other illnesses (e.g., hepatitis virus B) and nutritional disorders (e.g., protein malnutrition), especially in children.

Aflatoxins cause aflatoxicosis, which can lead to extensive liver damage and death in livestock and poultry. The most common symptoms of aflatoxicosis are:

- loss of appetite (feed refusal)
- loss of weight
- reduced milk/egg production

When mammals ingest aflatoxin, it is modified slightly, into a form known as aflatoxin M_1, and passes into the milk produced by dairy animals and lactating mothers. Consequently, the health risks are particularly high for infants, whose diet consists almost entirely of milk.

Where are aflatoxins found ?

Aflatoxins can be present in various groundnut products:

- apparently sound kernels
- groundnut oil (mainly unrefined)
- groundnut cake
- groundnut flour
- groundnut-based snack foods
- peanut butter

Which factors promote aflatoxin contamination ?

Preharvest

- damage to pods by soil pests and diseases
- mechanical damage to pods during weeding and at lifting
- late-season drought stress
- rains after long dry periods, particularly during pod maturation
- diseases that cause wilting and premature plant death
- delayed harvesting

Postharvest

- slow and irregular drying after lifting
- wet/humid conditions during drying in the field
- high seed moisture content (>9%)
- storage in hot and humid conditions
- poor storage conditions--insufficient ventilation, inadequate protection against insect pests, and moisture seepage from walls, roof, or floor

How to prevent or reduce aflatoxin contamination ?

There is no single practical way to prevent aflatoxin contamination. Several approaches need to be used in an integrated manner to prevent contamination and to segregate contaminated groundnuts. Farmers, extension services, agricultural marketing agencies, and those concerned with storage and processing should all adopt certain practices to prevent contamination.

The following practices will help reduce contamination:

- adjust sowing dates so that crops mature towards the end of the rainy season
- avoid damage to plants and pods during weeding and at lifting
- avoid damage to plants from soil pests and wilt and root rot diseases
- apply gypsum or lime to the soil when the crop is pegging
- provide irrigation if drought occurs during pod development and/or maturation
- provide adequate soil moisture for at least 1 month before harvest
- lift the crop when it is mature
- harvest diseased plants separately
- avoid mixing pods from diseased/drought-stressed plants with pods from healthy/non-stressed plants
- dry the lifted plants in inverted windrows
- dry the pods to below 9% moisture content as quickly as possible
- discard damaged and moldy pods
- store groundnuts in-shell in clean, cool, dry, insect-free conditions
- after shelling, discard discolored, damaged, and moldy kernels

A comprehensive control program requires general public awareness of the dangers of aflatoxins, and methods to prevent contamination. Public awareness of the problem will encourage support for governmental surveillance and aflatoxin control programs, and oblige each sector--production, marketing, trading, and processing--to employ practices that reduce the risk of contamination.

The responsibility for creating awareness should be shared by agricultural organizations, extension agencies, marketing agencies, and other government and non-governmental organizations. If every member of the groundnut industry, from the farmer to the processor, employs preventive measures and decontamination procedures,

consumer health could be improved, animal productivity maintained, and significant savings in food and feed costs effected.

Further information

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Suggested further reading

ICRISAT (International Crops Research Institute for the Semi-Arid Tropics). 1988. Summary and recommendations of the International Workshop on Aflatoxin Contamination of Groundnut, 6-9 Oct 1987, ICRISAT Center, India. Patancheru, A.P. 502 324, India: ICRISAT. 40 pp. Order code CPE 045.

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Copies are available from the **Distribution Unit**, ICRISAT Asia Center, Patancheru 502 324, Andhra Pradesh, India.