CROP PROTECTION PROGRAMME

Strategies for reducing aflatoxin levels in groundnut-based food and feed in India: A step towards improving health of human and livestock

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FINAL TECHNICAL REPORT

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Farid Waliyar

International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru 502 324, Andhra Pradesh, India

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Executive Summary

This project aims to reduce the risk of aflatoxin contamination to humans and livestock. Invasion of groundnut by *Aspergillus flavus* and *A. parasiticus*, leading to natural contamination by aflatoxins, can occur during crop growth (**pre-harvest**), at the time of lifting of plants and drying of pods (**post-harvest handling**) and during **post-harvest storage** of pods**.** The project will be organised in two phases and a developmental management framework used to integrate socio-economic and technical activities. In the first phase, stakeholders pre- and post-harvest practices and their knowledge of aflatoxin contamination will be studied in terms of the prevailing social and economic context. Aflatoxin content in haulms, confectionery and milk will be assessed and the relative importance of contamination at these three stages determined. Seed infection and distribution of toxigenic and atoxigenic ioslates of *A. flavus* and *A. parasiticus* will be assessed. At the end of Phase I a stakeholder workshop was held to discuss and agree on potential pre- and post-harvest practices for reducing contamination to be evaluated in the second phase. In Phase management strategies to reduce contamination at key stages will be identified and tested adaptively with the active participation of men and women farmers and other stakeholders. Successful strategies will be disseminated and promoted to stakeholders in Andhra Pradesh through existing “extension” systems established by government and NGO’s.

Background

Aflatoxins are potent carcinogenic, mutagenic, teratogenic and immunosuppressive agents. Aflatoxin contamination of groundnut has gained global significance due to the deleterious effects the contaminants have on human and animal health, and the consequent importance in international trade (enclosed, a cutting from “Economic Times”, a widely circulated daily newspaper). Groundnuts are a key commodity in the livelihoods of the rural poor in the semi-arid regions of Andhra Pradesh, both as a source of food for human and livestock consumption, and as a source of income. Those households relying on groundnut as a major source of protein or consuming milk and animals fed on groundnut cake or haulms face potentially severe health risks. In a recent report (Katiyar et al. 2000) risk of populations in India due to aflatoxin contamination with hepatitis B virus infection was clearly demonstrated. Concerns over aflatoxin contamination of Indian groundnut in both domestic and international markets restrict the access of produce by marginal farmers to these important and lucrative markets.

Project Purpose

Develop strategies that contribute to food security of poor households through improved quality and better access to markets promoted

The project will contribute to a reduction in aflatoxin contamination levels in groundnut seed, groundnut-based foods, haulms and cake, and milk. The project will focus on factors contributing to pre-harvest contamination and the subsequent effects of post-harvest handling and storage and will adaptively test and validate new practices and strategies with the active participation of farmers. Outputs will be delivered through the involvement of public and NGO actors in the development of these new practices in the groundnut sector. They will lead to food security and reduction in poverty due to improved health of humans and livestock.

Research Activities

- Socio-economic factors such as labour shortage, mechanization, credit mechanisms, power relations and social structure of livelihood pattern influence farmers' groundnut crop management practices and have implications for aflatoxin contamination.

- On-farm trials in 25 farmer's fields were conducted using improved versus farmer cultivation practices. Aflatoxin content of 58μg/kg at harvest with farmer practices was reduced to 18μg/kg with improved practices.
- The DNA sequence data of genes involved in a biosynthetic pathway have been analysed and PCR primers designed to amplify these genes from *A. flavus/A. parasiticus*
- Pre- and post harvest practices of farmers from different wealth categories and social status have been described. There is little or no awareness of aflatoxins among farmers or traders. It is not perceived as a problem by traders; as a result there is no incentive in the market to produce aflatoxin-free groundnut .
- The wealth or social status of a farmer did not have much effect on groundnut yield or aflatoxin contamination; both rich and poor farmers had contaminated fields.
- Pre-harvest aflatoxin contamination was found mainly in small and damaged pods: well-filled pods had no aflatoxin. Sorting pods to remove these fractions reduces contamination.
- During storage, there is strong relation between infection and contamination, and a strong relation between duration above threshold kernel moisture content and contamination.
- Two hundred and twenty-five villages belonging to 25 mandals of Ananthapur district (India) were surveyed for aflatoxin contamination and eight high risk zones were identified.
- New technologies for aflatoxins management were tested at ICRISAT Center and Ananthapur. However, severe drought in 2002 prevented groundnut planting or harvest in farmer's fields.
- Good progress was made to standardize ELISA test for detection of aflatoxin in crop residues and blood.
- Two meetings were conducted during the phase I: (1) March 4-6 to discuss the progress made and (2) 27-29 Nov to form consortium of partners for the second phase of the project and objectives and outputs for the second phase were identified.

Outputs

Contribution of Outputs to developmental impact

a. What further market studies need to be done?

Major information on markets has been identified and the outcomes will be used to address some of the issues such as price incentive. Other related market studies are beyond the scope of this project.

b. How the outputs will be made available to intended users?

The second phase of the project is focusing mainly on awareness campaign and transfer of technologies. Major partners have been identified for both awareness and transfer of technologies.

c. What further stages will be needed to develop, test and establish manufacture of a product?

Improved varieties are part of the new project that also focus on farmer's participatory breeding. Seed multiplication will require appropriate seed production technologies. In addition Trichoderma as a biological control will require attention as to appropriate isolates to be identified and used by manufacturers

d. How and by whom, will the further stages be carried out and paid for?

ICRISAT in collaboration with the major partners of the project (ANGRAU, STAAD and UoR) will be involved in assuring further stages be carried by formulating the new project, identifying appropriate partners and involving farmers and major private sector and government.

Biometricians Signature

The projects named biometrician must sign off the Final Technical Report before it is submitted to CPP. This can either be done by the projects named biometrician signing in the space provided below, or by a letter or email from the named biometrician accompanying the Final Technical Report submitted to CPP. (Please note that NR International reserves the right to retain the final quarter's payment pending NR International's receipt and approval of the Final Technical Report, duly signed by the project's biometrician)

I confirm that the biometric issues have been adequately addressed in the Final Technical Report:

Signature:
Name (typed):
Position:
Date:

Output 1: Stakeholder (small-scale farmers, traders and oil producers) pre-harvest, post-harvest handling and post-harvest storage practices, and their knowledge of aflatoxin contamination, described and understood.

Activity 1.1. Planning and coordination of workshop with all project stakeholders (ICRISAT, UK, and NARS scientists, NGOs)

Planning and Coordination workshop was held between 26 and 27 July 2000. A project management Committee (PMC) comprising the six main project stakeholders will manage the project. The stakeholders are: ICRISAT, UoR, AME, NRI, University of Belfast, ANGRAU and STAAD. Day-to-day and overall management will be by ICRISAT, with A Hall (NRI) being responsible for the socio-economic aspects.

Activity 1.2 Assessment of existing pre-harvest, post-harvest handling and post-harvest storage practices of farmers and other stakeholders, and the socio-economic context and identification of factors constraining these practices using PRA techniques. (K Rama Devi, Andy Hall)

This activity had been carried out with the help of two main studies – farmers surveys and surveys of groundnut market players. The farmers surveys were carried out to understand farmers' awareness about aflatoxin contamination and to identify the socio-economic factors patterning the pre-harvest, post-harvest, storage and marketing practices of the farmers that are potential causes of aflatoxin contamination in groundnut systems. Market surveys were conducted to understand the marketing practices of the various stake holders / players in the groundnut trade, the levels of awareness to aflatoxin contamination among the market players, and the reaction of the market to aflatoxin contamination.

1) Selection of locales –
The studies focused on two locations that were identified by the project partners as those that represent two agro-climatic situations that are supposedly conducive for aflatoxin contamination. Anantapur district and Pileru area of Chittoor district of Andhra Pradesh in the Deccan Plateau are the two locations where groundnut crop is predominantly grown under rain fed conditions. While the former represents 'drought stress' conditions the latter represents 'moisture conditions' at the time of harvest due to North-East monsoon rains, both thus creating congenial condition for aflatoxin contamination of the groundnut crop.

2) Reconnaissance surveys –
Exploratory surveys were conducted initially to identify villages that have varied socio-economic conditions, groundnut crop management practices and institutional interventions/support.

- Selection of villages – four villages from Anantapur district and two villages from Pileru area of Chittoor district were selected for farmers surveys based on the information gathered during the reconnaissance surveys.
- Selection of market players – a cross-section of market players were selected from the same locations by tracking them down from the information collected from farmers surveys and the reconnaissance surveys.

3) Farmers surveys

- PRA techniques (participatory rural appraisal techniques) were used to study farmers' groundnut crop management practices, their awareness and perceptions about aflatoxin contamination in groundnut production systems and the influence of various socio-economic factors that pattern these practices.

Village case studies and farmers case studies following this approach were undertaken in six villages of Anantapur and Chittoor districts of Andhra Pradesh.

4) Market surveys –
To study market stakeholders awareness and perceptions about aflatoxin contamination in the groundnut market systems case studies of traders, brokers, processing units were carried out through questionnaires and personal interviews, and visits to market yards etc. to observe the product movement, grading procedures, transactions etc.

5) Findings –
- Farmers' current production and post-harvest practices are likely to increase the chances of aflatoxin contamination. However, their ability to change these practices is restricted by credit constraints and restrictive credit arrangements, labour shortages and cost, seed supply constraints, ineffective markets and low incentive structures.
- Several socio-economic factors pattern farmers' groundnut crop management practices that have implications for aflatoxin contamination. We can sum up these factors as – labor shortages, credit mechanisms, mechanization, power relations and social structures of the livelihood systems and market responses.
- Groundnut marketing practices indicate that only physical parameters govern market prices hence penalties/premiums are absent for the sale of aflatoxins contaminated products.
- Neither farmers nor traders perceive aflatoxin contamination as a problem or as an economic or health risk due to the absence of incentives/informal sanctions in the markets and lack of awareness.
- The rich and the poor do not have the same opportunities hence have different constraints and priorities in groundnut farming.

6) Recommendations -
In view of these findings the following recommendations were made for further action
- Technical and management interventions will only be successful if they form part of a wider set of changes in awareness, price incentives, quality monitoring procedures, and food safety policy. These wider changes require the concerted efforts of a diverse group of scientific, advocacy and policy stakeholders.
- We will have to build coalitions of interests for providing incentives and necessary structures that support contamination free production for the entire food and feed chain.
- Incentives to farmers, health concerns, building up of consumer demands, trader responsiveness, and action research should be the operational focus of interventions. This needs to be done in the wider framework of the livelihood aspirations of the rural poor who will be the key implementers of technical change.

The impact of interventions for reducing aflatoxin contamination on power relations in the groundnut crop based livelihood systems need to be carefully monitored for their wider implications on the poor.

FOR TECHNICAL DETAILS, PLEASE SEE APPENDICES

Output 2: Importance of pre-harvest, post-harvest, and post-harvest storage on aflatoxin contamination of haulms (and subsequently milk), seed and

groundnut products including confectionery to overall aflatoxin contamination determined and priorities identified. Incidence of toxigenic and non-toxigenic strains of *A. flavus* and *A. parasiticus* determined.

Activity 2.1 Assessment of aflatoxin contamination at pre-harvest, post-harvest handling and post-harvest handling and post-harvest storage in experiments, farmers fields and stores, and traders and oil producers stores (ANGRAU, ICRISAT, STAAD)

Introduction

Mycotoxin contamination of peanuts, particularly aflatoxin contamination is a serious food safety problem. Aflatoxins are potent carcinogenic, mutagenic and immuno-suppressive agents, produced as secondary metabolites by the fungus *Aspergillus flavus* and *A. parasiticus* on wide range of food products. Aflatoxin contamination of agricultural commodities has gained global significance as a result of their deleterious effects on human as well as animal health and its importance to international trade. Aflatoxin M_1 (AFM_1) is a major metabolite of aflatoxin B_1 found in milk of animals that have consumed feeds contaminated with aflatoxin B_1. The toxic and carcinogenic effects of AFM_1 have been convincingly demonstrated in laboratory animals and therefore AFM_1 is classified as a class 2B human carcinogen. According to the Food and Drug Administration of the USA, AFM_1 in milk should not exceed 0.5 ng/mL. AFM_1 is relatively stable during pasteurization, storage and preparation of various dairy products and therefore AFM_1 contamination poses a significant threat to human health, especially to children, who are the major consumers of milk.

Aspergillus flavus invasion and aflatoxin contamination in groundnut can occur at pre-harvest, post-harvest and storage conditions. Both biotic factors (soil insects, soil diseases and foliar diseases) and abiotic factors (end-season drought, soil temperature) during the crop growth and storage conditions (high moisture, temperature, insect damage) influence *A. flavus* infection and aflatoxin contamination. Aflatoxins can enter in to human and cattle milk if contaminated food material is consumed.

Looking in to the gravity of the problem, Department For International Development (DFID), Government of UK, has granted a project entitled "Strategies for reducing aflatoxin levels in groundnut based food and feeds: A step towards improving health of human and livestock". In this project frame work, collaborating institutes/partners include University of Reading (UK), ICRISAT, ANGRAU, University of Belfast (UK) and STAAD together put concerted efforts to over-come the *A. flavus* invasion and aflatoxin contamination in groundnut in Anantapur and Pileru (Chittoor district) areas of Andhra Pradesh, India. The progress made in the project during 2000/02 is reported here.

Materials and Methods

Groundnut crop is grown in 800,000 hectares in Anantapur district and 200,000 hectares in Chittoor district. For management of *A. flavus* infection and aflatoxin contamination in groundnuts both preventive and curative methods have to be adopted. In absence of highly resistant varieties for aflatoxin contamination, to combat the menace it is essential to adopt integrated management approach. Therefore aflatoxin management starts in the farmer's field, continue crop produce handling, marketing, storage, processing and ends with consumer.

Field trials for aflatoxin management

Several research reports indicate that cultural practices such as application of farm yard manure (FYM), calcium, crop residues and plant protection measures will reduce the aflatoxin contamination in groundnut. As such there is no package of cultivation practices available specifically designed for reducing aflatoxin levels in groundnut. However, there are two general crop management practices (improved and farmer practices) which are widely adopted for groundnut cultivation in Anantapur and Chittoor districts of Andhra Pradesh state. The existing cultivation or management practices were tested in collaboration with Acharya NG Ranga Agricultural University (ANGRAU), Anantapur and Agriculture Man Ecology (AME, a non-governmental organization) and Andhra Pradesh Rural Reconstruction Mission (APRRM, a non-governmental organization) in Pileru division. Based on Participatory Rural Appraisal (PRA) survey, two villages (Pampanur and Linganpalli) in Anantapur district and two villages (Valasapalli and Nagulakunta) in Chittoor district (Pileru area) were selected for field experiments. During the year 2000 rainy season, sixty three farmer's fields in Anantapur area and twelve farmer's fields in Pileru area were selected. The fields for experiments during 2001 were selected based on socioeconomic status of the farmers and aflatoxin contamination of groundnut in the previous crop season. During 2001 rainy season, using improved and farmer practices, field experiments were laid-out in 25 farmer's fields (15 farmer's fields in Pampanur and 10 farmer's fields in Linganpalli) in Anantapur area and in 6 farmer's fields (4 farmer's fields in Valasapalli and 2 farmer's fields in Nagulakunta) in Pileru area. In all the fields the cultivar TMV 2 was planted between 27 July and 8 August 2001. In each field improved and farmer practices for groundnut production were tested simultaneously using 0.4 ha area for each of the practices.

Soil characteristics

Soil samples collected before sowing from Pampanur and Linganpalli experimental fields were analyzed and the characteristics were recorded (Table 1a and 1b).

Improved practices for groundnut production

The package of improved practices for Anantapur district includes seed treatment with Mancozeb (3g/kg) and chlorophyriphos (6ml/kg). Application of need-based fertilizers based on soil test, application of gypsum (500 kg/ha) and management of pest and foliar diseases. In Pileru area (Chittoor district) improved practices package includes, basal application of FYM (25 cart-loads), mussoriphos (50 kg/ha) along with phospho-bacteria culture (2.5 kg/ha) and seed dressing with *Rhizobium* (500 g/ha) and *Trichoderma* (700 g/ha). Gypsum application at flowering time and one spray to control foliar disease.

Farmer practices for groundnut production

In both Anantapur and Pileru areas generally farmers apply di-ammonium phosphate or complex fertilizers (NPK 17:17:17 or 28:28:0) as basal dose at the rate of 125 kg/ha and most of the farmers do not apply gypsum and fungicides for foliar disease control.

Sowing of groundnut

Sowings were taken up from 1-4 August at Pampanur and 4-7 August at Linganapalli and groundnut cultivar TMV 2 was planted in all the fields. Fertilizers were applied based on soil test and field wise fertilizer application is given in Table 2a and 2b.

Field observations

Gemini data loggers were installed in the experimental fields in plots with improved and farmer practices to record temperature, humidity and soil temperature in the pod zone during the crop growth period. All the crop data, from germination to storage stage, was collected for all the fields. All the activities followed in fields were chronologically recorded (Table 3). Collected rainfall data from both the villages of

Anantapur during crop growth period. Late leaf spot was observed at 70-75 DAS in plots with farmer practices and the incidence was up to 80%; in plots with improved practices the disease was kept under control by giving 0.2% hexaconazole foliar spray. End-of-season drought was experienced during pod filling stage (from 15 Oct to 6 Nov at Pampanur and 19 Oct till harvest at Linganapalli). To measure intensity of drought, soil moisture was measured in all the experimental plots (Table 4a and 4b).

Estimation of *A. flavus* population in soil

Soil samples were collected from both production practices plots in each field, one between flowering and early pod stage and other at final harvest. In each plot soil samples were drawn from five 1.9 meter radius circles demarcated for groundnut harvest (one circle each in four corners and one in the center of the field). From each sample, three sub-samples were drawn, and mixed to make a composite sample. Like wise, a total of 5 composite samples from each plot and 10 composite samples from each field were prepared. Aqueous soil suspension (10 g soil in 90 ml sterile distilled water) was prepared from each of the composite sample, was serially diluted to 10^{-3} and 500 μl of soil suspension was spread on AFPA (*A. flavus* and *A. parasiticus* specific medium) plates (2 plates per sample) before incubation for four days at 28^0C in dark. The soil sample at flowering provides initial measure of the *A. flavus* population. The soil samples at maturity give the indication of how environmental conditions have affected the fungus population. It also provides information on influence of management practices on *A. flavus* population.

Harvesting and threshing

The groundnut crop was harvested at maturity by lifting and laid on the field for 3-5 days for drying under sunlight. Then the produce (groundnut pods with haulms) was stacked for 20-50 days before the pods were stripped or threshed (Staking is the practice used by the farmers in the region). The reason for stacking the pods along with haulms was mainly due to shortage of labor to strip the pods or non-availability of machinery for threshing forced the farmers to go for stacking of the harvest produce. Gemini data loggers were installed in the stacks to record the temperature and humidity. After stripping the pods, most of the farmers sell their produce to traders or oil millers and farmers retain small quantity of pods for their consumption. To study the groundnut aflatoxin contamination in farmer stores, a bag of pod was kept in farmers stores and data loggers were installed in the bag to record the temperature and humidity.

Groundnut pod sampling for *A. flavus* infection and aflatoxin contamination

Sampling is an important step in testing groundnuts for aflatoxin contamination. If *A. flavus* infection and aflatoxin contamination were homogeneously distributed throughout the samples intended for analysis, then sampling should not have posed any problem. Unfortunately the highly skewed nature of the distribution of *A. flavus* and aflatoxin complicates the sampling procedure. Toxicity often resides in only a few contaminated kernels. Additionally there is extreme variation in the level of aflatoxin among contaminated kernels.

In all experimental fields pod samples were drawn from improved and farmer practices separately. During the year 2000, groundnut pods were harvested at randomly in one square meter area using 5 replications and the pods were dried under the sunlight; one sub-sample was used for aflatoxin estimation. During the year 2001, groundnut pods were harvested from five 1.9-meter radius circles demarcated at flowering time (four from the corners and one in the center of the plot) and pods were dried for 3-5 days under sunlight before recording the yield data. From each sample one sub-sample was drawn for *A. flavus* seed colonization and aflatoxin contamination. The remaining sample was categorized in to large pod, medium pod, small pod and insect damaged pods. After shelling the pods, sub-samples were drawn from all these four groups of pods for seed colonization and aflatoxin estimation by ELISA. Similarly five pod samples each of 5 kg were drawn from individual stacks and sub-sample were taken for seed colonization and aflatoxin contamination.

Plating method for seed colonization

All the sub-samples were shelled and picked randomly 100 undamaged kernels for seed colonization by blotter plate method. First soak the kernels in sterile distilled water for 3-5 minutes, then surface sterilize the seed with 1% sodium hypochloride solution for one minute followed by three washes with sterile distilled water. Then the seed was kept on sterile moist filter paper in the petridish and the petridishes were placed in moist humid boxes before they were incubated at 28^0C for five days. On sixth day the plates were observed for *A. flavus* seed colonization.

Sample preparation for aflatoxin analysis

It is essential to extract the aflatoxin from the seed before the analysis by ELISA. About 100g groundnut seed was made in to powder using a blender and 20g sub-sample was used for extraction. Then triturated the seed powder in 70% methanol containing 0.5% K Cl (100 ml for 20g seed) in a blender until the seed powder is thoroughly ground. Transfer the extract in to conical flask and shake on rotary shaker at 300 rpm for 30 minutes. The extract was filtered through Whatman No.41 filter paper and stored at 4^0C till they are used for analysis.

Aflatoxin estimation by indirect competitive ELISA:

Materials

I. Carbonate buffer (coating buffer)

Na_2CO_3	:	1.59 g
$NaHCO_3$	:	2.93 g
Distilled Water	:	1.0 L

pH of buffer should be 9.6. No need to adjust the pH.

II. Phosphate buffer (PBS)

Na_2HP0_4	:	2.38 g
KH_2P0_4	:	0.4 g
KCl	:	0.4 g
NaCl	:	16.0 g
Distilled water	:	2.0 L

III. Phosphate-buffered saline with Tween (PBS-Tween):

PBS: I L; Tween-20: 0.5 mL

IV. Albumin bovine serum (Sigma A 6793):

Dissolve 200 mg BSA in 100 ml PBS-Tween

V. **Substrate buffer for alkaline phosphatase system:** p- nitrophenyl phosphate (PNPP) should be stored at -20°C. It is preferable to buy the chemical in tablet form (5, 15 or 20 mg tablets available). Prepare 10% diethanolamine (v/v) in distilled water. Adjust pH to 9.8 with conc. H Cl. This solution can be stored but pH should be adjusted to 9.80 prior to use. Prepare 0.5 mg ml^{-1} PNPP in 10% diethanolamine, pH 9.80 (for each 15 mg tablet 30 ml solution is required).

ELISA Procedure

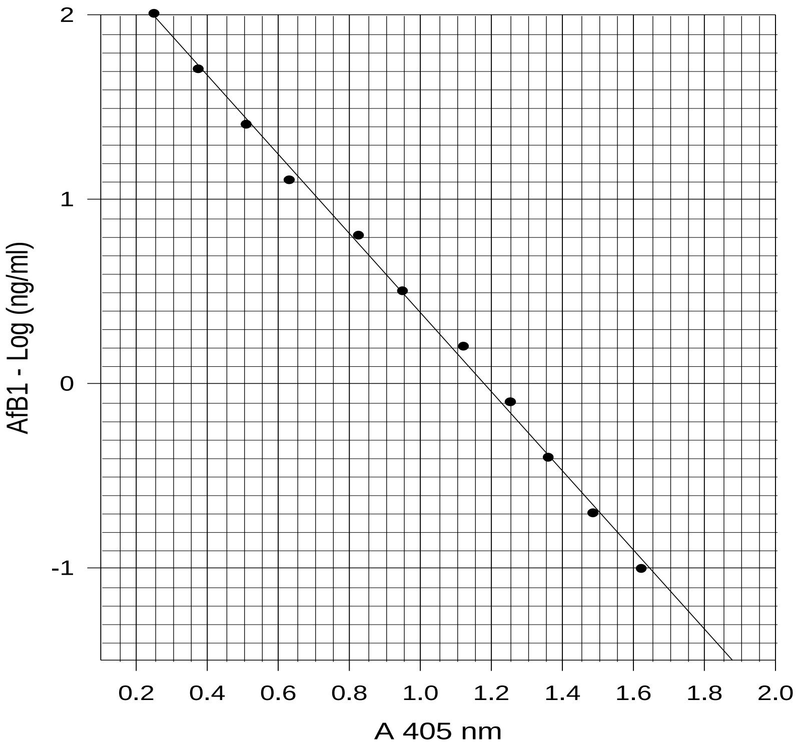
An indirect competitive ELISA method was used and prior to utilizing this procedure concentration of various reagents required to give optimum results was determined. This includes the concentrations of AFB_1-BSA and dilution of polyclonal antiserum and antirabbit IgGs labeled with alkaline phosphatase. Maxi-sorp (Nunc A/S, DK-4000 Roskilde, Denmark) ELISA plates were coated with 150 μl/well of AFB_1-BSA at a concentration of 100 μg/ml prepared in carbonate coating buffer pH 9.6. At each step plates were filled with 150 μl/well, incubated at 37^0C for one hour followed by three washes with PBS-tween. In the second step plates were treated with PBST-BSA. Dilute the AFB_1 standards ranging from 0.097 to 100 ng/ml using 1:10 diluted groundnut extracts free from toxin. Concentration of the standards used was 100, 50, 25, 12.5, 6.25, 3.12, 1.56, 0.78, 0.39, and 0.097 ng/ml and each concentration was duplicated in two wells. Similarly each test sample was duplicated in two wells. One hundred micro-liter of each of the test sample extract or standards was mixed with 50 μl antiserum diluted to 1:75000 in 0.2% PBST-BSA (Antiserum dilution was prepared and held at 37^0C for 30 min. before adding to the plate). This step was followed by the addition of alkaline phosphatase labeled anti-rabbit IgG conjugate diluted to 1:8000 in 0.2% PBST-BSA. After adding the substrate was *p*-nitrophenyl phosphate prepared in 10% diethanolamine the plates were incubated at room temperature and read in an ELISA reader. A maximum interval of 3 hours was allowed until optical densities from wells not containing any toxin reached 1.5-2.0 OD units at 405 nm. Regression curve was drawn with the help of computer by plotting $\log_{10}$ values of concentration of aflatoxin standards on 'Y' axis and corresponding optical density values on 'X' axis (Figure 1). Using the values of the regression equation the aflatoxin content in the sample was determined.

Calculations

$$AFB_1\ (\mu g/kg) : \quad \frac{AxDxE}{G} \quad \text{or} \quad \frac{AxE}{CxG}$$

A= AFB_1 concentration in diluted or concentrated sample extract (ng/ml)
D= Times dilution with buffer
C= Times concentration after cleanup
E= Extraction solvent volume used (ml)
G= Sample weight (G)

Figure 1. Regression curve for aflatoxin standard



Estimation of aflatoxin M1 in milk

Antibody production

A New Zealand White inbred rabbit was injected sub-cutaneously with 100 μg of AFM1-BSA in 500 μl of sterile 0.01M phosphate-buffered saline (PBS) emulsified with an equal volume of Freund's complete adjuvant. Subsequent immunizations were given with incomplete Freund's adjuvant. After four immunizations at weekly intervals followed by a booster after three weeks, the rabbit was bled at weekly intervals and the titer of the antiserum was determined by indirect competitive ELISA. Booster injections were given when a drop in the titer was noticed.

Source of milk samples

Four hundred and sixteen samples were collected from villages surrounding Hyderabad city (peri-urban) and from the Anantapur (rural) area of Andhra Pradesh, India. The samples included 352 raw milk samples, each of approximately 50 ml, collected from individual buffalos (116 samples from peri-urban and 236 from Anantapur), 44 (250 ml each) of commercially available factory sealed milk packets sold in Hyderabad, 10 samples of powdered milk marketed in sealed cans and 10 samples of milk-based confectionery sold in retail markets in Anantapur. Samples were either processed soon after collection or kept at 4°C and analyzed within 3-4 days.

Preparation of milk samples for ELISA

Samples (usually 15 ml) were centrifuged at ambient temperature for 10 min at approximately 2000 g. An equal volume of methanol was added and the mixture was shaken on a rotary shaker for 30 min at 250 rpm and then filtered through Whatman No. 41 filter paper. For samples of powdered milk (including CRM) and confectionery, 10 g was suspended in 100 ml distilled water, heated to about 50°C and homogenized in a Waring blender and then processed as for liquid milk.

Estimation of aflatoxin M1 by Indirect competitive ELISA:

The protocol was similar to that for determining aflatoxin in groundnut seed except that AFM_1-BSA conjugate 50 ng/ml was used for coating the plates and AFM_1 standards in 100 μl, ranging from 10 ng/ml to 1 pg/ml, were prepared in AFM_1-free milk sample extract (CRM milk samples with AFM_1 concentration of <0.05 ng/g). Methanol extracted and filtered test milk samples were diluted to 1:10 in PBS-T BSA. A 100-μl aliquot of each sample was added to a well containing 50 μl of antiserum diluted to 1: 300 000. Standard curves were obtained by plotting $\log_{10}$ values of AFM_1 standards against optical density at A_{405}. Concentration of AFM_1 in the sample extract was determined from the standard curves and expressed in ng/ml using a formula: AFM_1 concentration (ng/ml) in sample extract $\times$ dilution with buffer $\times$ extraction-solvent volume used (ml) / sample volume (ml). In order to test the recovery of AFM_1 from spiked milk samples, AFM_1 standards were added to obtain concentrations ranging from 0.25 to 50 ng/ml in 10 ml milk samples known not to contain detectable AFM_1, then extracted and assayed as above.

Post-harvest storage sampling (April to June 2001) and aflatoxin analysis

Based on Participatory Rural Appraisal (PRA) survey carried by STAAD, four villages viz., Linganapalli, Pampanur, Ghantapuram and Jalapuram were selected; in each village 25 farmers were selected for sampling of groundnut pods, groundnut haulms, and milk for aflatoxin analysis. The samples were collected from farmer's stores at monthly intervals for three months starting from April. In addition samples of groundnut pod, kernels, and groundnut cake from oil producing millers, traders and groundnut confectioneries from households, bakeries were collected for aflatoxin estimation.

Survey for groundnut aflatoxin contamination in Anantapur district

To understand magnitude of groundnut aflatoxin contamination, a survey was conducted covering about 300 villages spread over 30 mandals of Anantapur district. Soon after crop harvest, from each village 1 kg groundnut pod sample was drawn from one farmer and sub-samples were used for aflatoxin estimation by ELISA.

Identification of highly toxigenic *A. flavus* isolates

Isolates of *A. flavus* collected from different sources (seed, soil etc.) as well as locations and single spore cultures were maintained on Czepak-Dox agar medium. Aflatoxin producing abilities of these isolates were studied by colonizing these isolates on groundnut seed (JL 24) susceptible to aflatoxin contamination. Groundnut seed (20g) was surface sterilized with 1% sodium hypochloride followed by three washes with sterile distilled water. Spore suspension of the isolates was prepared using 10-day old cultures and a uniform dilution of one million spores per milliliter was prepared. Surface sterilized seed was inoculated with one-milliliter spore suspension in a petridish and incubated at 28°C for 7 days. Methanol extracts of the inoculated seeds were prepared and aflatoxin concentration was determined by indirect competitive ELISA.

Results and Discussion

Field trials for aflatoxin management

To develop management strategies for reducing aflatoxin levels in groundnut, year 2000 rainy season's pod samples at harvest were collected from 63 farmer's fields in Anantapur area and 12 farmer's fields from Pileru area. In these fields groundnut production practices (improved and farmer practices) were adopted and the results are presented in Tables 5 and 6. The aflatoxin levels were low in samples collected at harvest from Anantapur as well as Pileru areas. During 2000 rainy season there was well-distributed good amount of rainfall during crop growth period and there was no end of season drought which is one of the predisposing conditions for aflatoxin contamination. The aflatoxin analysis data (Table 5) indicate that the mean aflatoxin contamination 100 μg/kg in plots with farmer practices was reduced by 38% using improved production practices and samples from 25 fields were having aflatoxin >10 μg/kg.

Based on 2000 rainy season groundnut aflatoxin data, 25 farmer fields were selected for management trials and in these fields improved and framer practices were tested simultaneously during 2001 rainy season. At Pampanur pre-harvest sample analysis for *A. flavus* infection and aflatoxin contamination data presented in Table 7A indicate that there was low level of *A. flavus* infection and aflatoxin contamination in both the management practices. But in Linganpalli farmer's fields the pre-harvest *A. flavus* infection and aflatoxin contamination was higher than that of Pampanur farmer's fields in both management practices. At Linganpalli using farmer practices as high as 7% *A. flavus* infection and 796 μg/kg aflatoxin level was obtained but with improved practices highest 6.33% infection and 176 μg/kg was recorded. Although there was no significant difference in *A. flavus* seed colonization between the cultivation practices, a reduction of 72% in mean aflatoxin level obtained with improved practices at Linganpalli (Table 7B). It indicates that there is no correlation between *A. flavus* infection and aflatoxin contamination in groundnut pre-harvest samples and possible reason could be seed colonization with non-toxigenic *A. flavus* strains or lack of expression due to field condition.

Aspergillus flavus infection and aflatoxin contamination in pre-harvest groundnut at Pampanur and Linganpalli could be attributed to end season drought and soil temperatures of respective locations. The crop was under end season drought stress for 40 days at Linganpalli as against 17 days at Pampanur. Additionally mean soil temperatures were ranged 28-30C during pod filling stage (30 days) at Linganpalli, where as at Pampanur mean soil temperatures were <28^oC for most of the pod development stage (Figure 2). High soil temperature (28-30^oC) and end season drought for period of >20 days are predisposing factors for pre-harvest *A. flavus* infection. So end season drought for 30 days and high soil temperatures (>28^oC) at Linganpalli favored increased *A. flavus* infection and subsequent aflatoxin contamination over Pampanur fields. Although there was end season drought at Linganpalli, all the farmer's fields did not have similar level of *A. flavus* infection and aflatoxin contamination because change in soil temperatures in individual fields (Figure 3).

Figure 2. Rainfall and mean soil temperatures at Pampanur and Linganapalli

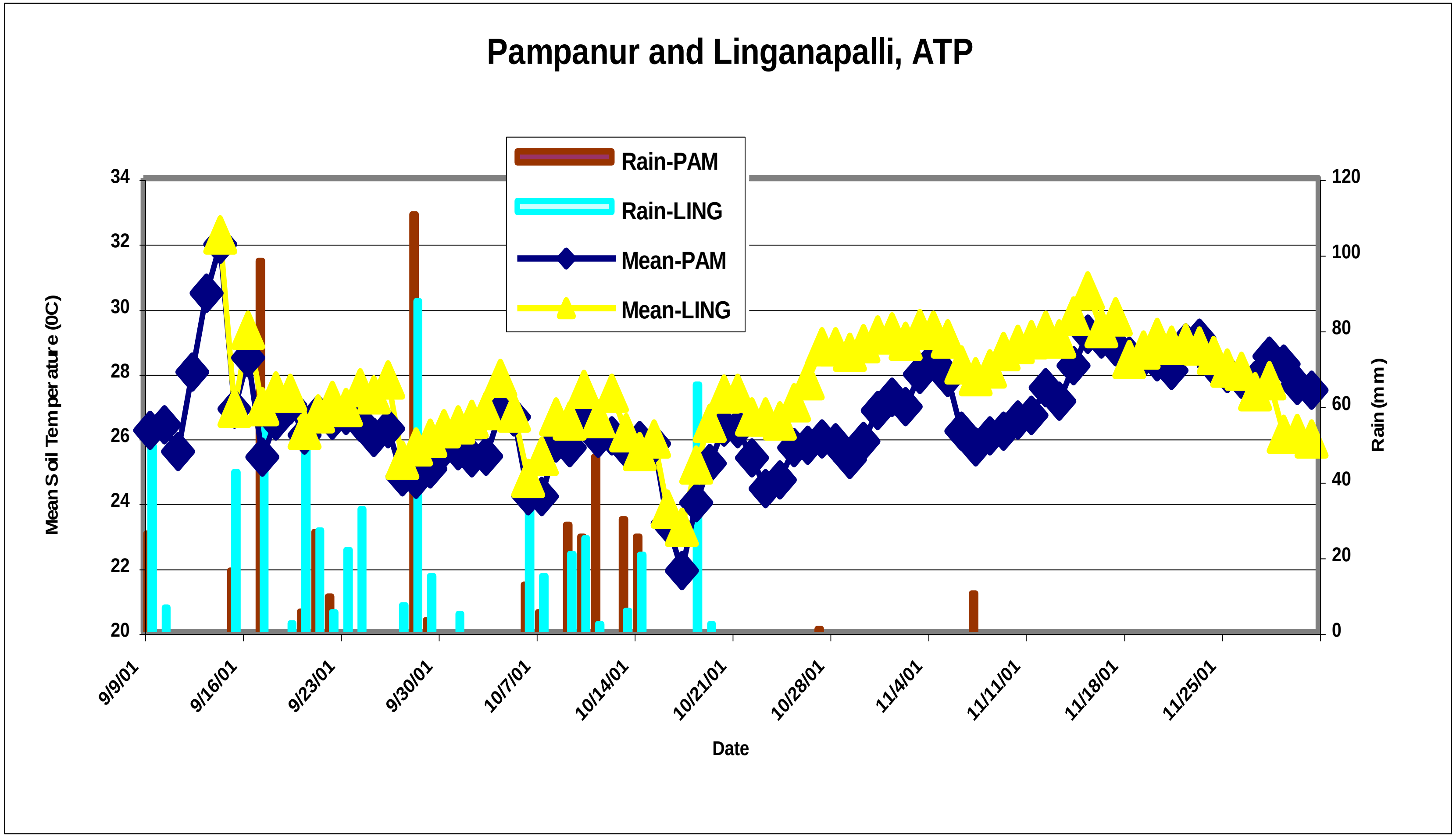


Figure 3. Rainfall and mean soil temperatures in individual farmers fields at Linganpalli

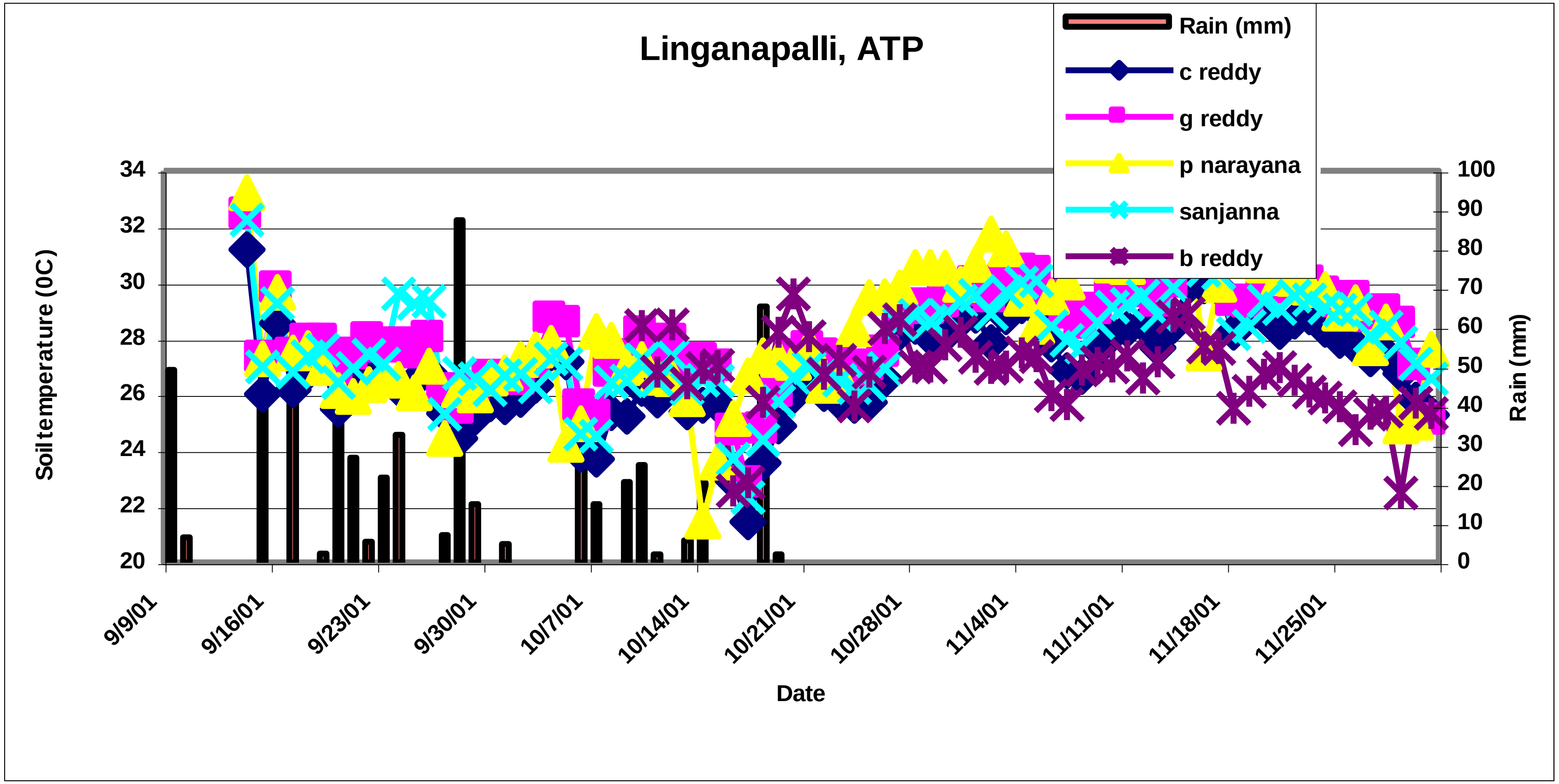
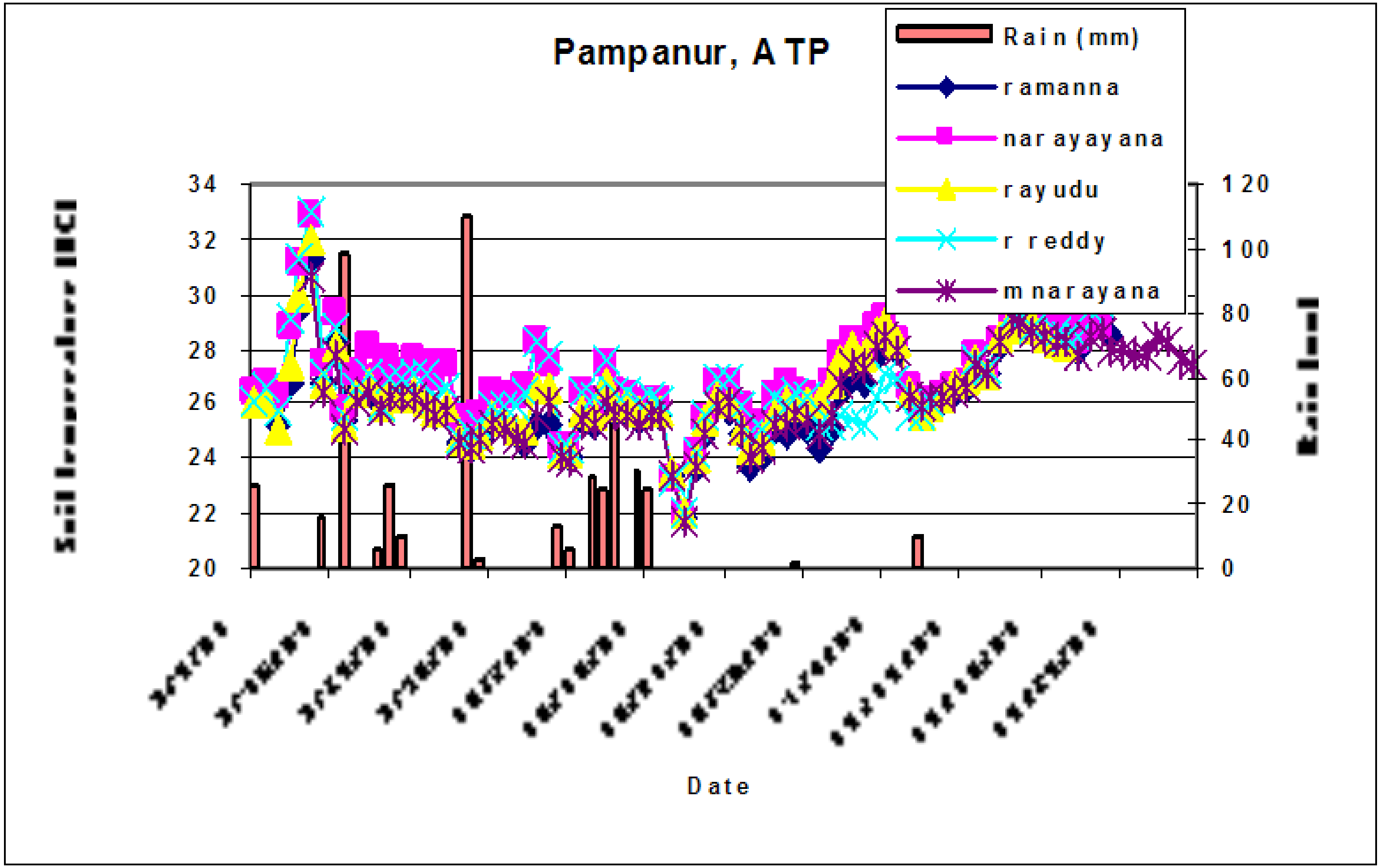


Figure 4. Rainfall and mean soil temperatures in individual farmers fields at Pampanur



At Linganpalli in two fields (Pedda Narayana and Pedda Sanjanna) high *A. flavus* infection and aflatoxin contamination was recorded because of end season drought and high soil temperature during the pod filling stage. Despite of favourable weather conditions in Chenna Reddy's field at Linganpalli, there was low *A. flavus* infection and aflatoxin contamination and there is need to look in to such a situation very carefully. Similarly at Pampanur, there was little (<20 days) end season drought and soil temperatures in individual fields were <28^{o}C during pod maturity period resulted in low *A. flavus* infection and aflatoxin contamination (Figure 4).

Farmer's fields with improved management practices produced higher mean pod yields by 24% (494 kg/ha) and 17% (340 kg/ha) at Pampanur and Linganpalli respectively (Table 8A and 8B). Since there was little or no end season drought at Pampanur, higher pod yields were obtained. At Linganpalli, because of prolonged end season drought period was responsible for lower yields. The two fields (Pedda Narayana and Pedda Sanjanna) with high level of aflatoxin contamination produced more pore pod yield than the village mean pod yield indicate *A. flavus* infection and aflatoxin contamination does not affect the pod yield.

Regarding social status of farmers, schedule caste (SC) farmers had extremely low social status and most of them are poorest among the poor people. Till recently SC group were considered as untouchable by the forward caste (FC) people and backward caste (BC) people had middle level of social status. In Pampanur farmers belonging to SC with poor socioeconomic status produced pod 604 kg/ha with improved practices and aflatoxin contamination was low. Farmers belonging to FC with good socioeconomic status produced 379 kg/ha with improved practices and aflatoxin contamination was also low. The SC farmers produced 59% more pod yield than the FC farmers and the aflatoxin contamination (<5 μg/kg) was low in both the cases. It indicates there was no relationship between the socioeconomic status of farmers and aflatoxin contamination. At Linganpalli using improved practices the SC farmers produced 318 kg/ha pod as against 349 kg/ha by FC farmers. However, in SC farmers fields the aflatoxin contamination was >456 μg/kg with farmer practice, 83 μg/kg with improved practices was higher than the FC farmers aflatoxin contamination 3 μg/kg with farmer practice and 20 μg/kg with improved practice. High aflatoxin contamination in SC farmers fields was due to high soil temperature and it does not relate to socioeconomic status of the farmers.

At harvest during 2001 rainy season in Pileru, 2 of the 6 fields were having higher *A. flavus* infection and aflatoxin contamination (Table 9). Late planting of groundnut in these two fields led to higher *A. flavus* seed colonization as well as aflatoxin contamination with both practices.

Groundnut seed from three different pod sizes were analyzed for *A. flavus* infection and aflatoxin contamination. Kernels from large size pods contain negligible (<5 μg/kg) amount of mean aflatoxin contamination under both management practices at Pampanur and Linganpalli (Table 10A and 10B).

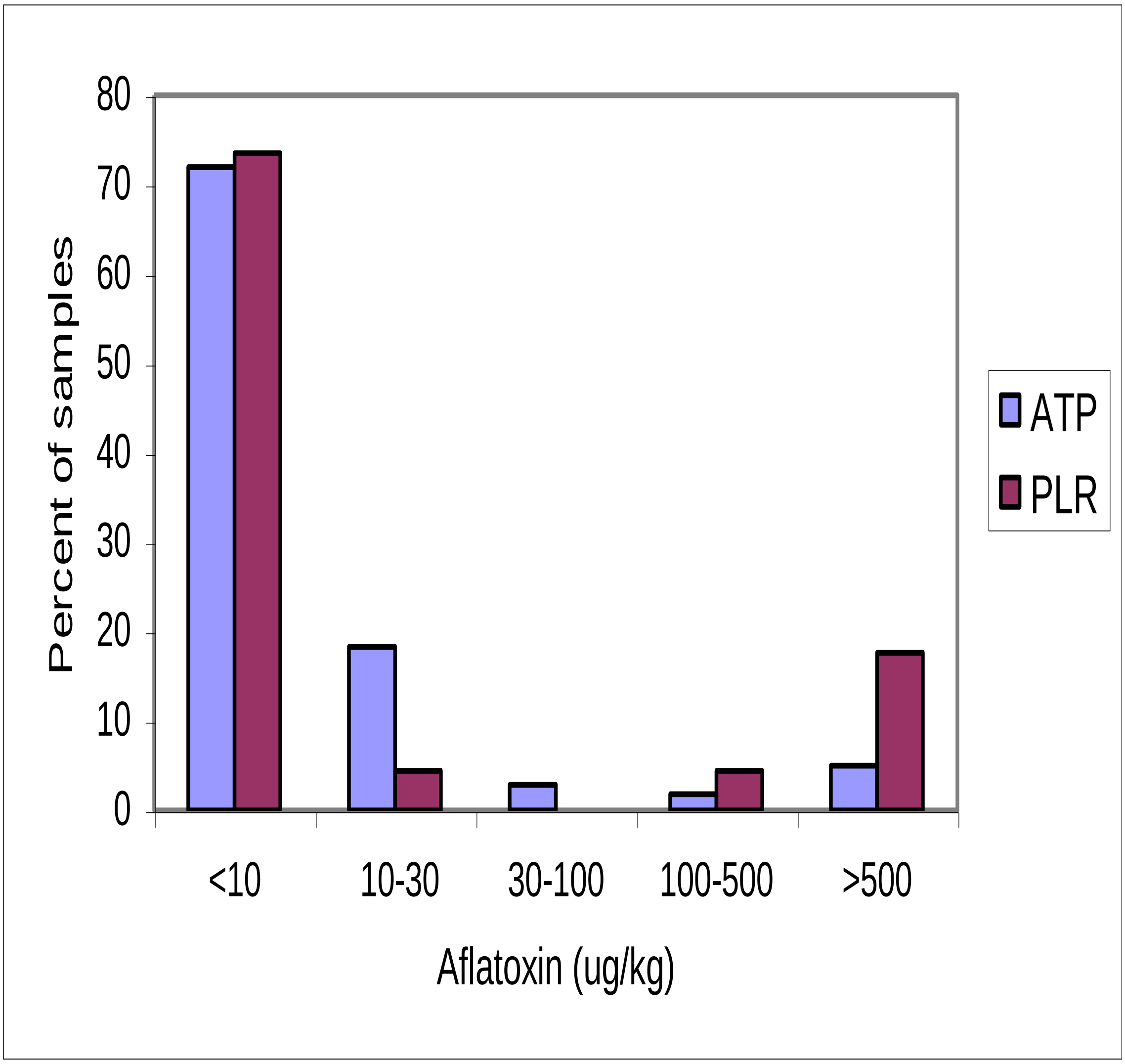
In Pampanur, kernels from medium size pods showed low levels of *A. flavus* infection and aflatoxin contamination (<6 μg/kg) under both cultivation practices could be due to reduced end season drought period (Table 11A). At Linganpalli groundnut seed from medium size pods grown with farmer practice pose high risk to human health with mean aflatoxin contamination of 324 μg/kg was reduced by 97% to 8.9μg/kg aflatoxin using improved practices (Table 11B).The reduction in aflatoxin contamination was more or less uniform in improved practices across the farmers of the Linganpalli considering aflatoxin level <10 μg/kg is below ELISA determination efficiency level. In the field of Mr. Pedda Narayana (farmer) *A. flavus* infection was high in both the management practices but high level of aflatoxin (1225 μg/kg) with farmer practices was reduced by 99% using improved cultivation practices.

Kernels from small size pods showed around 16 μg/kg aflatoxin in both cultivation practices at Pampanur (Table 12A). In certain fields with improved practices there is marginal increase in aflatoxin contamination needs to be looked in closely. In Linganpalli at individual farmers level, the seed from small size pods showed highest aflatoxin contamination of 1969 μg/kg with farmer practices and 812 μg/kg with improved practices (Table 12B). The mean aflatoxin level was reduced by 82% (from 535 to 95 μg/kg) using improved practices at Linganpalli. In two fields (Govinda Reddy and Narasimha Reddy) there was increase in aflatoxin level with improved practices. Aflatoxin contamination of >20 μg/kg was recorded in 70% of the fields grown with farmer practice as against 20% of the fields with improved practices at Linganpalli.

In Anantapur area soil inhabiting pests mainly pod-borers causes about 1% pod damage before the crop is harvested. Kernels from insect damaged pods, which were grown with improved practices, showed reduction in aflatoxin contamination by 75 and 35% at Pampanur and Linganpalli (Table 13A and 13B). Pre-harvest insect damage to groundnut pods predisposes seed colonization by *A. flavus* and aflatoxin contamination resulting minimized effect of improved practices.

Both villages put together, with improved cultivation practices the pre-harvest aflatoxin contamination levels were reduced by 68% in pre-harvest pod samples, 94% in medium size pods, 79% in small size pods and 51% in insect damaged pods. About 625 groundnut seed samples were analyzed by ELISA for aflatoxin contamination (Figure 5), 73% of the samples in both locations showed aflatoxin <10 μg/kg. Aflatoxin level >500 μg/kg was detected in 18% of Pileru samples as against 5% in Anantapur samples; although this category of samples are less in number they play crucial role when they are mixed with uncontaminated seed lot.

Figure 5. Distribution percentage for aflatoxin levels in Anantapur (# 557) and Pileru (#68) samples



Estimation of Aflatoxin M1 in Milk

Production of antibodies and ELISA

Antibodies specific to AFM_1 were detected 6 weeks after initial immunization and the titer increased with booster. Antiserum at a dilution of 1:300,000 and coating concentration of 50 ng/ml AFM_1 gave optimum results. The antibodies cross-reacted with AFB_1 (at 5% level) and weakly with AFB_2, AFG_1, AFG_2 and did not react with ochratoxin A.

Processing of milk samples for ELISA

It was found in the initial experiments substances present in milk extracts interfered in the analysis. In order to eliminate their influence, it was essential to prepare the AFM_1 standards in aqueous methanol extracts of certified AFM_1-free milk.

Recovery of AFM_1 from spiked and CRM milk samples

To test the accuracy of AFM_1 estimations ranging from 0.01 to 50 ng/ml were added to the milk samples and the extracts were analyzed by ELISA. Milk samples known not to contain AFM_1 were compared with known amounts AFM_1. It is apparent from the results presented in Table 14 that the procedure gave recovery of >93% for AFM_1 concentrations exceeding 2.5 ng/ml. The results of AFM_1 analysis were shown to be accurate by comparison at regular intervals with EU certified samples of known AFM_1 concentrations.

Milk sample analysis for AFM_1

Incidence and level of AFM_1 in samples are summarized in Table 15. Analysis of three replicates of 416 milk samples showed that 213 samples (51%) contained AFM_1 at levels ranging from 0.6 to 48 ng/ml. It was observed that the contamination of AFM_1 was greater (93%) in samples obtained from periurban areas than those from rural areas (34%). It is note worthy that 50% incidence was observed in the powdered milk samples intended for infants and 30% in milk based milk confectionery, although the number of samples tested were insufficient to obtain an accurate picture of the incidence of contamination.

This is, to our knowledge first report from India showing AFM_1 contamination of milk samples from periurban areas of rapidly developing metropolis. Anantapur was chosen to represent a rural area because more than 30% of small-scale farmers there produce milk and also groundnut haulms are used as fodder.

The major feed ingredients for cattle in periurban areas of Hyderabad city are cotton cake, groundnut cake, rice bran and straw. We have analyzed some of the ingredients for aflatoxin content. The majority of cotton and groundnut cakes are contaminated with aflatoxin at levels exceeding 500 ng/g and the highest was 3000 ng/g in one sample. They may be contributing to the high levels of AFM_1. High incidence of aflatoxins in various ingredients of cattle feeds has been reported from India. This can be attributed to prevalence of such optimum climatic factors as temperature and humidity for mold growth. In villages where AFM_1 levels were found to be low, the animals are allowed to graze and the main feed ingredient was rice bran. However, more detailed study is needed in order to understand the various factors that contribute to high versus low AFM_1 contamination. In rural areas like Anantapur, the majority of the farmers allow their animals to graze. Rice straw and food wastes are the main feed supplements. Interestingly, at rural locations where AFM_1 was found to exceed 0.5 ng/ml, groundnut haulms containing small pods were used as the major supplement.

Aflatoxin levels in storage samples

Groundnut pod, cake, haulms samples were collected from farmer's, oil miller's, trader's storage and analyzed by ELISA. Of the 696 samples tested for aflatoxin contamination levels, 35% of the samples contain >10 μg/kg aflatoxin (Table 16). About 16% of the samples stored in sacks in farmer storage contain >10 μg/kg aflatoxin followed by 27 and 30% samples in oil millers and traders storage. More than 16% of insect damaged kernel samples from storage showed aflatoxin >500 μg/kg and this level of aflatoxin contamination stands on the top among different category of post-harvest storage samples. Higher level of aflatoxin contamination (>100 μg/kg) was detected in >80% of the groundnut cake samples. When animals are fed with highly contaminated groundnut cake its milk also get contaminated with aflatoxin M_1.

Survey for groundnut aflatoxin in Anantapur district

Groundnut seed samples from 250 villages belonging to 25 mandals were collected and analyzed by ELISA for aflatoxin contamination. Using geographic information systems (GIS) mapped the aflatoxin levels in 25 mandals of Anantapur (Figure 6). Samples from seven mandals (28%) (D. Hirehal, O. D. Cheruvu, Somendapalli, Puttaparthy, Kalyanadurgam, Singanamala and Nallamada) contain >48 μg/kg, non-permissible level of aflatoxin and 5 of the 7 mandals received <300 mm rain during the season.Interestingly mean of aflatoxin contamination in 25 mandals (60.9 μg/kg) is one and same that we obtained from 25 farmer fields in two villages.

Identification of highly toxigenic *A. flavus* isolates

Groundnut seed separately inoculated with 31 *A. flavus* isolates were analysed by ELISA for aflatoxin concentration. All the isolates produced aflatoxin ranging 8 to 9581 μg/kg (Table 17). Of the 31 *A. flavus* isolates, 55% produce >30 μg/kg aflatoxin. The *A. flavus* isolate AF 11-4 produced highest (9581 μg/kg) aflatoxin and currently this isolate is being used to screen the genotypes for aflatoxin resistance. All the toxigenic isolates were sent to Dr. Averil E Brown, University of Belfast, Belfast, for further characterization using recombinant DNA technology.

Conclusion

The mean pod yields were greater at Pampanur (494 kg/ha) than Linganpalli (340) and higher pod yields were obtained with improved practices in both the villages. Aflatoxin contamination was more in Linganpalli than Pampanur. In Anantapur area (both villages together), there is an increase in mean pod yield 344 to 416 kg/ha with the improved production practices and these yields are far below 1081 kg/ha average yield of Andhra Pradesh State. However, the pod yields were not related to pre-harvest aflatoxin contamination because the improved production practices designed to increase the pod yield alone. Socioeconomic status of the farmers did not affect the yield and aflatoxin contamination. Although with increase in pod yield, there is also substantial reduction in aflatoxin contamination level (from 58 to 18 μg/kg) with the improved practices and this reduction in aflatoxin level is not sufficient to meet the international standards. Therefore there is need to develop integrated management approach to combat aflatoxin contamination as well as to increase the groundnut productivity in the semi arid tropic zone. Integration of suitable biological control agent along with resistant or tolerant cultivar with some adaptable cultural practices will be helpful for groundnut production and reducing aflatoxin contamination.

Frequent contamination of AFM_1 in milk and dairy products has lead to the assessment of risk due to liver cancer. Our data clearly show the need for such a risk assessment in India. The results also highlight the importance of surveillance particularly in periurban areas for AFM_1 contamination in milk and milk based confectionery. More detailed study is needed to understand the various factors that contribute to high versus low AFM_1 contamination in milk. The AFM_1 estimation methods described and illustrated could form the basis of a low cost risk assessment procedure. Ultimately such surveillance procedures must be linked to technical, policy and institutional interventions that will lead to the reduction of AFM_1 in milk production systems in India.

In post-harvest storage, about 35% of the samples were contaminated with aflatoxins and some of the samples contain high amount of aflatoxin (>500 μg/kg). Insect damage to groundnut pod in storage not only causing damage to kernels but also enhancing aflatoxin contamination. The number of samples and aflatoxin contamination levels in post-harvest storage samples are alarming, so there is need to develop post-harvest storage devices to eliminate insect damage as well as aflatoxin contamination. Groundnut cake (de-oiled) one of major ingredient in cattle and poultry feeds and >80% cake samples contain aflatoxin >100 μg/kg. In Anantapur area farmers use the haulms for cattle feed and high level of aflatoxin (>500 μg/kg) was detected in groundnut haulms (the toxin contamination was found in immature pods attached to haulms). There is need to develop strategies to reduce aflatoxin contamination in groundnut based animal and poultry feeds. The survey of 220 villages covering 22 mandals of Anantapur indicated high level of aflatoxin in some villages and these villages need to be monitored very closely and management strategies should target these particular villages.

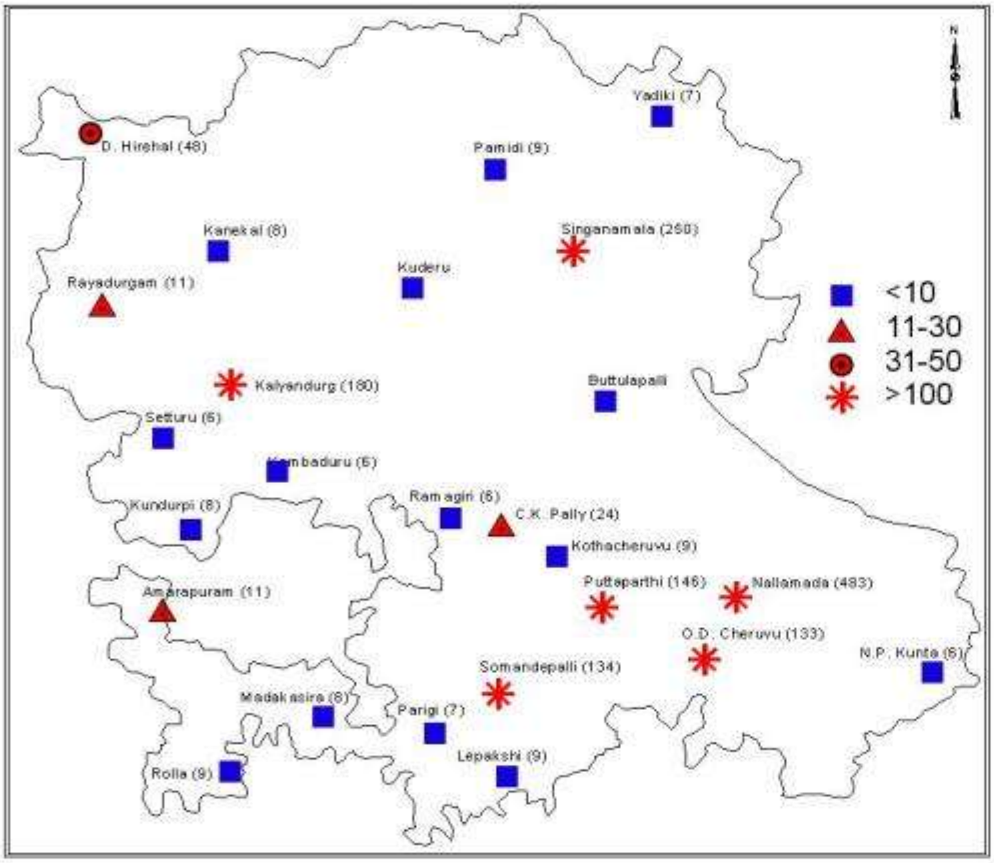


Figure 6. Aflatoxin contamination (µg/kg) in different mandals of Ananthapur Dist, Andhra Pradesh

Activity 2.2 Characterization of toxigenic and non-toxigenic A. flavus and A. parasiticus isolates. (GJ McKay, Averil Brown)

"The isolates will then be sent to Dr. A.E. Brown who will use existing molecular tools to distinguish toxigenic isolates. Techniques to be employed are PCR-based, already shown to be applicable to fungal species. They include RAPD analysis/microsatellites/PCR-RFLP analysis/nucleotide sequencing."

Isolates

The isolates in Table 18 were grown at 30°C in 100ml of liquid Czapek Dox medium in an orbital incubator (150 rpm) for 48 hrs. The resultant mycelium was filtered, freeze-dried and DNA extracted from each isolate following the protocol of Raeder and Broda (1985).

Molecular Characterisation

Micro satellite analysis

Micro satellite analysis was carried out on all isolates using some of the oligonucleotide primer combinations (AFPM1 and AFPM2) according to the protocol of Tran-Dinh and Carter (2000) and using the ABI 3100 Genetic Analyser. These primer combinations had been designed to flank micro satellite regions within genes identified in *A. flavus* and *A. parasiticus*. Results generated from the primer combinations suggest that they do not differentiate between isolates that are capable of aflatoxin B1 production and those that are not. In addition, these primers do not differentiate the isolates studied on the basis of their geographic origin.

Several genes have been PCR amplified and DNA nucleotide sequenced from several toxigenic and non-toxigenic isolates of both *A. flavus* and *A. parasiticus* from Indian, African and Australian origin. These genes included the non-transcribed ITS1, 5.8s and ITS2 regions of the rDNA, and the small mitochondrial subunit, the trpC polyprotein and the beta-tubulin gene (Geiser *et. al*., 1998) have also been analysed.

DNA sequence analysis of the ITS region of the rDNA

Isolates of *A. flavus* and *A. parasiticus* were PCR amplified using the primers ITS5 and ITS4 (White *et al*., 1990). The PCR product generated was purified and DNA sequenced using the ABI 3100 Genetic Analyser. DNA sequence data for all isolates was compared with that published in the European Molecular Biology Library (EMBL). Results indicated that all isolates tested, with the exception of Apnt2, were as expected. According to the DNA sequence data obtained isolate Apnt2 is, in fact, *A. flavus*.

Mitochondrial rDNA

DNA sequence analysis of the small sub-unit of the mitochondrial DNA has been carried out for a large number of the isolates studied and compared to the sequence data published in EMBL. The mitochondrial DNA is reported to be a good indicator of phylogenetic relationships as it is maternally inherited. However, no sequence variation within the small subunit was detected between any of the isolates of *A. flavus* or *A. parasiticus*, with all isolates for both species giving the same sequence data for this region. In addition, a large portion of DNA sequence data from the large mitochondrial sub-unit has also been reported in GenBank for several isolates. No sequence variation has been reported for this region.

Other 'phylogenetic genes'

DNA sequence data for the 18S and 28S ribosomal sub-units for both *A. flavus* and *A. parasiticus* have been published in GenBank. Multiple sequence alignments were carried out on this data, demonstrating a low degree of variation between the species. Consequently, the DNA sequence data from these genes was not analysed as they were not anticipated to be good indicators of intraspecific phylogeny within either *A. flavus* or *A. parasiticus*.

Geiser *et al*., (1998), reported the usefulness of several genes to study the intra- and inter-specific phylogenetic relationships between isolates of *A. flavus* and *A. parasiticus*. These authors carried out DNA sequence analysis on a number of isolates of both species for these genes and published the data. Multiple sequence alignments of this sequence data indicate that these genes are useful for the study of such relationships. The PCR primers required to carry out this analysis were used to analyse the isolates in the current study. The genes identified by Geiser *et al*., (1998) were:

1. Acetamidase
2. Polygalacturonase
3. Tryptophan synthesis
4. Beta-tubulin

Only the tryptophan synthesis and the beta-tubulin gene were used in the current study, as the other primer combinations were found not to be reliable in the amplification of gene product for the purpose of comparing isolates in the current study. The results from the tryptophan synthesis gene, while demonstrating variation both within and between *A. flavus* and *A. parasiticus*, did not suggest that there was sufficient evidence to differentiate isolates of Indian origin from those from elsewhere, on the basis of the data generated. Analysis of the beta-tubulin gene is currently on-going and will be completed before the end of the project.

Aflatoxin biosynthetic pathway genes

Previous investigations have suggested, that the loss in the ability to produce aflatoxin by an isolate may not be due solely to a loss of function or expression of the O-methyltransferase gene, but as it is only one gene in a biosynthetic pathway (see Figure 7), mutational events in other genes within the pathway may lead to loss of aflatoxin biosynthesis capability. The DNA sequence data for a number of other genes involved in the biosynthetic pathway have been analysed and PCR primers designed to amplify these genes from *A. flavus* and *A. parasiticus*. It has been reported previously (Kusumoto *et. al*., 2000) that the majority, if not all, genes involved in the aflatoxin biosynthetic pathway are arranged together in a gene cluster region as demonstrated in Figure 8 for *A. parasiticus*. Approximately, 35% of the DNA sequence data for this gene cluster arrangement has been ascertained in an attempt to identify possible mutation events which may lead to loss of gene structure and hence function, inevitably leading to a loss in the ability to produce aflatoxin. In addition, the DNA sequence data generated from these genes was used for the comparison of intra- and inter-specific phylogenetic relationships and to detect regions of sufficient nucleotide variation between *A. flavus* and *A. parasiticus* so as to facilitate the development of a rapid PCR based diagnostic test for the identification of both species.

The genes for which DNA sequence data has been ascertained to date are as follows:

1. Oxidoreductase (*ord*1 and *ord*A) gene (2200bp & 2700bp sequenced)
2. Cytochrome P450 monooxygenase (*ver*b) gene (1800bp)
3. Ketoreductase (*ver*1) gene (1750bp)
4. Polyketide synthase gene (*pks*) gene (1400bp)
5. Versicolorin B synthase (*vbs*) gene (1700bp)
6. *afl*R regulatory gene of the aflatoxin biosynthetic pathway (680bp)
7. O-methyltransferase (*omt*) gene (3000bp)

There are 2 oxidoreductase genes in *A. flavus* and *A. parasiticus*. The sequence data generated from both genes has demonstrated intra- and inter-specific isolates of *A. flavus* and *A. parasiticus*, although not to an extent of differentiating isolates of Indian origin. Both gene sequences, however, do facilitate differentiation between the toxigenic and non-toxigenic *A. parasiticus* isolates studied, through a number of single base mutations leading to amino acid shifts within the gene sequence.

The gene sequence for Cytochrome P450 monooxygenase (verb) has shown the most potential to date, with a large number of mutations detected leading to several amino acid changes within the protein sequence (and possible loss of protein function). Indeed, within all *A. flavus* isolates analysed to date, it would appear from the genomic DNA sequence data generated from this gene, that a truncation of the protein by 49 amino acid residues occurs. This truncation occurs in both toxigenic and non-toxigenic isolates and therefore its significance is not known at this point in time. Other mutations have been detected between these species and are also significant among some *A. parasiticus* isolates, which produce toxin, and some that do not, i.e. Apnt3 and Apnt4 (Australian in origin). Whether these mutations are responsible for the loss in the ability to synthesise aflatoxin still remains to be seen. It must be stressed however, that the literature suggests that the loss in the ability to produce aflatoxin is not necessarily associated with mutation within one particular gene in the biosynthetic pathway, but that mutational events within one or more genes may lead to a loss or reduction in the ability to produce aflatoxin. In other words, different non-toxin producing isolates may have lost their ability to synthesise toxin due to different mutations in different genes within the pathway. Due to the high level of inter-specific variation demonstrated by this gene, it may prove to be the most useful for the design of species-specific PCR primers for the development of a rapid diagnostic test. PCR primers designed from the DNA sequence data generated from this gene are currently being tested for their effectiveness at differentiating between *A. flavus* and *A. parasiticus*.

Analysis of the versicolorin B synthase (vbs) gene would suggest that it is sufficient to differentiate between isolates of Indian and non-Indian origin, suggesting that they may form a specific sub-population. However, more isolates are currently being analysed to confirm this.

The O-methyltransferase (omt) gene also demonstrated intra- and inter-specific variation. Several single base mutations within the non-coding 5' region of the gene facilitated the differentiation of toxigenic and non-toxigenic isolates studied.

While the ketoreductase (ver1) gene did demonstrate a low level of intra- and inter-specific variation, it was not sufficient to differentiate between isolates of Indian origin or toxin and non-toxin producers.

The aflR regulatory gene controls the expression of the aflatoxin biosynthetic pathway and was characterized by Watson et. al., 1999. The authors documented a 'HAHA' insertion and a premature termination mutation leading to a truncation of the protein in a non-toxigenic isolate of *A. oryzae* and *A. parasiticus* and in several isolates of *A. sojae*. To date only a small number of non-toxigenic isolates within the present study have been analysed for these mutations. The sequence data generated has identified that none of the non-toxigenic isolates studied so far contain the HAHA mutation, although a single non-toxigenic isolate has demonstrated a different insertion mutation, providing an additional 4 amino acids to the protein sequence. The region of the gene pertaining to the truncation mutation has not yet been analysed.

The advantage of studying the genes in the aflatoxin biosynthetic pathway are that it allows us to analyse the phylogenetic relationships between isolates of the same species and between the two species, based upon the DNA sequence data generated. In addition, it provides an opportunity to study the mutational events within the genes responsible for toxin production. It is hoped that identification of mutations responsible for the loss of toxin production may facilitate the development of a rapid PCR-based diagnostic test.

Figure 7. Schematic representation of the aflatoxin B1 biosynthetic pathway.

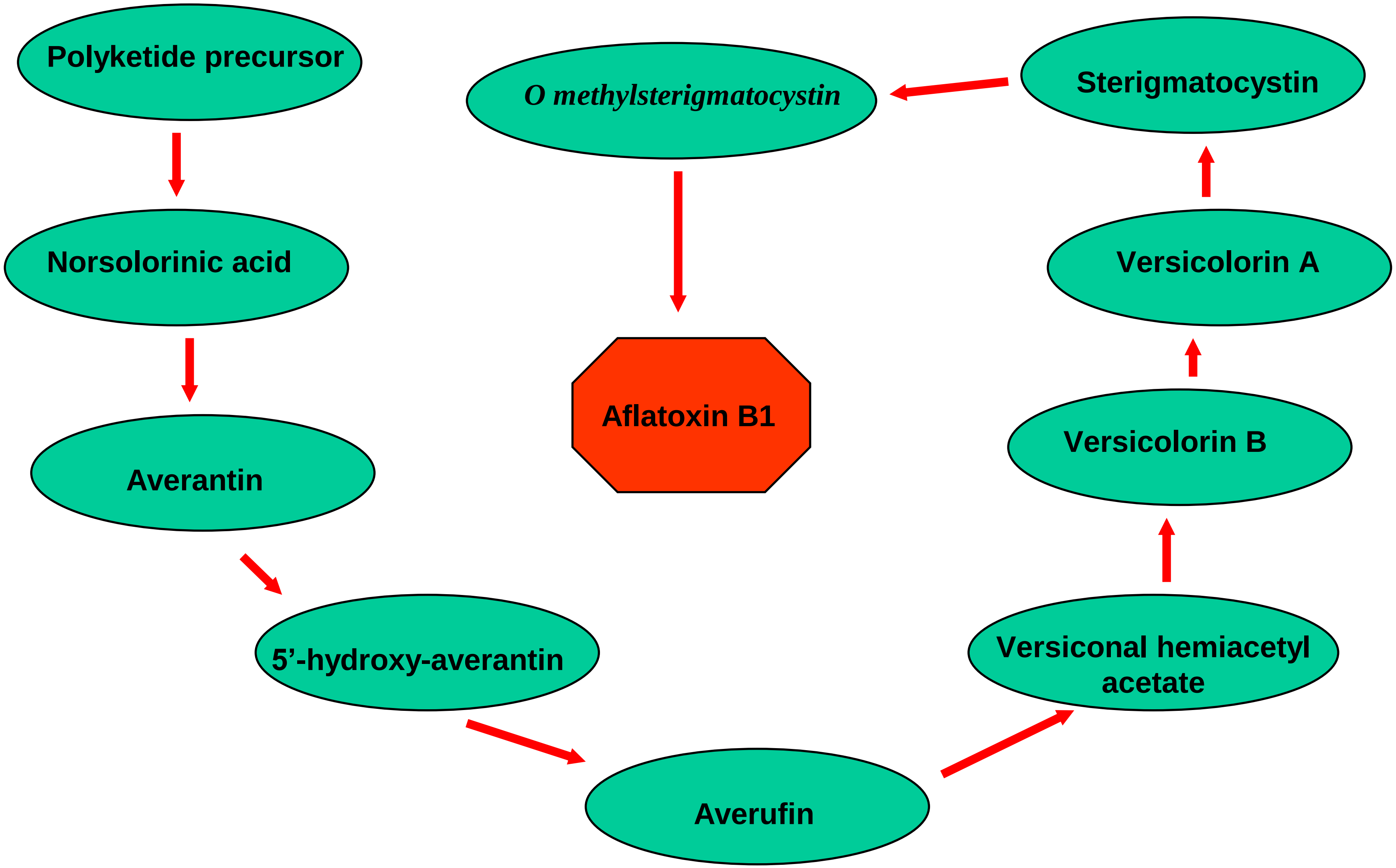
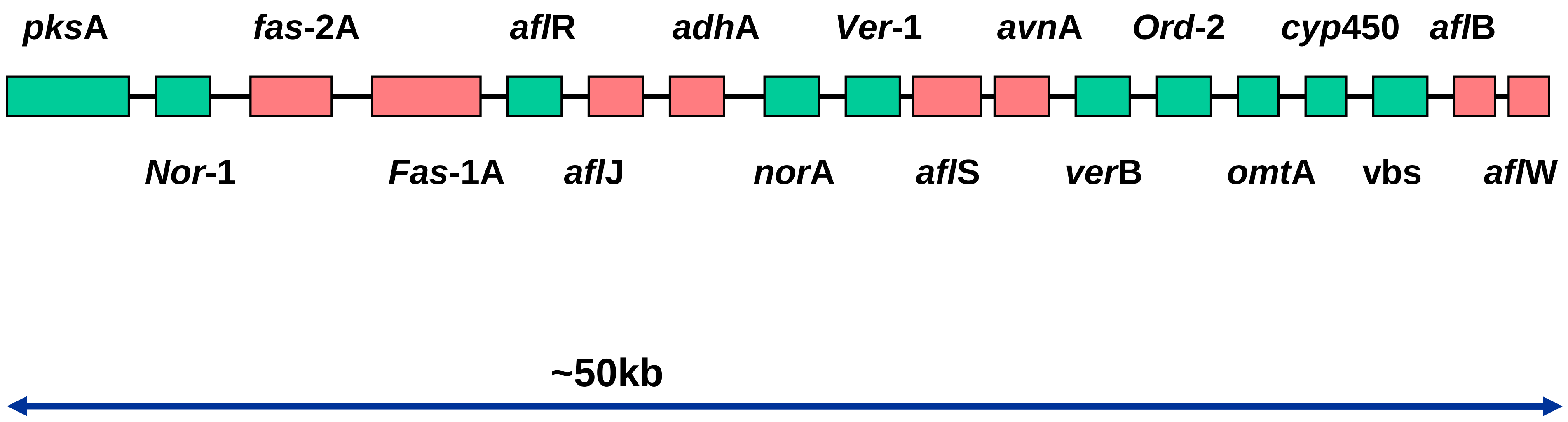


Figure 8. Schematic representation of the aflatoxin B1 biosynthetic pathway gene cluster in *A. parasiticus* (Kusumoto *et. al*., 2000). DNA sequence data has been ascertained for the genes coloured green (approximately 35% of the total gene cluster length).



Output 3: Factors contributing to contamination of food (including milk) and feed chains from pre-harvest, and post-harvest practices determined.

Activity 3.1: Factors contributing to pre-harvest contamination understood and

Activity 3.2: Factors contributing to post-harvest contamination understood (University of Reading)

The field experiments and *in situ* observations of temperature and soil moisture under Output 3 are reported by ANGRAU. The report does, however, include a brief statistical analysis of aflatoxin contamination and a brief discussion of how contamination may be related to the physical and biotic environment using data from the field experiments.

Background: review of the literature

Pre-harvest contamination

Pre-harvest infection by *A. flavus* and consequent aflatoxin contamination is strongly associated with the occurrence of drought stress during the last 3 to 6 weeks of the growing season. In a series of experiments using controlled soil temperature and soil water facilities, Cole and his co-workers (Cole et al., 1989, 1995) have shown that pre-harvest contamination requires a drought period of 30 to 50 d and a mean soil temperature in the podding zone of 29° to 31°C. Drought in the absence of high soil temperature has little effect. Shorter periods of drought (<20d), and drought early or late in the season, also result in less infection. Similarly, soil temperatures in the pod zone, not the root zone (Blankenship et al., 1985), cooler or warmer than 29° to 31°C also result in less aflatoxin contamination, even if a drought is imposed.

There have been few studies on the fungus and it's response to soil temperature and soil moisture content, and interactions with other soil mycoflora. The fungus grows between temperatures of 10° and 40°C and produces aflatoxin between 15° and 40°C. The fungus also needs RH values >85% (in the air) or moisture content of 30% (in the substrate) to thrive. Schearer et al. (1999) have shown that the optimum temperature for fungal growth (35°C) is higher than that for aflatoxin production (29°C). These reports highlight the importance of optimum soil temperature for aflatoxin production. Schearer et al. (1999) also showed that toxigenic and non-toxigenic strains have somewhat different temperature responses. This has led some workers to suggest that inoculation with competitive, but non-toxigenic strains, may provide a form of biological control, though this would not be relevant to small scale farmers in the SAT at present. The effect of soil temperature and drought on the mycoflora composition has not been studied.

Some progress has been made in understanding the mechanism of infection and contamination, though much remains to be learnt before this knowledge can be translated into genotypic resistance mechanisms. *A. flavus* and *A. parasiticus* are commonly isolated in the geocarposhere of developing groundnut fruits. Where drought does not occur and fruits are not damaged, aflatoxin contamination does not occur. This is thought to be due to the phytoalexins produced by the seed which inhibit Aspergillus growth. However, when groundnuts are subjected to drought and soil temperature increases (as leaf area of the shoot is reduced), seed moisture content is reduced, seed or kernel water activity (measured using a hygroline sensor: Dorner et al., 1989) is reduced, and phytoalexin production ceases. However, when kernel water activity becomes too low, <0.90, Aspergillus growth and toxin production is also affected. Phytoalexins are produced in both mature and immature kernels and it is kernel water activity, rather than maturity, that determines aflatoxin contamination. However, mature kernels are generally less affected than immature kernels and do possess some other resistance mechanism. Thus the window for pre-harvest infection and contamination is very small, requiring a critical combination of soil temperature and kernel moisture content or water activity.

Pre-harvest aflatoxin contamination is most common in pods or seed that have been damaged by insects or drought during their development and growth, though studies have also shown that undamaged kernels can also be contaminated by aflatoxin. Small seeds are more susceptible than large seeds and mature seeds less susceptible than immature seeds. Nonetheless, the greatest aflatoxin contamination occurs in damaged seeds, loose shelled seeds and small, immature seeds. Therefore measures that reduce seed damage in the pre-harvest phase, most notably by soil insects, and the proportion of small poorly filled seeds, will have the largest potential impact on aflatoxin contamination (Coker, 1999). Practical insect control must be an integral part of any strategy to reduce pre-harvest aflatoxin contamination. Timely harvesting to reduce the number of over mature pods and immature pods is also important here.

Post-harvest handling contamination

The harvesting and post-harvest handling and drying phases are of critical importance to the subsequent aflatoxin contamination of seeds. Considerable invasion of seed from the shell can occur during harvesting, particularly when seed moisture contents are high. Freshly harvested pods can vary in moisture content from 20 to 50%. In India, Mehan et al. (1991) found that seed infection with *A. flavus* was consistently higher in groundnuts harvested from the post-rainy or rabi season (October to February) than from the rainy or kharif season (June to October). They attribute this difference to the higher air temperatures experienced during field drying (windrowing) at the end of the rabi season. Other studies have shown that the integrity of the testa is affected by high temperature and low RH. Therefore windrowing (inverting groundnut haulms in the field after harvest) for 2 d rather than 1 d during the rabi season increased *A. flavus* seed infection. In contrast during the kharif season when mean temperatures are lower and RH higher, and drying is slower, drying for 2 or 4 d made little difference to infection.

Some studies, however, have reported higher levels of infection with slow drying. This is probably related to RH rather than the speed of drying per se. Studies have shown that drying pods at 85% RH resulted in 20 to 50% of seeds containing aflatoxin, compared with only 1% when RH was 50%. In Nigeria, when pods were artificially dried rather than field dried, no aflatoxin contamination occurred.

Post-harvest storage contamination

The most important factor influencing aflatoxin contamination during storage is the moisture content of the seed. High mycofloral counts are most closely associated with high seed moisture content (Diener and Davis, 1977) and no fungal growth or aflatoxin contamination occurs in seeds whose moisture content is <8%. The most important factors influencing fungal growth in store are RH, temperature and gaseous compounds in the atmosphere. High RH and warm temperatures promote fungal growth and aflatoxin production and stores therefore need to be dry and well ventilated. Seeds need to be surface-dry, have a moisture content <10%, and rewetting should be avoided at all costs.

Modelling aflatoxin contamination

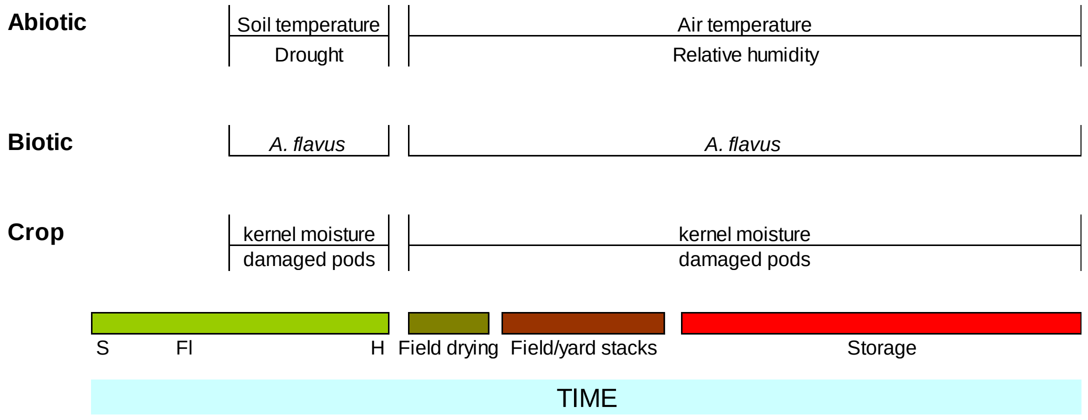
The effects of soil temperature and drought on pre-harvest contamination described above have been modelled using neural networks and regression techniques (Parmar et al., 1997). Using data from the experiments of Cole et al. (1989), they showed that four factors were needed to accurately predict aflatoxin pre-harvest contamination: soil temperature, duration of drought, crop age (time of harvest) and accumulated soil temperature above a threshold value of between 25° and 29°C. However, this model has not been validated on independent data sets and, at present, the data needed to predict aflatoxin contamination are not available outside research stations in most semi-arid countries.

The experiments reported above were carried out under controlled conditions with inoculation, and therefore high levels of infection and contamination. However, in order to model contamination under natural field conditions information will be needed on: the distribution of *A. flavus* and the toxigenicity of the strain(s), the proportion of pods/kernels that are infected, and the conditions influencing contamination (soil temperature, soil moisture, number damaged pods). Of particular importance are factors affecting the proportion of pods that are infected and contaminated. On any given plant, only a small proportion of pods will potentially become contaminated, depending on whether they are damaged (allowing infection to occur) and/or if they are at the critical kernel moisture content. Furthermore, pods that are damaged may well have extremely high levels of contamination and skewed distributions of contamination reflecting this are common. Therefore it is important to study the distributions and proportions of infected and contaminated pods/kernels.

Available quantitative data, and that collected during project experiments, will be used to model post-harvest aflatoxin contamination.

Framework for studying infection and contamination

The biotic, abiotic and crop factors affecting infection and contamination at different pre- and post-harvest stages are show below:



Experiment 1: Preliminary investigation of the relations between pod initiation, kernel moisture content and pod maturity

Introduction

Individual groundnut kernels can be infected by the fungus *Aspergillus flavus* leading to contamination with the toxin aflatoxin, particularly when drought occurs during pod-filling. Infection and contamination most commonly occur when pods are damaged. However, undamaged and healthy pods and kernels (kernels) can also be infected and contaminated. Infection of healthy pods and kernels apparently occurs when the kernel moisture content (kernel water activity) is at a critical value, and/or when pods and kernels are immature.

Now, at maturity or harvest, pod yield comes from a population of pods and kernels all initiated at different times and of different maturities and kernel moisture contents. A sub-sample from these pods for aflatoxin will give the average contamination, but will give no information about how this average is made up. In order to model/predict pre-harvest contamination, and design post-harvest experiments, we need to know the proportion and distribution of pods/kernels in any lot that are susceptible to infection and contamination. A preliminary experiment to develop a methodology for studying individual pod development and moisture contents was therefore initiated at Reading.

Aim

Describe temporal pattern pod production and individual pod growth, development and kernel moisture content under well-watered and drought conditions.

Quantify pod production and kernel moisture content, and develop a model to predict kernel moisture content.

Materials and Methods

The experiment was carried out in a polyethylene covered tunnel (polytunel) at the Plant Environment Laboratory, The University of Reading, Reading, UK between July and October 2001. The polytunnel was maintained at 32°/24°C day/night temperature with a 12 h photoperiod. This temperature regime is representative of mean temperatures in Anantapur and should give soil temperatures of about 29°C during the day – the optimum temperature for *Aspergillus* infection. Air temperature at canopy height and soil temperature at 5 cm depth were also recorded using thermocouples and data-loggers.

Genotype

Spanish cv. TMV2, which is widely grown in Anantapur District (project area). Seed of TMV2 was supplied by ICRISAT.

Treatments

Drought in the target area is usually a terminal drought, i.e. the rains end during pod-filling and there is little or no more rain until harvest. The duration of the drought should be at least 25d to ensure *Aspergillus* infection. Therefore two treatments were planned: a well-watered control and a terminal drought from podding to harvest (i.e. from 55 to >90 DAS).

Experimental design

The experiment was initially laid out in two treatment blocks, one well-watered and one droughted, both with guard rows. The well-watered treatment comprised 240 pots (15 rows of 16 pots, with inner 13 rows × 14 pots for harvesting), and the drought treatment 256 pots (16 rows of 16 pots, with inner 13 rows × 14 pots for harvesting plus one row for monitoring water content). Within each treatment block , pots were arranged in 26 sub-blocks (=harvests) of seven replicates. Harvesting was done systematically from one end of the block.

Cultural details

Uniform seeds were selected and planted in module trays filled with potting compost until emergence. The seedlings were then sown, one per 15 L pot. The rooting medium comprised sand, gravel, vermiculite and loamless peat compost mixed in proportions of 4:2:2:1 by volume, respectively. A commercial controlled-released fertiliser (0.15 kg kg^{-1} N, 0.10 kg kg^{-1} P, 0.12 kg kg^{-1} K, 0.02 kg kg^{-1} MgO plus trace elements; Osmocote Plus, Scotts UK Ltd. UK) was incorporated into the mixture at the manufacturer's recommended rate of 5 g L^{-1}. Seeds were not inoculated with rhizobia and plants were dependent on inorganic nitrogen. All pots were soaked with tap water and allowed to drain for 24 h before sowing; thereafter they were irrigated as necessary through an automatic drip irrigation system.

At flowering, soil in the pots was inoculated with a toxigenic strain of *Aspergillus flavus*. Inoculum was prepared on autoclaved sorghum seeds and then the sorghum seeds mixed with sand. One teaspoon of this sand/seed mixture was then incorporated into each pot. The number of spores was not determined.

Observations

Destructive samples were collected at 2 to 3 d intervals from podding (about 45 DAS) to maturity (about 95 DAS). In total 24 harvests were made.

At each harvest plants were carefully removed from the growing medium and the roots washed, removed and dried. The shoot (including attached pegs and pods) was then separated into cotyledonary and nodal branches. For each branch, and the mainstem, the nodal position of each peg and pod was noted, and the respective maturity score, pod fresh and dry weight, and kernel fresh and dry weight of each individual pod determined. Pod maturity scores were based on Williams and Drexler (1951).

From the primary data total plant dry weight, pod and peg production rate, and kernel moisture contents (fresh weight basis) were determined.

Results and Discussion

Plant to plant variability in morphology was very high in this experiment and some plants had abnormal leaflets. TMV2 is a farmers cv. and it is known to be an extremely variable cv. Also seed quality was not high and emergence poor, possibly because this seed was from a crop grown and harvested in the hot season. Therefore it was decided to keep the most uniform plants and to reduce the experiment to a well-watered treatment only.

TMV2 started flowering 26 DAE and the first pegs and pods were produced at 34 and 40 DAE, respectively. Peg and pod production increased steadily until about 70 DAE (Figure 9). Pod number continued to increase until final harvest at 96 DAE. At 96 DAE there were about 30 pod per plant on average. Flowers and pods were therefore being initiated over a long period of time – about 60 d – under the favourable conditions used for this experiment. This gives rise to considerable variation in the age (maturity: Figure 10), size and moisture content (Figure 11) of the individual pods that make up the 'population' of pods on a plant.

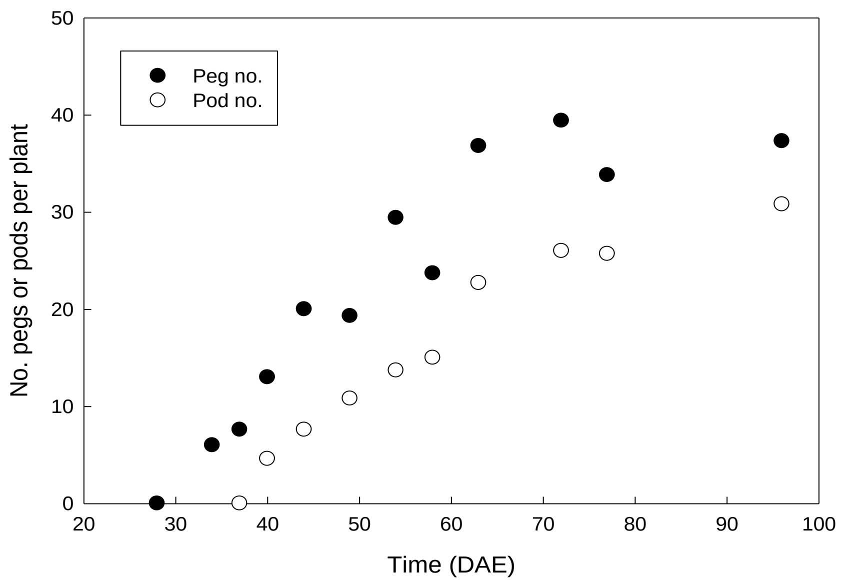


Figure 9. Production of pegs and pods over time

Kernel moisture content and pod maturity score were noted for each individual pod on every plant at each harvest. The distribution of pod maturity classes at two times – 68 and 96 DAE, is shown in Figure 10. At 68 DAE the largest and most advanced pods were at stage 4 (mesocarp yellow and becoming rigid; pod at full size with distinct reticulations). At 96 DAE pod maturity ranged from 1 to 6.5, with something approaching a normal distribution centered on Stage 4.

The distribution of kernels of different moisture contents is shown in Figure 11. Kernel moisture contents were distributed normally at 68 and 79 DAE, but not at 96 DAE. The range in kernel moisture content was also similar at each harvest, with low and high moisture content kernels being present at each harvest. As kernels developed, moisture content declined and at 96 DAE the most advanced kernels were at 21 to 30% moisture content. The bulk of the kernels, however, were at 31 to 40% moisture content, just above the critical level.

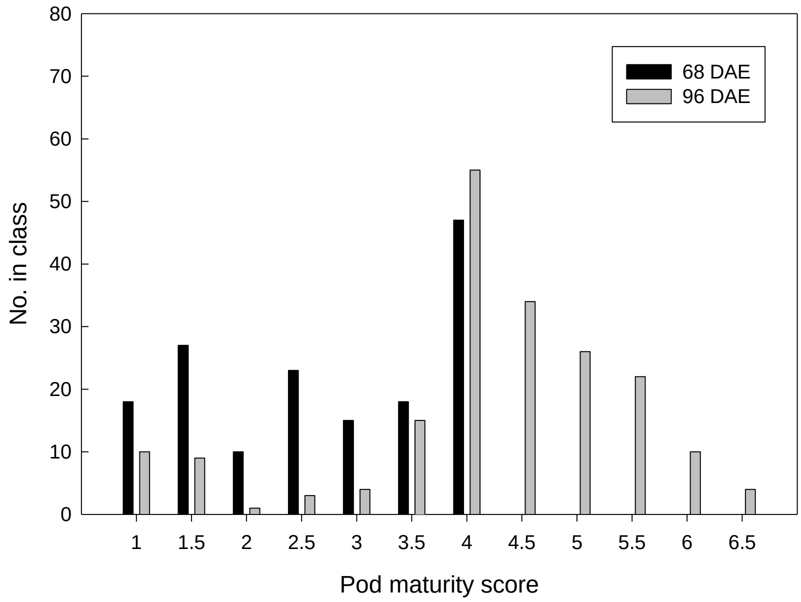


Figure 10. Frequency of pods in different pod maturity scores at 68 and 96 DAE

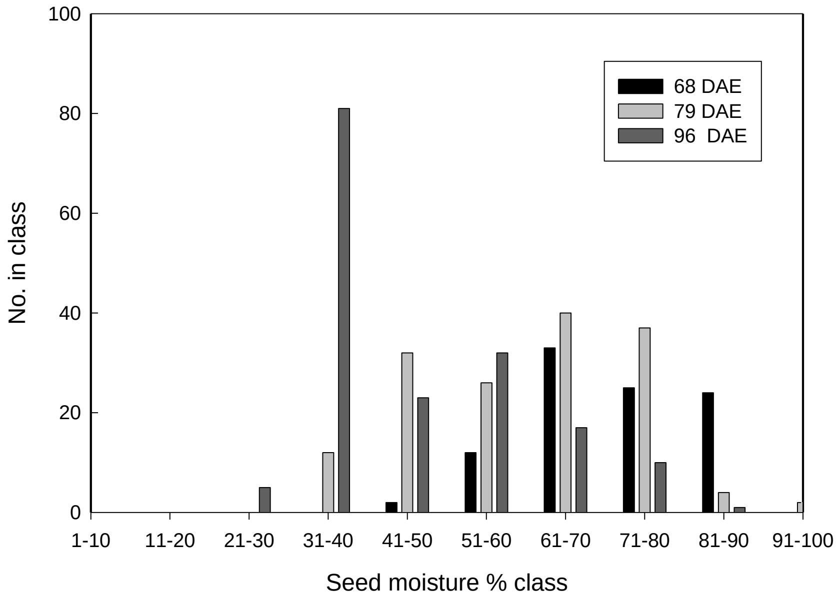


Figure 11. Frequency kernels in different kernel moisture content classes at 68, 79 and 96 DAE**.**

The change in kernel moisture content of individual kernels over time is sown in Figure 12. Flowers, pegs and pods were produced over a long period of time (about 60 d) and therefore at any given time each plant had pods of different ages (maturity) and size. Average kernel moisture content declined from >90% when pods first formed to about 50% at 96 DAE. In pods from pegs that appeared before 40 DAE, kernels were at 30-40% moisture by 96 DAE, compared with 50-60% for pegs formed between 60 and 75 DAE. Intermediate times of peg formation have not been shown for clarity, but kernel moisture followed a similar trend. Apparently, under the well-watered and uniform growing conditions, the change in kernel moisture content is predictable through time, and is similar for all kernels. Therefore, if the time of peg and pod formation can be predicted, then the kernel moisture content can also be predicted. The effect of drought on pod production and the change in kernel moisture content under field conditions needs to be determined at Anantapur to confirm that a simple model can work.

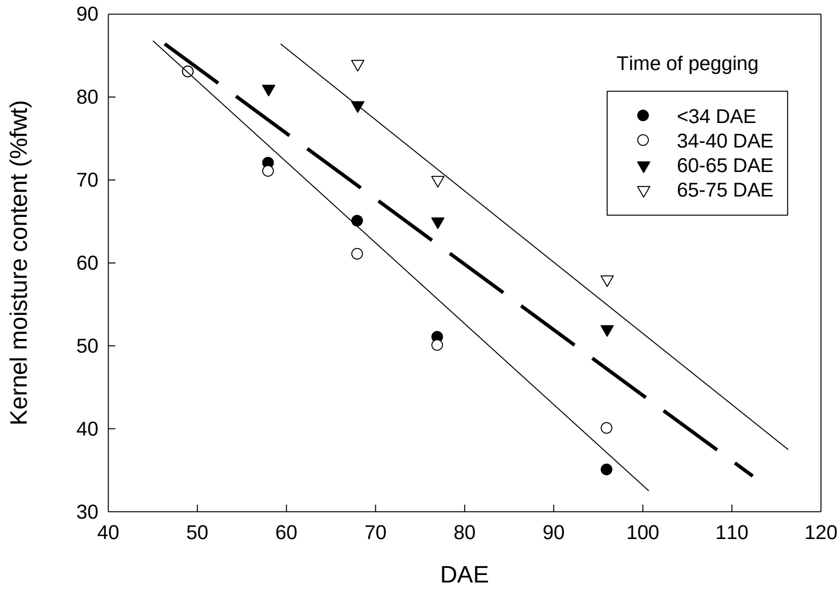


Figure 12. Change in kernel moisture content of individual kernels from pegs appearing at different times (solid line) and the mean kernel moisture content per plant (hashed line).

Experiment 2: Effect of temperature, relative humidity and kernel moisture content on aflatoxin contamination in pods and kernels

Introduction
There have been few studies on post-harvest infection and contamination in groundnut, despite the clear importance of this stage in the chain from pre-harvest to consumption. High mycofloral counts are most commonly associated with high kernel moisture contents, between 14 and 30%. However, it is not moisture content per se but the equilibrium RH surrounding the seed that matters. No aflatoxin contamination occurs at 30°C when RH is about 80 to 85% or greater. This limiting RH is in equlibrium with 9 to 11.5 % kernel moisture content (Diener et al., 19xx). No multi-factorial studies with temperature, RH and kernel moisture content appear to have been carried out and no quantitative models of aflatoxin in storage have been published.

Aim
Quantify and model effects of temperature, relative humidity and kernel moisture content during storage on aflatoxin contamination

Materials and Methods
Two separate experiments have been conducted at Reading, one with kernels and one with pods. Experiments were carried out in Saxcil growth cabinets which very accurately control temperature and relative humidity (RH).

Approximately 80 kg of pods of TMV2 were harvested at the end of November 2001 from ANGRAU Research Station at Anantapur and shipped to UK in January 2002. In UK, pods and kernels were kept in sealed bags in a cold room at 4°C until experiments were set up. Kernels were tested for infection with *A. flavus* and aflatoxin contamination before the storage experiments started.

Experiment 1: Kernels
This was a multi-factorial experiment comprising temperature × RH × kernel moisture content treatments × harvest date. There were three storage temperatures (24, 30, 36°C), five RH treatments (13, 25, 43, 57 & 75% RH), two kernel moisture contents (20 & 30% moisture) and six sampling dates (7, 21, 42, 70, 105 & 150 d after inoculation). Each treatment was replicated twice.

The treatments were imposed by using three growth cabinets for the temperature regimes, within each of which were 'mini-chambers' containing 0.5 L saturated salt solutions to control RH. The mini-chambers were made from 2.5 L plastic pots with a perforated grid to hold the kernels above the salt solution, sealed with a plastic bag. Each mini-chamber held six (i.e. harvest dates) 100g mesh bags of kernels. The saturated salt solutions used were: LiCl, (13% RH); $KC_2H_3O_2$ (25%); K_2CO_3 (43%); NaBr (57%); and NaCl (75%). These solutions were chosen because they are stable over a wide range of temperatures (Hong *et al*. 2002). Within each growth cabinet there were 20 mini-chambers.

At each sampling date, one mesh bag from each mini-chamber was removed. The whole sample was first weighed and then a 20g sub-sample removed. This 20g sub-sample was used to determine kernel moisture content and aflatoxin contamination (in India). The remainder of the sample was used to determine *Aspergillus* infection following the ICRISAT method. In brief, 50 kernels were surface sterilized (using 1% hypochlorite) for 30 secs, and then washed three times in distilled water. Kernels were then placed in petri-dishes with filter paper (keeping kernels apart), kept moist (and at as high an RH as possible) and placed in a growth cabinet at 25°C and >90% RH. After 5 to 6d the percentage of infection was scored by counting the number of infected kernels.

At each harvest all the remaining mesh bags were also removed and weighed in order to track changes on moisture content.

Experiment 2: Pods

This was also a multi-factorial experiment with temperature, RH, kernel moisture content and harvest date treatments. There were two temperatures (24° & 30°C), four RH treatments (30, 50, 70 & 90% RH), three initial pod (kernel) moisture contents (10, 18 and 30%) and six harvest dates (7, 21, 42, 70, 105 & 150 d after inoculation). Each treatment was replicated twice.

In contrast to Experiment 1, combinations of temperature × RH were imposed using whole growth cabinets rather than mini-chambers. Approximately 100g of pods for each treatment were placed in mesh bags as for Experiment 1 and bags kept in a specially constructed box made from dust/pollen filters to contain spore contamination. Air temperature and RH within each box was controlled by sensors within the box and air flow was adequate to ensure that RH was accurately controlled. Each cabinet contained two such boxes, each acting as a replicate of kernel moisture × harvest date treatments.

Pods were harvested, shelled and then processed in the same way as kernels in Experiment 1.

Inoculation

In both experiments pods and kernels were inoculated with a toxigenic strain of *A. flavus* following a protocol used at ICRISAT. Prior to inoculation kernels were abraded in a motorized drum for 5 mins to damage the testa. Likewise pods were scarified by hand on coarse sandpaper. Spore suspensions (10^7 spores per ml) were prepared on the day of inoculation from cultures that were sporulating strongly in petri-dishes. Kernels or pods were then turned in a motorized drum for 5 mins with the spore suspension using 1 L per kg. After inoculation kernels and pods were surface dried and then approximately 100g of kernels or pods was placed into a labeled mesh bag and weighed.

Kernel moisture treatments

Kernels were at an initial moisture content of about 6% upon arrival in the UK. In order to raise moisture contents, kernels and pods were either placed between damp tissue paper for about 7d, and then sealed in plastic bags for 2d or more, or spread out in a cold room at high RH for 7d and then sealed in bags. Throughout kernels were sampled for moisture content until the target moisture content had been reached.

Results and Discussion

Initial infection with *A. flavus* and contamination with aflatoxin

Two random samples of kernels were tested for infection with *A. flavus* before setting up the storage experiments (Table 19). Less than 1% of kernels were infected with *A. flavus* and about 3% with *A. niger*. Natural infection was therefore low, confirming the need to artificially inoculate kernels and seeds used in the experiments. Five sub-samples were also analysed for initial aflatoxin contamination. The average contamination was 35 (SE 11.9) $\mu g\ kg^{-1}$.

Experiment 1: kernels

There were consistent significant effects of initial kernel moisture content (%MC), RH and temperature × %MC on kernel moisture content and aflatoxin contamination. Kernel moisture content × RH and %MC × RH × temperature interactions were not significant.

Infection with *A. flavus*

All kernels after 7 and 21 d in storage were highly infected with *A. flavus*, averaging >97% infection. There were no significant effects of RH or temperature on % infection at either date, or interaction between factors. However, differences between wet (100%) and dry (97%) kernels were significant ($P<0.001$), albeit small. The technique used for inoculating kernels was therefore successful. Given the near complete infection subsequent samples were not tested for *A. flavus* again.

Kernel moisture content

Initial kernel moisture contents immediately after inoculation were 18.7% (SE 0.23) and 26.2% (SE 0.35) in the dry and wet kernel treatments, respectively. Kernel moisture contents initially increased, and then from 7d declined rapidly (Figure 13). At 21 d there were still differences between wet and dry kernels, but by 70d these had disappeared and moisture contents were similar at about 5 to 8%.

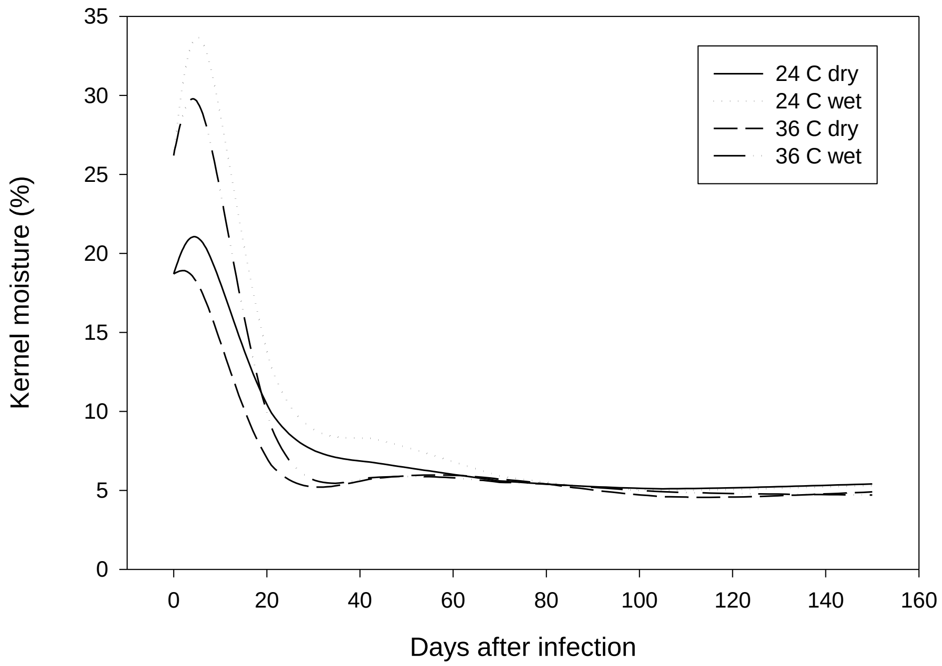


Figure 13. Change on kernel moisture content of dry and wet kernel treatments during storage

RH had a significant effect (P<0.001) on %MC as expected (Table 20). Within 21 d, %MC had fallen from an average of 22% at the start to between 5% in the lowest RH treatment to 15% In the highest RH treatment. By 150 d, values for %MC were 3.1 and 7.9% in the lowest and highest RH treatments, respectively. By 70 d kernels were apparently close to equilibrium and %MC did not change appreciably after this time.

Aflatoxin contamination

Contamination levels were generally higher at 24° and 30°C than at 36°C, particularly in the high %MC kernels. There was a significant interaction (P<0.001) between temperature and %MC at 7d (Table 21). At 30° and 36°C high %MC kernels had much lower levels of contamination. By 42 d, however, this interaction had disappeared and contamination levels were similar in dry and wet kernels. This interaction is not due to kernel moisture per se, as %MC was highest at 7d in the 24°C dry kernel treatment (Figure 13).

Seven days after inoculation, aflatoxin contamination was 4542 and 1747 μg kg^{-1} in the dry and wet kernel moisture treatments, respectively (Table 22). By 42 d, wet and dry kernels had similar values of about 4000 μg kg^{-1}. The relation between contamination and moisture content in the wet and dry treatments is shown in Figure 14. This figure suggests three things: at %MC >20 to 25% there was little increase in contamination; between about 20 and 8% moisture content in both wet and dry kernels aflatoxin contamination increased at a similar rate, about 2000 μg kg^{-1}; and when %MC was <10%, there was no further increase in contamination. These data therefore support published data that suggests that dry kernels will not become contaminated or further contaminated. Contamination was lower at high as opposed to low RH, even though at high RH kernels took longer to dry and therefore were apparently in the susceptible %MC range for longer. However at high external RH the internal RH or kernel water availability (K_{AW}) would have been higher, and this would have reduced contamination. Water activity was not measured and so this cannot be confirmed.

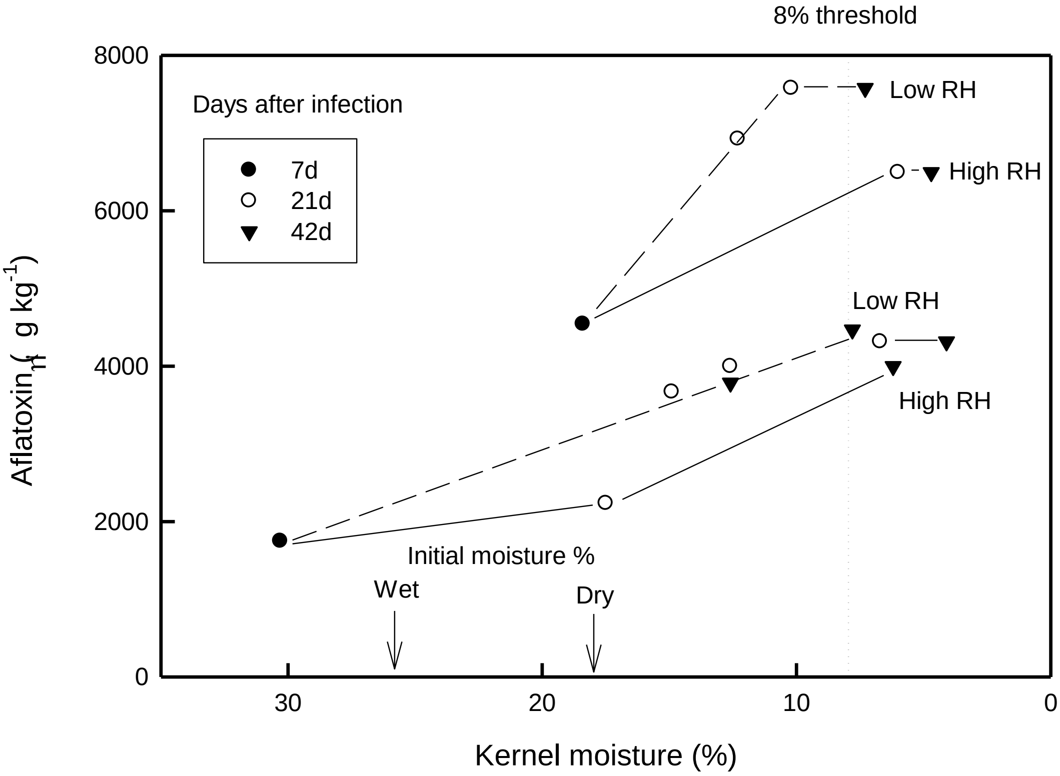


Figure 14. Relation between aflatoxin contamination and kernel moisture content (% dry weight) in wet and dry treatments stored for 7, 21 or 42 d at low and high RH.

These data show that the strain used was indeed very toxigenic and very high levels of aflatoxin were produced within a comparatively short period of time, i.e. <7 d. For this particular strain, the optimum temperature for aflatoxin production was between 24° and 30°C, and therefore similar to the optimum of 29°C reported in other studies (Schearer et al., 1999). The interaction between temperature and wet or dry kernels is probably due to differences in equilibrium RH within kernels (Diener et al., 19xx). Although wet kernels at 24° and 36°C had high %MC, the equlibrium RH would vary with temperature. Measurements of equlibrium RH or kernel water activity (K_{AW}) are needed to explain this interaction.

In conclusion, this experiment showed: that the mini-chamber technique with saturated salt solutions can be used to impose different storage RH; that the strain and inoculation techniques worked well; that following inoculation and in favourable conditions very high levels of contamination can occur within days; that the optimum temperature for contamination is about 30°C; and that the lower threshold for contamination is about 8 to 10%MC.

Experiment 2: Pods

The experiment with pods used eight combinations of temperature and RH combined with three kernel moisture content treatments. The initial kernel moisture contents were 22.7, 15.5 and 8.4% in the wet, intermediate and dry treatments, respectively.

At all sampling dates there were significant effects of RH and initial pod moisture content on infection with *A. flavus*, as well as RH × %MC interactions at 42 and 70 d. However, RH only affected kernel moisture content; temperature had little or no effect. Although pods varied in %MC from 8 to 23% at the start of the experiment, within 7d all initial %MC treatments had kernels at 8% (Table 22). Thereafter %MC did not change much and kernels had therefore apparently reached equilibrium very quickly. The percentage of kernels infected was significantly affected by moisture content, ranging from 36% in kernels initially at 8% to 70% in kernels initially at 23% (Table 22). After 7 d infection did not increase much. Kernel water activity (K_{AW}) at 150 d was also similar, 0.64, in all three %MC treatments.

Kernel moisture contents were affected by RH, increasing as RH changed from 30 to 90% (Table 23). Again, there was little change in %MC after 7 d, kernels at 30 and 90%RH remaining at 4-5 and 12-14% after 7 and 105 d, respectively.

Given that %MC very quickly fell below the threshold value of 8% (Figure 14), only data from the 7 d sample will be considered further. There was a strong relation (R^2=0.77, n=12) between aflatoxin contamination and infection with *A. flavus*, as expected (Figure 15). Infection was higher in wet than dry kernels and in high as opposed to low RH. At high RH treatments %MC was >8%, and wet kernels probably dried slower than dry kernels given that other conditions were similar. To examine the effect of %MC, which is also an important factor, the duration kernels in each treatment spent at %MC >8% was calculated by extrapolation from initial and 7d moisture contents. This relation (Figure 16) shows very clearly that aflatoxin contamination is proportional to the duration of time at >8%MC (R^2=0.87, n=10) , with a threshold or minimum duration of 3 d. Apparently a minimum of 3 d above 8% MC is required for contamination.

These data confirm that contamination is related to both infection and moisture content. A linear, additive regression model with infection and duration >8% MC explained 93.6% of the variation in aflatoxin contamination (P<0.001, n=12). This model was better than a model with an interaction term for infection × duration.

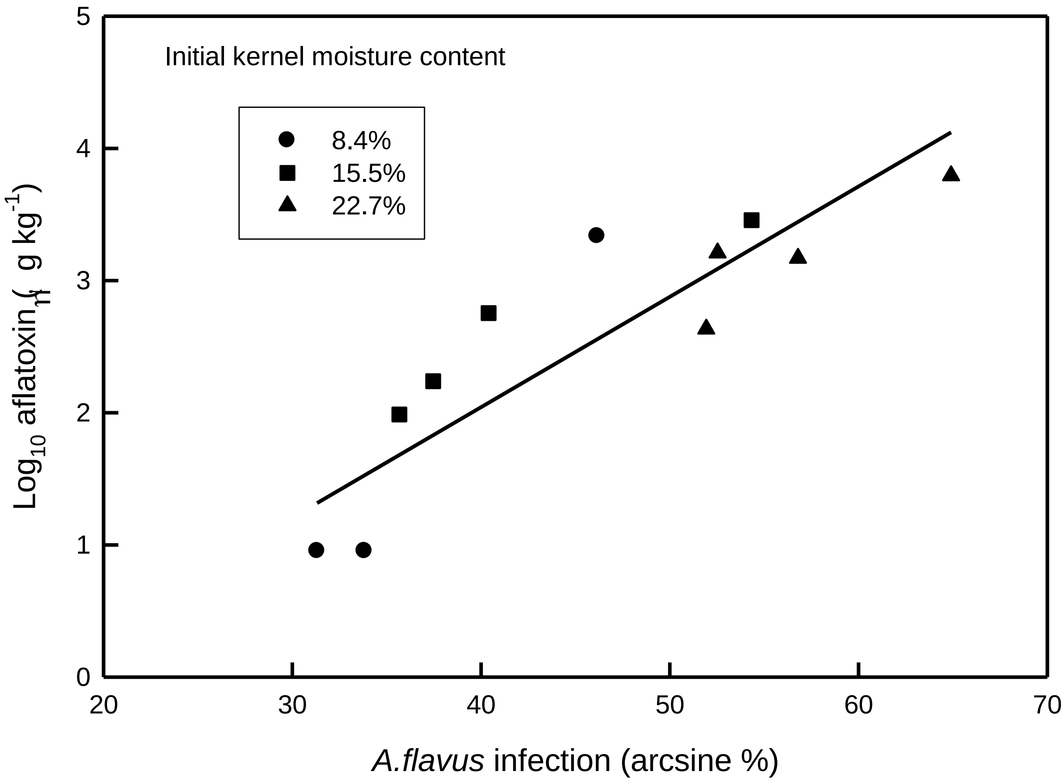


Figure 15. Relation between aflatoxin contamination and *A. flavus* infection in pods at three moisture contents stored for 7 d at RH of 30 to 90%.

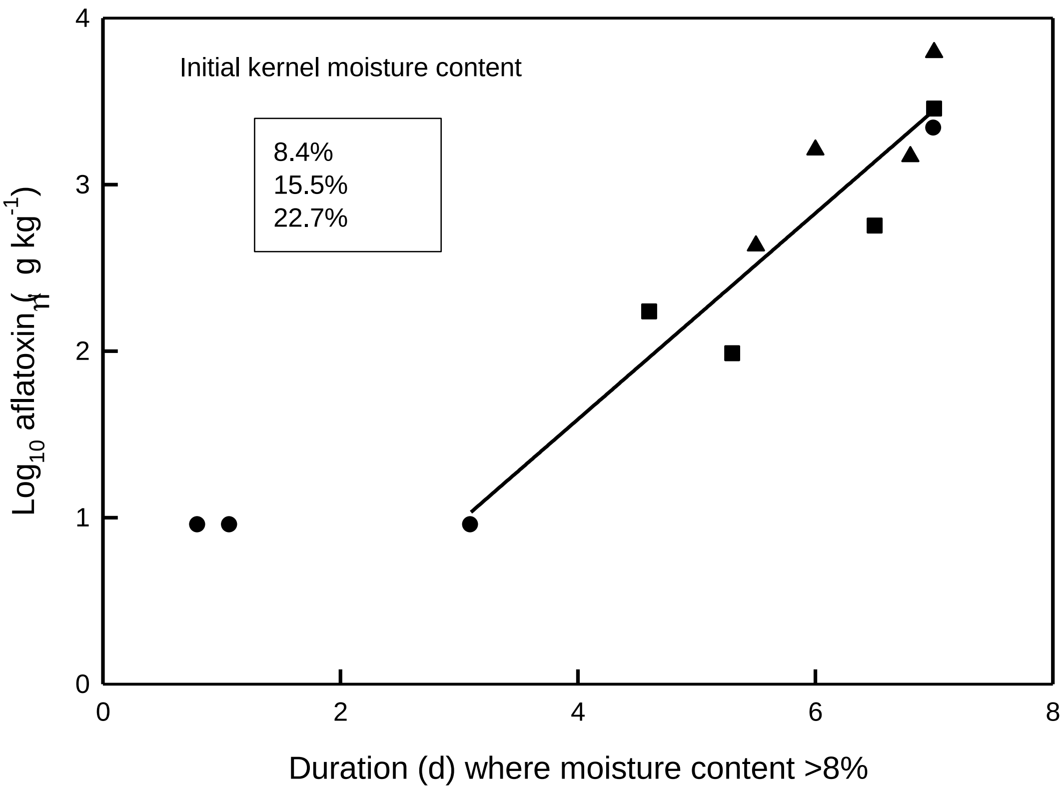


Figure 16. Relation between aflatoxin contamination and duration of the period kernels moisture content was >8%.

In conclusion, Experiment 2 also showed that storage experiments with pods, the usual storage method, can be successfully carried out in controlled conditions. The advantage of using growth cabinets over saturated salt solutions is that RH can be controlled and maintained more accurately, and much larger quantities of pods can be stored. Future experiments with pods should (a) concentrate on sampling more intensively over a much shorter period of time (i.e. 0 to 30 d) and (b) vary the initial inoculum load by varying the number of infected pods in any lot rather than inoculating all the pods.

Identification of Links between Pre-Harvest Factors in Farmer's Fields and Aflatoxin Contamination in Anantapur District

Data from the 25 farmer's fields in Linganapalli and Pampanur in Anantapur District from the work undertaken by ANGRAU in the kharif season of 2001 were combined in order to identify any associations between pre- harvest factors and aflatoxin contamination at the time of harvest. Analyses of the full dataset will be undertaken once all the primary data has been processed. We report the preliminary analyses here.

Data currently available for the preliminary analysis are summarized in Table 24. Observations were available for 15 farmers in Linganapalli and 10 farmers in Pampanur. For each farmer, the mean of five sample areas from each of two management practices (farmer practice and improved) were used. The nature of the variability among observations for each parameter was examined in the first stage of the analysis in order to check for homogeneity of the parameter variance.

The observations for aflatoxin contamination were not normally distributed (Figure 17). Instead, the bulk of the observation were zero or near-zero, with a few observations were > 100 μg kg $^{-1}$. Advice on the appropriate transformation for the analyses of these data was provided by the Statistical Services Centre, The University of Reading. As a result the distribution of the error term of models fitted in any statistical analysis will be examined for normality. Where the residuals of the statistical model are not normal, a logarithm transformation will be used, with all observations in the range 0-5 μg kg^{-1} set to 5μg kg^{-1}.

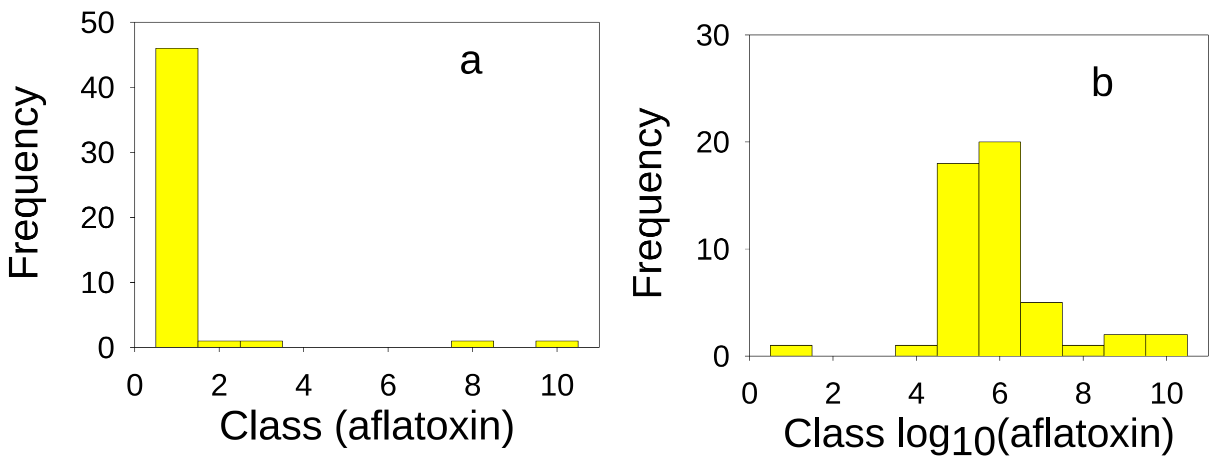


Figure 17. The distribution of observations of aflatoxin contamination (a) and the logarithm of aflatoxin contamination (b). The classes are equally spaced between 0 and 796 (a) and 0 and 10 (b).

Pod yield was greater in the improved production practice compared with farmer's practice. However, pod yield was not related to aflatoxin contamination of pods at the time of harvest (Figure 18). Contamination of pods was greater in Linganapalli compared with Pampanor (Table 25). The fraction of small pods was also greatest in Linganapalli. Hotter soil temperatures and a longer dry spell during pod-filling were found at Linganapalli compared with Pampanur.

To date the distribution of *A. flavus* colonies in the soil is not available and a complete analysis can not yet be carried out. When these data are available the full dataset will be processed using a general linear regression of both the variables and categorical data. However, the data do suggest that higher contamination is indeed associated with longer drought, high soil temperature and a larger proportion of small pods. Other studies at ANGRAU have shown that most aflatoxin is found in the smaller pod fraction, which includes both small pods and unfilled pods.

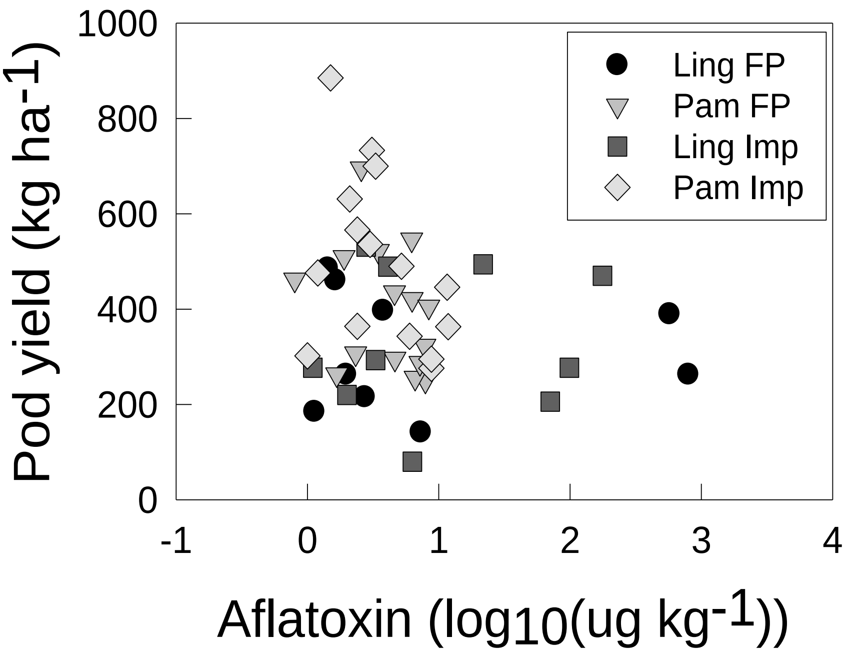


Figure 18. Relation between pod yield and aflatoxin contamination in farmer and improved production practices at Linganapalli and Pampanur

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Output 4: Informed judgements made of the viability of potential contamination reducing management systems and/or other practical approaches based on the socio-economic and technical framework of current practice developed in outputs 1, 2 & 3

Activity 4.1
Identification of management practices to reduce aflatoxin contamination at pre-harvest, harvest and post-harvest stages

Literature search for aflatoxin management was completed. All references from 1968 to 2001 were included and CD-ROM was produced and distributed to partners and users. Few copies of the CD's were sent to DFID. This data is also available on our newly developed aflatoxin web page (www.aflatoxin.info). Information on aflatoxin contamination, management practices, sources of resistance, effect of aflatoxin on human and animal healths and many other useful information is included on the web page.

Activity 4.2
Workshop to develop strategy for Phase II

This activity has been combined with Activity 5.1 which was included during the extension period of the project (July to December 2002). Reported under Activity 5.1

Output 5: Build coalition of partners (stakeholders): to promote public awareness of aflatoxin; to develop and advocate strategies and policies that enable the production of aflatoxin-free groundnut; and to develop and promote aflatoxin-free production and processing practices among farmers and within the animal and human food chain

Activity 5.1
Identify potential partners concerned with commodity production, pricing policy, animal health, milk quality, human health among government, NGOs, research institutions, consumer groups and dissemination organisations

Potential partners were identified for stakeholders meeting during November 2002. Participants from various fields including policy makers, Government officials, Medical Doctors, Veterinary Doctors, Extension Service, Public Awareness, Traders, Millers, Oil Processors, Farmers and project partners were involved in the meeting.

Strategy for Phase 2 produced and PMF written and submitted to DFID for funding

Activity 5.2
Hold a Workplanning meeting to: conduct a stakeholder analysis of aflatoxin problem with partners; identify 'themes' and develop a project framework; and form groups to develop and implement agreed workplan for each 'theme'.

A meeting from November 27-29 was organized at ICRISAT-Patancheru (India) to identify the coalition of partners. Summary proceedings of the meeting were sent to DFID. For more details, please refer the Summary Proceedings document.

Summary
Aflatoxin contamination of groundnut is a major hazard to the health of human beings and animals, and seriously affects the quality of groundnut and groundnut by-products. ICRISAT, in collaboration with ANGRAU, The University of Reading and STAAD have benefited from DFID funds to initiate work on groundnut aflatoxin. This has led to a better understanding of the importance of aflatoxin contamination in groundnut and groundnut-based food/feed chain. Management practices that reduce groundnut aflatoxin contamination have also been tested in India. However, the dissemination of information to farmers, the use of appropriate technology or extension approach is not dependent only on research organizations and

collaborative organizations. There are many more stakeholders involved in the process who can contribute to the solutions effectively by working in partnership. Therefore there is need to bring many partners together to be able to combat aflatoxin contamination effectively.

Many different stakeholders, including farmers, oil manufacturers, traders, scientists, social scientists, medical scientists, veterinary scientists as well as economists, participated in the workshop. Given the diverse nature of the participants and their awareness and knowledge of aflatoxin, it was necessary: first, to give them some understanding of the present state of knowledge about aflatoxin; second, through working together, increase all participants understanding of the aflatoxin problem from many different perspectives; and third, emphasize the necessity of working in partnerships to resolve this complex issue and identify better solutions collectively.

A three-day workshop was organized at ICRISAT to achieve this objective. In the first two days, participants discussed how:

- To form a consortium of partners to combat aflatoxin for the benefit of poor farmers and other stakeholders
- To identify means to promote awareness of aflatoxin among farmers, processors and consumers
- To identify technologies that reduce aflatoxin contamination and means to transfer these to farmers and processors
- To promote the transfer of technology among stakeholders.

The third day was reserved for project collaborators to meet and formulate the objectives for a second phase of the project.

On the first day of the workshops there were expert presentations by the participants covering broader aspects of the aflatoxin contamination problem such as importance of aflatoxin in food and feed, socio-economic background and farmers' constraints in adopting aflatoxin reducing practices. The results from previous DFID supported projects were summarized. A range of potential technological solutions to reduce pre- and post-harvest contamination were presented and discussed. On the second day participants worked in smaller groups to produce a 'problem tree' of the causes of aflatoxin and constraints influencing the adoption of aflatoxin reducing technologies. The consensus from these problem trees was that increasing awareness of aflatoxin is the number one priority. The meeting ended with an open discussion of the strategy to be adopted in order to promote awareness, and how a coalition of partners could be formed to promote awareness of the deleterious effects of aflatoxin and technologies to reduce aflatoxin.

Activity 5.3
Produce information (in appropriate forms) and start to promote awareness of aflatoxin among stakeholders

An aflatoxin website (**www.aflatoxin.info**) was launched on 27 November at ICRISAT during the stakeholders meeting.

Many leaflets were developed and circulated to farmers, NGOs and many other stakeholders. A full set of these publications were sent to DFID.

Output 6: Experimentation and validation on-farm and on-station of management practices to reduce contamination (identified in Output 4) in partnership with farmers and extension agencies, and the adoption of these practices into a technical and socio-economic framework

Activity 6.1
Stakeholder analysis and meetings with farmers, extension agencies and processors to: understand local incentive and marketing structures, discuss potential management options and agree participatory validation process appropriate for different genders and livelihoods

Further surveys were conducted as a sequel to the participatory rural appraisals (PRAs) carried out earlier in Anantapur district under phase I study of the project. The earlier study helped identify/ assess the socio-economic and institutional factors that patterned the farmers' management practices that are likely to lead to aflatoxin contamination in the groundnut based livelihood systems, and helped in understanding why farmers do what they do.

It was realized that technological interventions that aim to reduce aflatoxin contamination in groundnut production should be conscious of the fact that the institutional factors like marketing, access to inputs etc. do impinge upon farmers will to adopt new practices (see STAAD reports for details). Within this scenario, it was further realized that farmers from different socio–economic backgrounds might have differential opportunities and constraints for adopting technologies. It had therefore become important to have an understanding of farmers' preparedness in technology adoption and know at the outset, which of technologies might work and which may not before the next step is taken.

Against this background, another round of PRAs were conducted during September – November 02, in two villages of Anantapur district, which were covered by the earlier study to get a preliminary idea about the technologies that farmers would be prepared to test and validate in their fields, the ones that may require additional resources or modifications and the technologies that are likely to be resisted. This pre-introductory evaluation of technologies by the farmers would also help address the constraints faced by them, through a range of technological options that could provide varied opportunities to different categories of farmers in the choice and selection of the technologies that are more practical to adopt.

Objective of the study
The main aim of the study was to assess farmers' perceptions and potential constraints for adopting selected aflatoxin reducing technologies for participatory testing in the coming seasons by men and women farmers of the various socio-economic categories of Ananthapur region of Andhra Pradesh in South India.

Methodology

The study was carried out in an iterative manner. Discussions were held at project team level initially to short list technologies that are expected to have some potential for conducting on farm research, subsequent validation and adoption by farmers. The project team put together a set of technologies that are most likely to produce aflatoxin free groundnuts and fodder.

Based on the findings in Phase I research of the project, careful consideration was given to the potential constraints of the farmers while short-listing of technologies to be proposed for on farm testing and adoption. The final list of technologies short-listed by the project team and confirmed by the ANGRAU research team at Anantapur district for discussions with farmers of the region are listed in the Table below.

Short List of Proposed Technologies for Participatory validation with farmers
Seed treatment (Trichoderma)
Bacteria to improve manure quality
Application of FYM
Fungicides
Application of Gypsum
Mulching (Crop residues)
Compost manures
Drying techniques (wind rowing)
Sorting (of damaged, small or immature pods)
Early pod stripping / threshing - without stacking and by machines
Removal of immature/left over pods from haulms
Improved storage methods
Aflatoxin resistant varieties

Farmers participation

The short-listed technologies were described to various farmer groups of Lingannapalli and Pampanur villages of Anantapur district for a pre-introductory assessment of aflatoxin reducing technologies in the groundnut based livelihood systems of the region and to assess their potential to start the process of technical change.

Participatory rural appraisals (PRAs) were conducted with different farmer groups of Lingannapalli and Pampanur villages where PRAs were carried out earlier under Phase I of the project. During the present study, PRAs were mainly based on focused group discussions, matrix scoring and ranking exercises carried out with the participation of farmers groups selected from the rich, poor and women categories.

Farmer Group Selection

Farmers constituting the groups were mainly selected from the social maps of the villages drawn during Phase I study of the project based on their wealth criteria. Importance was given to selecting the same set of farmers who had participated with the ICRISAT / ANGRAU teams for on farm research activities of the project during phase I of the project.

The rich group essentially consisted of farmers of the middle and large farm (5 to 10 acres and above 10 acres respectively) category, while the poor farmer groups consisted of the small and marginal farmers (2 to 5 acres and less than 2 acres respectively). Women farmer groups were however, selected based on the social maps and their participation in self-help group activities of their respective villages and those from families of farmers who participated in the ICRISAT/ ANGRAU trials. Hence, the group consisted of women farmers of mixed wealth categories and those who actively work on the farm.

Process of Participatory Assessment

Focused group discussions were held initially with the selected groups of farmers to explain the new technologies and the various implications of adopting them. Subsequently, scoring and ranking exercises were carried out with each group of farmers separately. For this purpose, farmers listed out the various criteria that they perceived as important for adoption of given technologies that could help reduce aflatoxin. The criteria are listed and described in the Table below.

Description of Farmers Criteria/ Factors for Adoption of Technology

Criteria/ Factors	Description
Cost	Cost of inputs required for the activity under each of the proposed technologies
Labor cost	Additional labor cost input required for undertaking the activities for each of the proposed technologies
Labor availability	Possibility of availability of additional labor where required
Work load / drudgery	Process involving greater attention and/ or intensity for the activities
Yield	Increase in yields (pod and fodder) compared to current yields
Crop quality	Better crop characteristics that include field and marketable features.
Resistance	Resistance to pest and disease attack and drought conditions
Health	Reduced ill-effects on health of humans and animals
Market	Acceptability of produce in the market, better pricing and access to the markets.
Availability of machinery	Most of the machinery is hired and availability at the right time is subject to demands elsewhere. Additional or timely requirement of machine time is a constraint.
Availability of inputs	Some of the inputs required for adoption of new technologies may not be available either with the farmers or in the general market. Organizing availability of new inputs is critical to adoption of new technologies.

Each of the technologies provided by the project team were assessed against the criteria listed out by the farmer groups. Each technology thus was given a score on 0 to 10 scale against each of the criteria. The cumulative scores for each of the technologies were used to rank them in order of the preferences exhibited by the farmers. The ranking exercise was intended mainly to indicate the relative preferences of the farmers for testing and subsequent adoption of the technologies.

Farmers found it difficult to score their preferences for the technologies as most of the technologies differed in the methods of operations, cost implications and their potential benefits. The ranks presented in the matrices thus indicated a general order of preference rather than a strict hierarchy of ranking for each of the technologies.

Conclusions

The critical aspects required for adoption of technical interventions clearly spelt out by the farmers are - economic considerations like costs involved in adoption of the interventions, availability and accessibility of known and new inputs required for undertaking interventions, market acceptances of the specialized produce and premium pricing have dominated the consensus among the farmers.

However, farmers were mainly tending to resist technologies where new methods of practice are involved that appeared laborious or time consuming and those required additional labor such as in windrow drying, sorting, removal of immature pods from haulm, etc. Even though all the groups concerned were critical of this aspect of technological intervention, women farmers were particularly resistant to such interventions.

The willingness of poor farmers, to adopt technologies that could reduce aflatoxin content in their groundnut crop is limited to technologies that do not require any additional inputs, either by way of cash requirements, material inputs, labor requirements or even drudgery.

Women farmers uniformly expressed their desire that, technology interventions have to ensure that women are not burdened with additional labor or drudgery and do not face problems with accessibility to any new inputs.. They were in favor of the technologies that required minimum labor but did not mind additional input costs.

Farmers in general were, favourable to try out new technologies even if it meant marginal increases in production cost for procuring inputs such as aflatoxin resistant varieties, seed treatment with trichoderma and applying fungicides, but under the condition that they were assured of additional incomes from producing aflatoxin free groundnuts.

It is important that technologies need to be –

- Sensitive to 'different strokes'.
  Technology interventions have to be customized to suit differential preferences of the divergent groups of farmers.
- Apprehensive to workloads and drudgery.
  Farmers are apprehensive of increased workloads and drudgery associated with the interventions such as post harvest drying, sorting and storage procedures.
- Considerate to costs, availability and access of inputs (particularly new inputs).
  Preferences for adoption of technologies were based on the farmers' experiences and perceptions of observed causes and effects or costs and savings.
- 'Market-able' through acceptance, accessibility and better pricing.
  Concerns for market acceptances of the specialized produce and premium pricing have dominated the consensus among the farmers especially when the current marketing practices do not distinguish aflatoxin free products from the contaminated ones.
- Perceptive to farmers' current experiences (bovine tastes - small pods are more tasty
  to animals - and no perceived ill effects on health).

Realization of the effects of consumption of aflatoxin contaminated groundnuts and haulms and the farmers did not explicitly understand its relationship to the ill effects on human and animal health.

- Conscious to the awareness of farmers to new technology interventions.
  Seeing is believing to these farmers as their farming systems are highly risk prone and hence need to be reassured of any new changes.

In conclusion
Careful attention has to be given to the approach – technological interventions as the realities indicated are complex and diverse. It is therefore essential that technological interventions should be suitable for adoption to a wide stakeholder base. Hence a group approach to reach the diverse groups of farmers is desired. Care is necessary while selecting the technologies offered for adoption so that the poor and the women farmers' are also made stakeholders in the process of technical change.

Since the issue is complex, involving several institutional and socio-economic factors. It is important that several actors need to be involved in the process of change. Hence, the foundations for technical change needs to be based on a coalition of partnerships that will sustain processes of change holistic and sustainable.

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Activity 6.2
Test improved pre-harvest, harvest and storage management practices on farm and on-station

Experiment 1: Testing new technologies for aflatoxins management at ICRISAT-Patancheru
The problem of aflatoxins contamination in groundnut is endemic to rain-fed groundnut facing end season drought. Since there is good correlation between drought at the end of cropping season and aflatoxins contamination in groundnut, any crop management practice that can improve water retention at the end of season, is likely to reduce the aflatoxins contamination. We initiated a trial using cost crop management options to manage the groundnut aflatoxins contamination, a field trial was laid out at ICRISAT-Patancheru and the experimental details are as follow.

Experimental design
Location: ICRISAT-Patancheru
Objective: To develop integrated management practices to reduce the aflatoxins contamination in groundnut

Treatments:

1. Compost application (5 t/ha)
2. Cereal residue application (5 t/ha)
3. Gypsum application (500 kg/ha)
4. Bio-control agent (Tricoderma)
5. Compost + Cereal residue
6. Compost + Gypsum application
7. Compost + Bio- control agent
8. Cereal residue + Gypsum
9. Cereal residue + Bio-control
10. Gypsum + Bio-control
11. Compost + Cereal residue + Gypsum
12. Compost + Cereal residue + Bio-control
13. Cereal residue + Gypsum + Bio-control
14. Gypsum + Bio-control + Compost
15. Compost + Cereal residue + Gypsum + Bio-control

Treatment application

1. No application (control)
2. Treatment application

Genotypes

1. JL 24
2. J 11

Replications: Three
Experimental design: Spilt-Spilt-plot
Block structure: 15x2x2 x 3 reps
Plot size: 4 x 4 m, flat bed
Planting: 18 July 2002
Harvesting: 18 Nov. 2002

Inoculation: Highly toxigenic strain (AF 11-4) of *A. flavus* was multiplied on pearl millet seed in the laboratory was broadcasted before groundnut planting, followed by row application of inoculum at 40 and 60 days after sowing.

Plant protection: The crop was sprayed once with Kavach to control foliar diseases

Observations: Weather parameters including soil temperatures, humidity, air temperatures and rainfall were recorded, Pod and haulm yield, seed infection by *A. flavus* and aflatoxins contamination were measured.

Results and discussion

Pod yield:
The pod yields ranged from 624 to 927 kg ha-1 in JL 24 and range from 548 to 784 kg ha-1 in J 11 across the treatments (Table 26). Highest pod yield were recorded in combined application of Gypsum and Bio control treatment. However, there is 5-19% increase in pod yield in both cultivars in some treatments (compost, cereal residue, gypsum + bio-control + gypsum and gypsum + bio-control + compost treatment). The low yield response is mainly due to erratic rainfall in 2002 and also because some of the interaction need longer time take place. Future experiments will provide more satisfactory response to these treatments.

Seed infection by *A. flavus* and aflatoxins contamination:
Groundnut pod sample from each plot were taken and sub-samples were processed for *A*. *flavus* infection and aflatoxins contamination. The results indicate that (Table 27) *A. flavus* infection ranged from 0-15% and aflatoxin contamination ranged from 1 to 5081 μg/kg across the treatments and genotypes. Reduction of 85-99% in aflatoxins contamination was recorded with application of cereal residue or gypsum, or gypsum + bio-control or gypsum + bio-control + compost for both cultivars. The highest reduction in aflatoxins contamination >97% was observed in cultivar JL 24 with application of bio-control which was reduced from 1067 to 23 μg/kg. In addition application of gypsum, bio-control, and compost when applied together was reduced from 1811 to 49 μg/kg. Likewise six other treatments (cereal residue, gypsum, compost + cereal residue, compost + gypsum, gypsum + bio-control and compost + cereal residue + bio-control) showed 64-96% reduction in aflatoxins contamination in variety JL 24. Gypsum, bio-control, and compost when applied to the same plot reduced by >99% aflatoxin in J 11 (from 3381 to 6 μg/kg). Also eight other treatments (compost, cereal residue, gypsum, cereal residue + gypsum, cereal residue + bio-control, gypsum + bio-control, compost + cereal residue and cereal residue + bio-control + gypsum) applications showed 65-96% reduction in aflatoxins contamination in J11. There was no correlation between *A. flavus* infection and aflatoxins contamination and possible reason could the fluctuation in rainfall and temperature.

Groundnut pod from each plot was sorted in to large, medium, and small size pods and insect damaged pods. After shelling the sorted pod separately, sub-samples were drawn from all these four groups of pod for *A. flavus* infection and aflatoxins contamination using ELISA (Table 28). Kernel from large size pod contain negligible amount of aflatoxin (<5μg/kg) in most of the plots irrespective of treatment of both cultivars with exception to compost + cereal residue applied plots with susceptible variety JL 24 and compost + gypsum applied plots with resistant variety J 11, where high level (>100μg/kg) aflatoxins contamination was recorded. These results must be confirmed in future experiments.

Groundnut seed from medium size seed showed 0-9.33% infection and aflatoxins ranging from 0 to 832 μg/kg in different treatments (Table 29). The treatment application of gypsum + bio-control + compost reduced 84% *A. flavus* infection and 99% aflatoxins in JL 24 and 33% infection and 79% aflatoxins in J11. Three treatments (bio-control, compost + bio-control, cereal residue + bio-control) applications in J 11 also reduced aflatoxins contamination (>98%)

Seed from small size pods showed 0-24.7% *A. flavus* infection and 0-2601 μg/kg aflatoxins contamination across the treatments and genotypes (Table 30). Aflatoxin contamination level was reduced by 98% (from 2718 to 48 μg/kg) in JL24 and 30% (from 1471 to1031μg/kg) in J11 with bio-control treatment. Plots gypsum application showed >94% reduction in *A. flavus* seed colonization in both the genotypes.

Soil inhabiting pests mainly pod borers causes <1% pod damage before the crop is harvested. Kernels from damaged pods showed aflatoxins level raging from12 to 2227 μg/kg (Table 31) and gypsum treated plots showed 50 and 33% reduction in aflatoxins levels in JL 24 and J 11 cultivars respectively. Pre-harvest insect damage to groundnut pods predisposes seed infection by *A*. *flavus* resulting high level of aflatoxins in most of the plots irrespective of the treatments.

Aflatoxin risk assessment in food and feeds

To assess the aflatoxins risk in food and feeds, about 206 samples were collected from the market and analyzed them by ELISA (Table 32). Aflatoxin level in the food and feed samples ranged from 0-1776 μg/kg and 42% of the samples showed >10 μg/kg. And also >16% samples showed aflatoxins >100 μg/kg.

Milk sample analysis for AFM1

Earlier we have tested buffalo milk for AFM1 contamination and it is interesting to see the toxin contamination in cow milk. About 50 milk samples from individual cows were collected from a well-managed public sector dairy farm and AFM1 was extracted as mentioned previously. The extracts from the milk samples were analyzed using ELISA for aflatoxins M1 contamination and results are presented in Figure 19. The aflatoxins M1 in the cow milk ranged from 0-2 μg/L and 34% of the samples contain non-permissible level (>0.5 μg/L) and 16% samples contain AFM1 in the range of 1-2 μg/L.

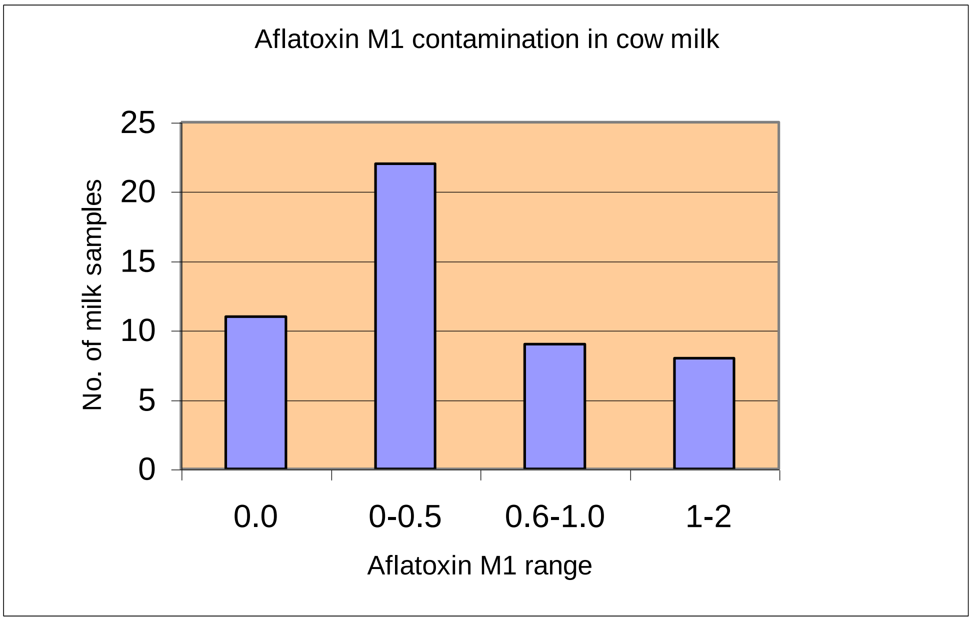


Figure 19. Aflatoxin M1 contamination in the cow milk collected from public sector dairy farm.

Experiment 2. Testing new improved technologies in Anantapur and Chittor district.

During the year 2001 rainy season 31 on-farm trials were organized in Anantapur and Chittor districts of Andhra Pradesh. Good progress was made to reduce the aflatoxins levels using the improved practices especially in Anantapur district. To improve further the efficiency of improved management practices to reduce the aflatoxins levels in groundnut, Trichoderma application was included in the improved management practices. To test the new improved technologies, 50 on-farm trials (25 each in Anantapu and Chittoor district) and also to develop new technology an on-station trial at Anantapur was planted.

On-station trial for aflatoxins management

The on station experiment was laid out at ARS, Anantapur with two main plots and five sub plots as treatments. The sowing was taken up on 4th August 02.

Details of on station experiment

To study the effect of management practices and the role of drought in reducing aflatoxin contamination of groundnuts under *A. flavus* sick condition, an experiment was laid out with split plot design with two main plot treatments and five sub plot treatments which are as under.

Main plot treatments

Supplemental irrigation (one during end of season drought)

1. Rain fed

Sub plot treatments

1. Control
2. Seed treatment with mancozeb @ 3g/kg and chlorpyriphos @ 6 ml/kg
3. Gypsum application @ 500 kg/ha at 40 DAS
4. LLS management with 0.2% Hexaconazole as foliar spray at 85 DAS
5. *Trichoderma viridae* application @ 2 kg/ha in 500 kg FYM at 45 DAS

Details of on farm trials

The package of improved practices for Anantapur district includes

- Seed treatment with Mancozeb (3g/kg) and chlorophyriphos (6ml/kg).
- Intercropping with mixed pulses (horsegram, cowpea, redgram, field bean) at 11 : 1 ratio
- Application of Trichoderma viridae @ 2 kg/ac with 200 kg FYM at 35 DAS
- Application of gypsum (500 kg/ha) at flowering (45 DAS)
- Management of late leaf spot with Hexaconazole @ 2 ml/lt water at 85 DAS.

Farmer practices for groundnut production

Farmers practice includes

- Seed treatment with only chlorpyriphos @ 3 ml/kg seed
- Application of di-ammonium phosphate or complex fertilizers (NPK 17:17:17 or 28:28:0) as basal dose at the rate of 125 kg/ha
- No gypsum and fungicides for foliar disease control.

Field observations

Gemini data loggers were installed in the experimental fields to record temperature, humidity and soil temperature in the pod zone during the crop growth period. Late leaf spot was observed at 75-80 DAS in both on station and on farm trials. But the disease incidence was very less and kept under control in improved practices by giving 0.2% hexaconazole foliar spray. End-of-season drought was experienced during pod filling stage.

Estimation of *A. flavus* population in soil

Soil samples were collected from both production practices plots in each field, one between flowering and early pod stage and other at final harvest. In each plot soil samples were drawn from four $2m^2$ blocks for groundnut harvest (one block each in four corners of the field). From each block, samples were collected from 5 spots and mixed to get one composite sample. Like wise, a total of 4 composite samples from each plot and 8 composite samples from each field were collected. Aqueous soil suspension (10 g soil in 90 ml sterile distilled water) was prepared from each of the composite sample, was serially diluted to 10^{-3} and 1000 μl of soil suspension / plate was spread on 5 plates of AFPA (*A. flavus* and *A. parasiticus* specific medium) and incubated for four days at 28^0C in dark. The soil sample at flowering provides initial measure of the *A. flavus* population. The soil samples at maturity give the indication of how environmental conditions have affected the fungus population. It also provides information on influence of management practices on *A. flavus* population.

Similarly, soil samples were collected from on station experiment one at flowering just before sicking the plot with *A. flavus* and the other at harvest. Five samples from each treatment plot were collected. In total 75 samples were collected from each main plot and 150 samples from the experiment. *A. flavus* population was estimated in all the samples by plating each sample in 5 plates. The population at flowering gives an indication of natural distribution of *A.flavus* in the soil and the population at harvest give the effect of different treatments on *A. flavus* population

Harvesting

The groundnut crop was harvested between 30^{th} November to 4^{th} December at Pampanur and on 22^{nd} November (rainfed block) and 8^{th} December (irrigated block) in on station experiment.

Groundnut pod sampling

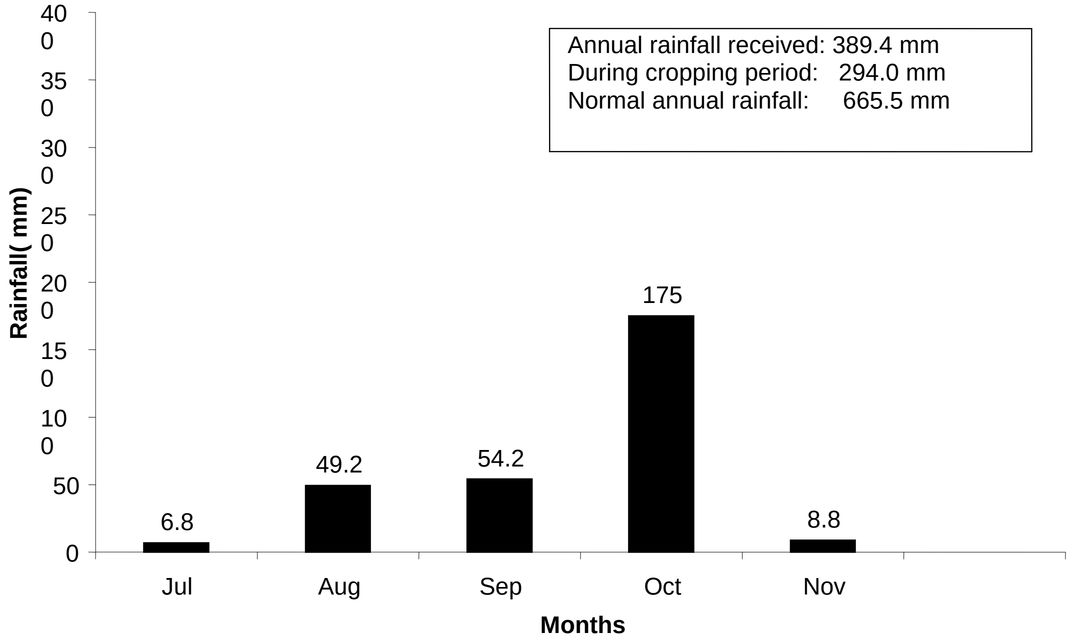
In all experimental fields pod samples were drawn from improved and farmer practices separately. Groundnut pods were harvested from four blocks of 2.0 m^2 demarcated at flowering time and pods were dried for 3-5 days under sunlight before recording the yield data. All the four samples from each practice were bulked and one sub-sample was drawn for *A*. *flavus* seed colonization and aflatoxin contamination. Likewise 2 samples were drawn from each farmer for *A*. *flavus* colonization and toxin estimation.

The on station experiment was harvested treatment wise and yield data was recorded and presented. From each treatment, one sub sample was drawn for aflatoxin and *A. flavus* colonization estimation. In total, 30 samples were drawn from the experiment.

Results and Discussion

There was a severe drought condition in India during 2002 rainy season more specifically in Anantapur and Chittoor districts of Andhra Pradesh. The rainfall at Anantapur was 42% less than the normal (Figure 20). Of the 50 on-farm trials planted, the crop was little bit better in only 14 farmer's fields at Pampanur and the crop in the remaining 36 farmer's fields abandoned due to poor germination (<20%).

Figure 20. Rainfall at Agricultural Research Station, Anantapur during Kharif 2002



***Aspergillus flavus* population**

Fourteen farmer fields were selected for management trials and in these fields improved and framer practices were tested simultaneously during 2002 rainy season. At Pampanur the sample analysis for *A. flavus* population at flowering and harvest (Table 33) indicate that there was no significant difference between the *A.flavus* populations in both farmer's practice and improved management practice. There is 9-10 fold increase in soil at harvest in both the practices. In on station experiment, the results of soil sample analysis for *A. flavus* population at flowering and harvest (Table 34) indicate that there was no significant difference in the population with different management practices tested, either at flowering or at harvest in both the irrigated and rainfed situations. However, supplemental irrigation has significantly contributed to increase in *A. flavus* population compared to rainfed situation, which may be attributed to increased moisture availability and decreased soil temperatures which might favour the growth and development of the fungus.

***Aspergillus flavus* infection and aflatoxins contamination**

Seed infection by *A. flavus* ranged from 0-9% in farmer practice plots and 0-6% in improved practice plots (table 35). Mean *A. flavus* infection was reduced by 32% with improved practices. However mean aflatoxins levels were increased with improved practice in one field. In Vadde Adi Narayana's field aflatoxins level was reduced by 77% (from 52.4 to 11.7 μg/kg) with improved practices. Since the results are very erratic the trial needs to be retested next year.

Groundnut yield

The results of on farm trials (Table 36) indicate that the pod and haulm yields of groundnut were significantly higher with improved management practice than with farmers practice. The results of on station experiment (Tables 37 & 38) indicate that the pod and haulm yields of groundnut were significantly higher with supplemental irrigation than with rainfed crop. Different management practices did not influence the pod yield. The aflatoxin levels varied across treatments and need to be tested in more samples.

Experiment 3. Risk assessment of aflatoxins exposure in animals and human beings

Aflatoxins are one of the most potent known carcinogens that occur naturally in many foods and feeds. Exposure of human beings to aflatoxins particularly at population level is being studied actively, because they are carcinogens and their synergistic role with hepatitis b in the aeitiology of liver cancer is proved.

Exposure assessment to aflatoxins can be done by two ways

1. By estimating the total amount of aflatoxin intake by an individual.
2. By estimating the aflatoxin-albumin biomarker present in the exposed individuals.

The second one is preferred way because, dietary exposure can be from variety of sources and it is practically difficult to monitor complete dietary aflatoxin intake. Aflatoxins enter in to animal and human body thru food and 3-5% of the toxin will remain in the blood in the form of aflatoxins-albumin adduct.

For estimating aflatoxin –albumin adduct level in blood, many physico-chemical methods like HPLC and MS are available. However, these are very costly and require extensive sample cleanup mechanisms.

Immunochemical methods like ELISA are gaining wide importance in measurement of biomarkers of exposure due to their high specificity, reproducibility and adaptivity.

The present work's objective is development of indirect competitive ELISA for estimation of aflatoxin albumin adducts in blood.

Materials and Methods

Apparatus

(a.). Pre coated thin layer chromatographic plates – precoated polyester silica gel plates plates (size 20 x 20 cm; particle size 2-25μm sigma chemical co ., St.Louis , MO).

(b). Microtiter plates – NUNC Germany .

(c). Spectrophotometer- Beckman DU50, Beckman Co.

(d). Microcentrifuge- CHERMLE Z360k- Forma scientific Co. USA

Chemicals and Reagents.

Chemicals: AFB1, BSA, Ovalbumin, N-α-acetyl –l-lysine, goat anti rabbit IgG , pNPP were procured from sigma chemical company. MCPBA and Dichloromethane were purchased form ICN biomedical inc.USA.

b. Sodium phosphate buffer- sodium phosphate .0.1 M(pH 7.2)

c. Coating buffer- Carbonate buffer 0.1M pH 9.6

d. Washing buffer – PBS with Tween 20

e. Substrate buffer- 1 mg/ml – para nitro phenyl phosphate in 10% diethnolamine. (pH 9.8).

<u>Animals</u>

Rabbits – female (In bred New Zealand white strain. 13 months old.)

All reactions were performed under subdued light to avoid formation of photo adducts. All the reactions must be carried out in glass tube with a glass bead .

Preparation of Aflatoxin-Lysine Adduct

Aflatoxin–lysine conjugate is synthesized in two steps. First step aims at generation of aflatoxin epoxide by oxidation of AFB1 (100 μg, .032 μmoles) using MCPBA (60%). In the second step this epoxide is conjugated with N-α-acetyl –l- lysine (1 mg 5.32 μmoles) in a bi-phasic reaction mixture containing dichloromethane and 0.1M phosphate buffer (pH 7.2).

Procedure

In 250μl of dichloromethane, 0.6 mg (60% MCPBA , 2μmol) was dissolved. This is washed thoroughly with 500μl phosphate buffer for three times. In another 250μL dichoromethane 100μg AFB1 (0.32 μmoles) is dissolved. This is added to dichloromehtane containing MCPBA and allowed to react (gentle stirring) for 100 min at 5^0 C. Then 1 mg of N-α-acetyl –l-lysine is dissolved in 250μl of phosphate buffer and added to the prior solution and allowed to react for another 60 min at 5^0C. After the reaction, the reaction mixture was centrifuged at 10000 rpm for 5 min in a micro centrifuge. The organic phase (dichloromethane) was separated form the buffer fraction containing the AFB1-Lysine conjugate. This was washed three times, with dichloromethane to remove unreacted AFB1. Then both the organic phase and aqueous are subjected to TLC for the presence of adducts and unreacted AFB1 and its derivatives. The ratio of AFB1 to Lysine is 1: 16.

Synthesis of AfB1-BSA Immunogen

Aflatoxin–BSA conjugate is synthesized in two steps. First step aims at generation of aflatoxin epoxide by oxidation of AFB1 using MCPBA (60%). In the second step this epoxide is conjugated with BSA (5 mg 75 nmoles) in a bi phasic reaction mixture containing dichloromethane and 0.1M phosphate buffer (pH 7.2).

Procedure

In 250μl of dichoromethane, 3.53 mg (60% MCPBA , 12.26 μmol) was dissolved. This is washed thoroughly with 500μl phosphate buffer for three times. In another 250μL dichoromethane 588μg AFB1 (1.88 μmoles) is dissolved. This is added to dichloromehtane containing MCPBA and allowed to react (gentle stirring) for 100 min at 5^0 C. Then 5 mg of **BSA** is dissolved in 250μl of phosphate buffer and added to the prior solution and allowed to react for another 60 min at 5^0C. After the reaction, the reaction mixture was centrifuged at 10000 rpm for 5 min in a micro centrifuge. After centrifugation the precipitate and the organic phase (dichloromethane) were separated and the buffer fraction containing the AFB1-BSA conjugate was washed three times, with dichloromethane to remove unreacted AFB1. Then both the organic phase and aqueous are subjected to TLC for the presence of adduct and unreacted AFB1 and its derivatives. The ratio of BSA to AFB1 is 1:20.

Synthesis of AfB1-Ovalbumin

Aflatoxin–OVA conjugate is synthesized in two steps. First step aims at generation of aflatoxin epoxide by oxidation of AFB1 using MCPBA (60%). In the second step this epoxide is conjugated with OVALBUMIN (5 mg 111 nmoles) in a bi phasic reaction mixture containing dichloromethane and 0.1M phosphate buffer (pH 7.2).

Procedure

In 250μl of dichoromethane ,5.68 mg (60% MCPBA , 19.75 μmol) was dissolved. This is washed thoroughly with 500μl phosphate buffer for three times. In another 250μL dichoromethane 775μg AFB1(2.48 μmoles) is dissolved. This is added to dichloromehtane containing MCPBA and allowed to react (gentle stirring) for 100 min at 5^0 C . Then 5 mg of **OVA** is dissolved in 250μl of phosphate buffer and added to the prior solution to react for another 60 min at 5^0C. After the reaction, the reaction mixture was centrifuged at 10000 rpm for 5 min in a micro centrifuge. After this the precipitate and t he organic phase (dichloromethane) were separated and the buffer fraction containing the AFB1- OVA conjugate was washed three times, with dichloromethane to remove unreacted AFB1. Then both the organic phase and aqueous are subjected to TLC for the presence of adduct and unreacted AFB1 and its derivatives. The ratio of BSA to AFB1 is 1:15.

Characterization by TLC

Polyester silica gel TLC plates were used for analysis of buffer and organic fraction. The plate was developed in Chloroform –Acetone (9 + 1) solvent system. The florescence of the resulting compound was visualized under long wave UV light (365 nm) in an UV cabinet.

Spectral Analysis of AFT- Lysine for Quantification

Spectral analysis of the adduct was performed using a Beckman DU 50 recording spectrophotometer. The sample was scanned from 200- 500 nm. The absorbance was also taken at 343 nm to quantify the concentration of AFT-Lysine Adduct. (Standard solution of AFT- lysine (1 mg / ml gives an absorbance(A_{343}) of 7.42)

Quantification of AFB1- BSA and AFB1-OVA

The protein content of the aqueous fraction of AFB1 –BSA and AFB1- OVA is measured using UV 280 method.

Production of Polyclonal Antibodies against AfB1-BSA

Ployclonal antibodies against AFB1-BSA are being produced in a single Inbred Newzealand white rabbit (13 months old, body mass 2.5-3 kg). A primer dose of 250 μg/ml of AFB1-BSA was throughly emulsified with complete Freud's adjuvant and was subcutaneously administered The subsequent doses were placed at an interval of one week where 300μg/ml of AFB1-BSA was administered subcutaneously in incomplete Freud's adjuvant. As of now, five times the rabbit was administered the antigen.

Monitoring Titers of Antibody

An indirect ELISA procedure was used to monitor the antibody titers. Microtiter plares were coated with 0.2 μg/ml of AFB1 – OVA (to avoid interference due to antibodies specific to carrier protein BSA) in 0.2 M sodium carbonate buffer, pH 9.6 (150μl/well) and incubated overnight in a refrigerator. Subsequent steps were performed at 37^0 C for one hour. The wells were blocked for nonspecific binding with 165μl/well using blocking buffer (4% dried milk prepared in phosphate buffer saline containing 0.05% Tween-20. Anti serum dilutions in 50μL/well were added to 100μL of AFT-Lysine at concentrations ranging from 100 ng /ml to 100 pg /ml. Goat anti rabbit immunoglobulins (GAR IgG) conjugated to alkaline phosphatase were used at a 1:1000 dilution to detect antibodies attached to AFB1-Lysine. P-nitrophenyl phosphate was used as a substrate at 1 mg/ml and allowed to develop for one hr at room temperature. Asorbance was recorded at 405 nm (A_{405}) with an ELISA plate reader (Titretek Multiskan, Labsystems).

Results and Discussion

Characterization of adducts by TLC

TLC analysis of the buffer fraction of reaction mixture showed a single fluorescent spot at base with zero R_f valve, indicating the presence of AFB1-lysine. Free unreacted AFB1 was not detected.

Similarly the TLC analysis of AFB1-BSA and AFB1-OVA showed single fluorescent spots at the origin indicating the fromation of adduct. Even in this case unreacted AFB1 was not detected.

The organic phases of all the three synthesis showed unreacted AFB1 (compared to standard) and other fluorescent spots probably corresponding to aflatoxin- diols and hydroxy esters.

Spectral Analysis of Lysine adducts

The UV absorbtion spectrum of the AFB1-Lysine adduct showed two peaks (275 and 335 nm) and was similar to the spectrum earlier reported (Figure 21).

The absorption of the synthate(AFT-Lys adduct) indicated the concentration as 12.4 μg/ml ($A_{343}\rightarrow$ .092).

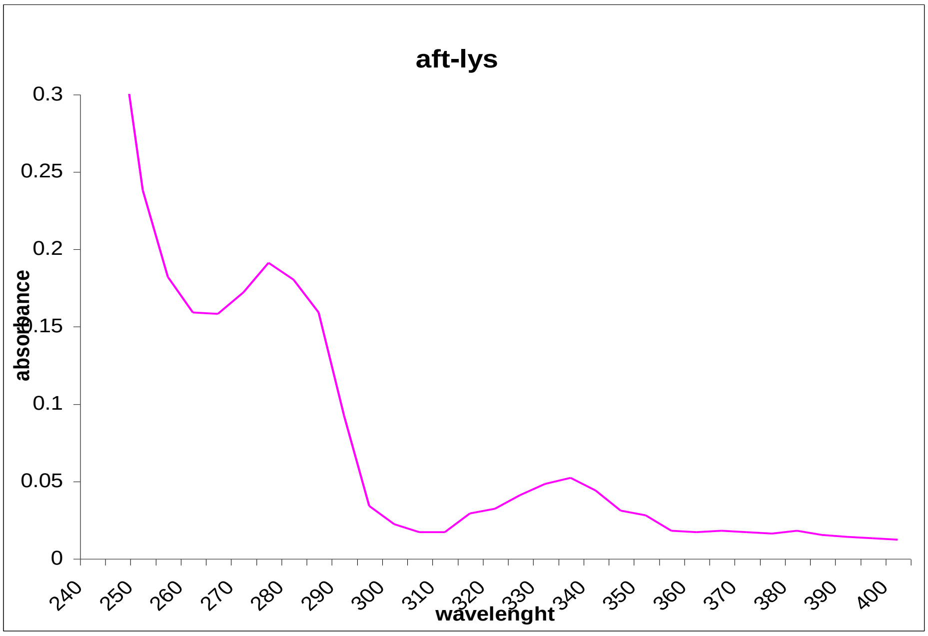


Figure 21. Spectral analysis of AFB1-lysine adduct

Quantification of AFB1-BSA and AFB1-OVA

The protein content of aqueous phase of AFB1-BSA and AFB1- OVA showed that the quantity of AFB1-BSA was 6.2 mg / ml and that of AFB1-OVA was 3.4 mg/ml. Low recovery of AFT-OVAlbumin can be attributed to the fact that ovalbumin is less soluble in buffer when compared to the BSA. This can also be observed by the amount of precipitate generated in respective cases.

Antibody Titers

The antibody titers after for the first bleed (one month from first antibody injection) was 1:2000 and of the second week bleed was 1:16000.

The progress made towards development of an ELISA based tool for estimation of aflatoxin on blood is promising and should be able to accomplish this work within next few months.

Conclusion

The data on station trial (ICRISAT-Patancheru center) on groundnut aflatoxins management indicate that certain treatments (cereal residue, gypsum, gypsum + bio-control and gypsum + bio-control + compost) application reduced >95% aflatoxins level over their control in both the genotypes. These results need confirmation and there is need to study long term effect of treatment applications on aflatoxins contamination level as well pod yield. Treatment applications in on-station trials at both locations (ICRISAT-Patancheru and Anantapur) could not influence the pod yield as these treatments were targeted to reduce the aflatoxins levels.

The data on *A. flavus* infection and aflatoxins contamination from the on farm trials is insufficient to draw any meaningful conclusion on improved management practice. Most of the on farm trials were abandoned due to severe drought conditions and left over very few trials data was erratic to draw any conclusion. So it is essential to repeat the on farm trials once again in next year with integration of bio-control agent and resistant or tolerant cultivar in improved practices. However, it is encouraging to note that higher pod yield was obtained with improved practices in these limited farmers fields at Pampanur.

Aflatoxin risk assessment of the market samples showed that very high level of aflatoxins contamination (>100 μg/kg) in 16% of the samples indicate that need of continued efforts to reduce the aflatoxins contamination in food and feeds.

Table 1a. Soil characteristics of experimental farmer's fields at Pampanur

S.No	Farmer name	Soil depth (cm)	Water holding capacity (%)	pH	EC (dS/m)	Available potash (kg/ha)
1	Pedda Sardanappa	30	28.3	6.5	0.1	196
2	H. Narayana	30	26.4	6.1	0.1	141
3	Akkampalli Narayana	30	26.4	6.4	0.1	106
4	G. Naramma	25	23.2	6.4	0.1	110
5	G. Sreeramulu reddy	25	27.5	7.3	0.1	124
6	Edamala Ramanna	30	24.4	6.2	0.1	124
7	Meenaga Narayana	30	25.2	6.3	0.1	136
8	G. Ranga Reddy	30	25.4	7.0	0.1	183
9	Potte Ramanna	25	30.8	8.2	0.2	207
10	Potte Rajanna	25	24.4	6.3	0.1	125
11	Vadde Adinarayana	25	25.3	7.5	0.2	124
12	Kuruvu Akulappa	25	23.7	6.9	0.1	237
13	Kummari Thimmappa	30	25	7.4	0.5	329
14	G. Lakshmi Devamma	25	27.3	6.5	0.1	187
15	M. Mallarayudu	25	33.6	6.6	0.1	231

Table 1b. Soil characteristics of experimental farmer's fields at Linganpalli

S.No	Farmer name	Soil depth (cm)	Water holding capacity (%)	pH	EC (dS/m)	Available potash (kg/ha)
1	Chenna Reddy	25	27.3	8.2	0.4	179
2	Govinda Reddy	30	23.5	8.3	0.1	150
3	Raghava Reddy	25	28.3	8.2	0.1	119
4	Narasimha Reddy	25	26.9	7.7	0.2	146
5	Bayyapu Reddy	25	22.6	7.0	0.1	91
6	Pedda Narayana	30	26.4	7.0	0.2	117
7	Chinna Narayana	30	29.3	7.4	0.1	106
8	Pedda Sanjanna	25	27.2	7.5	0.1	98
9	Venkata Reddy	30	23.3	7.9	0.1	77
10	Ramachandra Reddy	25	26.3	8.0	0.2	220

Table 2a. Fertilizer application in experimental farmer's fields under improved practices at Pampanur

S.No	Farmer name	Urea (kg/ac)	Muriate of potash (kg/ac)
1	Pedda Sardanappa	20	15
2	H. Narayana	20	25
3	Akkampalli Narayana	20	25
4	G. Naramma	20	25
5	G. Sreeramulu reddy	20	25
6	Edamala Ramanna	20	25
7	Meenaga Narayana	20	25
8	G. Ranga Reddy	20	15
9	Potte Ramanna	20	15
10	Potte Rajanna	20	15
11	Vadde Adinarayana	20	25
12	Kuruvu Akulappa	20	…
13	Kummari Thimmappa	20	…
14	G. Lakshmi Devamma	20	15
15	M. Mallarayudu	20	15

Table 2b. Fertilizer application in experimental farmer's fields under improved practices at Linganpalli

S.No	Farmer name	Urea (kg/ac)	Muriate of potash (kg/ac)
1	Chenna Reddy	20	15
2	Govinda Reddy	20	25
3	Raghava Reddy	20	25
4	Narasimha Reddy	20	25
5	Bayyapu Reddy	20	25
6	Pedda Narayana	20	25
7	Chinna Narayana	20	25
8	Pedda Sanjanna	20	25
9	Venkata Reddy	20	25
10	Ramachandra Reddy	20	15

Table 3. Calendar of operations at Pampanur and Linganpalli

DATE		OPERATION
June,2001	::	Initial soil sample collection
4th July,2001	::	Distribution of fertilisers for Linganpalli demonstations
7thJuly,2001	::	Distribution of fertilizers for Pampanur demonstations
1st Aug-4th Aug 2001	::	Sowing at Pampanur
4th Aug- 7 thAug2001	::	Sowing at Linganapalli
7th and 8th sept2001	::	Data loggers installed at Pampanur fields
11th and 13th Sept 2001	::	Weeding at Pampanur
13th and 14th Sept2001	::	Weeding at Linganapalli
13th Sept,2001	::	Data loggers installed at Linganapalli
14th Sept,2001	::	Gypsum application at Pampanur
16th Sept ,2001	::	Gypsum application at Linganapalli
17th Sept,2001	::	Marking five spots in demonstration plots
30th sept,2001	::	Pesticide spraying at Pampanur
3rd Oct,2001	::	Pesticide spraying at Linganapalli
30th Oct,2001	::	Hexaconazole spraying at Pampanur
1st Nov,2001	::	Hexaconazole spraying at Linganapalli
23rd & 24th Nov,2001	::	Harverting at Pampanur
25th-28thNov,2001	::	Sundrying of harvest crop at Pampanur
28th-30thNov,2001	::	Harvesting at Linganapalli
29th-3rdDec,2001	::	Stack formation at Pampanur
29th-3rdDec,2001	::	Sundrying of harvestcrop at Linganapalli
4th-6th Dec,2001	::	Stack formation at Linganapalli
5th & 6th Dec,2001	::	Loggers installed in the stacks at Pampanur
7th Dec,2001	::	Loggers installed in the stacks at Linganapalli
15th-20thDec,2001	::	Threshing at Pampanur
20thDec-11th Jan,2001	::	Threshing at Linganapalli
6th&7th Jan,2002	::	Loggers installed in farmer stores at Pampanur
20th Jan,2002	::	Loggers installed in farmer stores at Linganapalli

Table 4a. Percent of soil moisture in Pampanur farmer's fields

S.No	Farmer name	Farmer practice		Improved practice	
		90 DAS	105 DAS	90 DAS	105 DAS
1	Pedda Sardanappa	3.1	1.9	2.1	1.0
2	H. Narayana	1.7	0.4	7.0	2.6
3	Akkampalli Narayana	3.3	1.2	3.4	1.9
4	G. Naramma	1.8	0.5	2.6	0.7
5	G. Sreeramulu reddy	2.0	0.6	2.3	0.9
6	Edamala Ramanna	3.8	1.4	3.6	1.2
7	Meenaga Narayana	4.2	1.2	2.4	0.7
8	G. Ranga Reddy	4.9	2.0	14.2	2.8
9	Potte Ramanna	1.9	0.7	1.7	0.8
10	Potte Rajanna	7.1	0.8	10.5	1.0
11	Vadde Adinarayana	9.7	1.9	3.8	2.6
12	Kuruvu Akulappa	2.0	0.4	2.5	0.5
13	Kummari Thimmappa	2.1	0.6	2.6	1.0
14	G. Lakshmi Devamma	3.5	0.5	3.4	0.6
15	M. Mallarayudu	3.3	0.8	3.5	0.8

Table 4b. Percent soil moisture at Linganpalli

S. No	Farmer name	Farmer practice				Improved practice			
		80 DAS	90 DAS	95 DAS	At harvest	80 DAS	90 DAS	95 DAS	At harvest
1	Chenna Reddy	3.0	1.8	1.3	0.9	3.1	1.9	1.2	0.9
2	Govinda Reddy	3.2	2.0	1.7	0.7	3.3	2.6	1.8	1.2
3	Raghava Reddy	2.5	1.5	1.3	1.0	2.4	1.8	1.7	1.3
4	Narasimha Reddy	3.1	1.5	1.0	0.7	3.6	2.1	1.0	0.8
5	Bayyapu Reddy	2.4	1.6	1.4	0.9	2.1	1.7	1.0	0.8
6	Pedda Narayana	3.4	2.2	1.6	0.9	2.9	1.4	0.7	0.4
7	Chinna Narayana	3.1	2.6	2.2	1.6	2.8	2.3	1.8	1.3
8	Pedda Sanjanna	2.8	1.8	1.3	0.8	3.0	1.5	1.1	0.8
9	Venkata Reddy	3.6	1.2	1.0	0.6	3.7	1.9	1.7	0.7
10	Ramachandra Reddy	2.9	2.3	0.8	0.4	3.3	3.1	0.7	0.5

Table 5. Aflatoxin levels in pre-harvest groundnut samples collected from farmer fields in Anantapur area during 2000 rainy season

S.No.	Field number	Farmer practice	Improved practice
1	Field 1	7.1	200.3
2	Field 2	343.7	501.5
3	Field 3	7.6	12.3
4	Field 4	6.5	6.3
5	Field 5	5.6	5.5
6	Field 6	5.8	6.1
7	Field 7	5.9	6.7
8	Field 8	13.3	7.4
9	Field 9	6.0	6.2
10	Field 10	5.5	6.9
11	Field 11	8.9	5.5
12	Field 12	7.6	6.8
13	Field 13	5.6	5.9
14	Field 14	7.2	7.1
15	Field 15	528.3	19.1
16	Field 16	531.7	99.9
17	Field 17	100.6	10.0
18	Field 18	5.2	271.6
19	Field 19	4.5	4.3
20	Field 20	4.2	209.7
21	Field 21	6.0	5.0
22	Field 22	4.3	5.3
23	Field 23	5.1	4.4
24	Field 24	5.4	5.0
25	Field 27	4.2	4.5
26	Field 28	468.6	5.8
27	Field 29	5.5	6.4
28	Field 30	3.6	3.0
29	Field 31	5.4	4.7
30	Field 32	6.2	7.3
31	Field 33	6.8	6.7
32	Field 34	4.1	4.5
33	Field 36	32.2	686.9
34	Field 37	26.1	714.6
35	Field 38	12.3	79.7
36	Field 39	7.1	7.9
37	Field 40	5.5	8.4
38	Field 41	4.0	450.5
39	Field 42	16.5	16.7
40	Field 43	1.7	2.1

41	Field 44	6.1	28.6
42	Field 46	3.7	2.6
43	Field 47	4.1	3.4
44	Field 49	5.4	4.7
45	Field 50	4.3	2.9
46	Field 51	1371.9	6.9
47	Field 52	1061.9	6.8
48	Field 53	7.5	103.2
49	Field 54	6.1	6.7
50	Field 55	289.9	6.5
51	Field 56	11.4	8.8
52	Field 57	3.8	6.0
53	Field 59	5.5	33.0
54	Field 60	4.9	5.1
55	Field 61	821.6	4.5
56	Field 65	234.5	169.9
57	Field 66	3.9	6.5
58	Field 67	5.8	3.6
59	Field 68	6.9	9.7
60	Field 69	6.4	5.4
61	Field 70	180.3	12.1
62	Field 73	7.4	8.9
63	Field 74	4.3	4.6
	Mean	100.0	61.6
	SE	112	
	CV (%)	246	

Table 6. Aflatoxin levels in pre-harvest groundnut samples collected from Pileru area during 2000 rainy season

S.No.	Farmer name	Aflatoxin (μg/kg)	
		Farmer practice	Improved practice
1	P. Rajanna	1.5	1.7
2	S. Ramaiah	4.6	2.0
3	Subramanyam	4.1	1.7
4	P. V. Ramana	18.8	6.3
5	Nagaiah	3.2	13.8
6	Venkata Swamy	4.5	5.7
7	P. Murali	10.7	3.3
8	C. Chalapathi	7.7	4.3
9	S. Siddaiah	2.4	2.5
10	K. Thataiah	2.9	1.0
11	S. Hari	4.9	4.8
12	G. Maraiah	5.9	2.2
	Mean	5.9	4.1

Table 7a. *Aspergillus flavus* infection and aflatoxin contamination in pre-harvest groundnut seed samples collected from Pampanur (Anantapur) farmer fields during 2001 rainy season

S.No	Farmer name	Farmer practice		Improved practice	
		A. flavus infection(%)	Aflatoxin (μg/kg)	*A. flavus* infection(%)	Aflatoxin (μg/kg)
1	Pedda Sardanappa	0.00	6.23	0.67	2.13
2	H. Narayana	3.00	0.80	0.67	5.20
3	Akkampalli Narayana	0.33	2.57	0.33	1.47
4	G. Naramma	0.67	7.90	0.67	2.40
5	G. Sreeramulu reddy	3.67	4.63	0.67	11.60
6	Edamala Ramanna	0.00	1.90	5.00	3.13
7	Meenaga Narayana	0.33	8.40	0.33	1.23
8	G. Ranga Reddy	0.33	2.33	0.00	5.97
9	Potte Ramanna	2.00	1.67	0.67	8.77
10	Potte Rajanna	0.00	6.60	1.33	0.97
11	Vadde Adinarayana	1.00	7.20	0.33	8.80
12	Kuruvu Akulappa	0.67	6.27	0.33	2.43
13	Kummari Thimmappa	1.00	3.47	1.00	3.30
14	G. Lakshmi Devamma	0.67	7.83	0.00	11.83
15	M. Mallarayudu	3.67	4.60	2.33	3.00
	Mean	1.16	4.83	1.10	4.82
	SE	0.33	0.66	0.34	0.96
	CV (%)	112	53	122	77

Table 7b. *Aspergillus flavus* infection and aflatoxin contamination in pre-harvest groundnut seed samples collected from Lingannapalli farmers fields during 2001 rainy season

S.No	Farmer name	Farmer practice		Improved practice	
		A. flavus infection(%)	Aflatoxin (μg/kg)	*A. flavus* infection(%)	Aflatoxin (μg/kg)
1	Chenna Reddy	2.33	1.13	2.00	3.30
2	Govinda Reddy	0.67	7.30	1.00	6.30
3	Raghava Reddy	1.33	2.73	1.67	1.97
4	Narasimha Reddy	2.67	1.43	2.67	21.83
5	Bayyapu Reddy	2.00	3.77	0.00	2.77
6	Pedda Narayana	7.00	570.63	6.33	176.50
7	Chinna Narayana	1.00	0.00	2.00	70.60
8	Pedda Sanjanna	6.67	796.30	1.67	1.47
9	Venkata Reddy	1.00	1.63	0.67	4.10
10	Ramachandra Reddy	2.00	1.97	4.67	98.87
	Mean	2.77	138.68	2.27	38.77
	SE	0.79	92	0.60	18
	CV (%)	90	210	84	152

Table 8a. Socioeconomic status of farmers in relation to Pod yield, haulm yield and aflatoxin contamination at Pampanur

S.No	Farmer name	Social status	Wealth status	Pod yield (kg/ha)		Haulm yield (kg/ha)		Aflatoxin (μg/kg)	
				FP*	IP*	FP	IP	FP	IP
1	Pedda Sardanappa	SC	Poor	546	631	1565	1878	6.23	2.13
2	H. Narayana	SC	Poor	462	490	1109	1191	0.80	5.20
3	Akkampalli Narayana	SC	Poor	695	885	1405	1568	2.57	1.47
4	G. Naramma	FC	Mid	250	364	1014	1092	7.90	2.40
5	G. Sreeramulu reddy	FC	Rich	296	446	1033	1269	4.63	11.60
6	Edamala Ramanna	BC	Mid	509	733	1723	2037	1.90	3.13
7	Meenaga Narayana	SC	Poor	405	476	1722	2114	8.40	1.23
8	G. Ranga Reddy	FC	Rich	307	343	1796	2032	2.33	5.97
9	Potte Ramanna	BC	Mid	263	276	1207	1247	1.67	8.77
10	Potte Rajanna	BC	Mid	256	302	1248	1364	6.60	0.97
11	Vadde Adinarayana	BC	Mid	287	295	1565	1763	7.20	8.80
12	Kuruvu Akulappa	BC	Poor	421	566	1252	1562	6.27	2.43
13	Kummari Thimmappa	BC	Poor	522	700	1407	1484	3.47	3.30
14	G. Lakshmi Devamma	FC	Mid	323	363	1248	1326	7.83	11.83
15	M. Mallarayudu	SC	Rich	435	536	942	1098	4.60	3.00
	Mean			398	494	1349	1535	4.83	4.82
	SE			34	47	71	91	0.66	0.96
	CV (%)			33	37	20	22	53	77

SC = Schedule castes, BC = Backward castes, FC = Forward castes
*FP = Farmers' practice; IP = Improved practice

Table 8b. Socioeconomic status of farmers in relation to Pod yield, haulm yield and aflatoxin contamination at Linganpalli

S.No	Farmer name	Social status	Wealth status	Pod yield (kg/ha)		Haulm yield (kg/ha)		Aflatoxin (μg/kg)	
				FP*	IP*	FP	IP	FP	IP
1	Chenna Reddy	FC	Rich	185	293	1246	1324	1.13	3.3
2	Govinda Reddy	FC	Mid	80	142	898	938	7.3	6.3
3	Raghava Reddy	FC	Rich	216	220	1246	1479	2.73	1.97
4	Narasimha Reddy	FC	Mid	486	494	1401	1556	1.43	21.93
5	Bayyapu Reddy	FC	Mid	397	531	1516	1633	3.77	2.77
6	Pedda Narayana	SC	Poor	390	470	1515	1629	571	176.5
7	Chinna Narayana	SC	Poor	168	206	1091	1207	0.0	70.6
8	Pedda Sanjanna	SC	Poor	263	277	1205	1322	796	1.47
9	Venkata Reddy	FC	Mid	461	489	1399	1516	1.63	4.1
10	Ramachandra Reddy	FC	Mid	263	277	1205	1322	1.97	98.87
	Mean			291	340	1272	1393	139	38.78
	SE			43	45	61	68	92	19
	CV (%)			44	42	15	15	210	152

SC = Schedule castes, BC = Backward castes, FC = Forward castes

*FP = Farmers' practice; IP = Improved practice

Table 9. *Aspergillus flavus* and aflatoxin contamination in pre-harvest groundnut samples at Pileru during 2001 rainy season.

S.No.	Farmer name	Farmer practice		Improved practice	
		A. flavus infection (%)	Aflatoxin (μg/kg)	*A. flavus* infection (%)	Aflatoxin (μg/kg)
1	Bhaskar	0.0	2.0	0.0	3.5
2	Kannaiah	0.0	1.1	0.2	2.3
3	Peddabba	0.0	2.8	0.0	3.6
4	Penchalaiah	0.6	3.5	0.0	2.4
5	Nagaraju	21.4	1859.4	5.6	2554.8
6	Rajanna	1.4	323.0	16.0	990.4
	Mean	3.9	365.3	3.6	592.8

Table 10a. *Aspergillus flavus* infection and aflatoxin contamination in groundnut seed from large size pods from Pampanur farmer's fields

S.No	Farmer name	Farmer practice		Improved practice	
		A. flavus infection(%)	Aflatoxin (μg/kg)	*A. flavus* infection(%)	Aflatoxin (μg/kg)
1	Pedda Sardanappa	0.00	7.7	1.85	5.4
2	H. Narayana	1.85	3.0	0.46	5.1
3	Akkampalli Narayana	4.17	2.7	0.93	4.0
4	G. Naramma	0.00	5.1	0.93	0.6
5	G. Sreeramulu reddy	1.39	9.2	2.78	8.8
6	Edamala Ramanna	0.93	1.1	1.85	4.9
7	Meenaga Narayana	0.93	4.7	0.93	3.6
8	G. Ranga Reddy	2.78	4.2	0.00	2.1
9	Potte Ramanna	1.85	7.5	2.78	9.4
10	Potte Rajanna	5.56	2.3	0.00	3.0
11	Vadde Adinarayana	0.00	2.7	0.00	1.0
12	Kuruvu Akulappa	1.39	4.2	0.46	4.2
13	Kummari Thimmappa	2.31	4.6	0.93	2.2
14	G. Lakshmi Devamma	2.08	5.0	1.39	7.1
15	M. Mallarayudu	0.69	2.1	0.69	5.3
	Mean	1.73	4.41	1.06	4.45
	SE	0.40	0.59	0.23	0.66
	CV (%)	89	52	85	57

Table 10b. *Aspergillus flavus* infection and aflatoxin contamination groundnut seed from large size pods from Lingannapalli farmer's fields

S.No	Farmer name	Farmer practice		Improved practice	
		A. flavus infection(%)	Aflatoxin (μg/kg)	*A. flavus* infection(%)	Aflatoxin (μg/kg)
1	Chenna Reddy	2.78	2.7	0.69	3.8
2	Govinda Reddy	1.39	3.1	0.00	1.9
3	Raghava Reddy	0.00	2.3	1.39	1.1
4	Narasimha Reddy	3.24	8.7	6.25	5.7
5	Bayyapu Reddy	10.19	1.6	2.31	6.0
6	Pedda Narayana	7.87	6.0	13.19	19.3
7	Chinna Narayana	0.69	1.8	4.17	4.1
8	Pedda Sanjanna	0.00	2.0	0.00	1.8
9	Venkata Reddy	6.48	4.1	3.70	3.1
10	Ramachandra Reddy	0.46	4.3	4.17	1.7
	Mean	3.31	3.66	3.59	4.85
	SE	1.15	0.71	1.25	1.68
	CV (%)	109	61	110	110

Table 11a. *Aspergillus flavus* infection and aflatoxin contamination in groundnut seed from medium size pods from Pampanur farmer's fields

S.No	Farmer name	Farmer practice		Improved practice	
		A. flavus infection(%)	Aflatoxin (μg/kg)	*A. flavus* infection(%)	Aflatoxin (μg/kg)
1	Pedda Sardanappa	0.46	3.4	3.24	2.6
2	H. Narayana	0.00	4.6	0.00	8.8
3	Akkampalli Narayana	0.93	5.9	0.93	3.3
4	G. Naramma	0.00	8.4	0.00	11.9
5	G. Sreeramulu reddy	2.78	2.3	4.17	8.1
6	Edamala Ramanna	0.00	5.6	0.00	4.0
7	Meenaga Narayana	0.93	0.8	1.85	4.2
8	G. Ranga Reddy	1.39	1.9	0.00	1.8
9	Potte Ramanna	0.46	10.5	1.39	2.3
10	Potte Rajanna	0.00	8.9	0.00	12.0
11	Vadde Adinarayana	0.00	7.3	1.39	5.9
12	Kuruvu Akulappa	0.69	3.3	0.00	6.6
13	Kummari Thimmappa	0.46	3.1	0.93	4.7
14	G. Lakshmi Devamma	1.39	3.2	0.00	3.8
15	M. Mallarayudu	0.00	6.9	0.93	4.5
	Mean	0.63	5.07	0.99	5.63
	SE	0.20	0.73	0.33	0.83
	CV (%)	122	56	130	57

Table 11b. *Aspergillus flavus* infection and aflatoxin contamination in groundnut seed from medium size pods from Linganpalli farmer's fields

S.No	Farmer name	Farmer practice		Improved practice	
		A. flavus infection(%)	Aflatoxin (μg/kg)	*A. flavus* infection(%)	Aflatoxin (μg/kg)
1	Chenna Reddy	0.00	7.0	0.00	11.8
2	Govinda Reddy	1.39	774.5	1.39	3.4
3	Raghava Reddy	0.00	1.9	1.39	3.6
4	Narasimha Reddy	3.24	11.5	6.48	4.6
5	Bayyapu Reddy	7.87	12.3	1.39	12.0
6	Pedda Narayana	9.72	1224.9	12.50	15.5
7	Chinna Narayana	2.08	13.8	0.00	11.5
8	Pedda Sanjanna	1.39	1177.8	0.00	12.7
9	Venkata Reddy	0.00	7.2	1.85	5.9
10	Ramachandra Reddy	0.46	10.4	0.00	7.8
	Mean	2.62	324.13	2.50	8.88
	SE	1.09	164	1.26	1.37
	CV (%)	131	160	160	48

Table 12a. *Aspergillus flavus* infection and aflatoxin contamination in groundnut seed from small size pods from Pampanur farmer's fields

S.No	Farmer name	Farmer practice		Improved practice	
		A. flavus infection(%)	Aflatoxin (μg/kg)	*A. flavus* infection(%)	Aflatoxin (μg/kg)
1	Pedda Sardanappa	2.78	6.4	3.24	22.4
2	H. Narayana	3.70	14.1	0.46	12.4
3	Akkampalli Narayana	5.56	18.9	0.00	9.2
4	G. Naramma	0.00	17.0	3.24	29.1
5	G. Sreeramulu reddy	1.85	9.3	4.17	33.5
6	Edamala Ramanna	0.00	22.6	0.00	2.4
7	Meenaga Narayana	0.93	16.1	0.00	30.7
8	G. Ranga Reddy	0.00	12.7	1.39	7.6
9	Potte Ramanna	0.93	18.3	1.39	24.1
10	Potte Rajanna	2.78	9.9	0.00	8.3
11	Vadde Adinarayana	0.00	22.0	0.69	3.9
12	Kuruvu Akulappa	0.46	9.6	0.46	14.4
13	Kummari Thimmappa	0.46	25.3	0.93	5.1
14	G. Lakshmi Devamma	0.00	24.5	1.39	21.0
15	M. Mallarayudu	2.36	6.2	0.46	16.4
	Mean	1.45	15.53	1.19	16.15
	SE	0.43	1.6	0.34	2.66
	CV (%)	115	41	112	64

Table 12b. *Aspergillus flavus* infection and aflatoxin contamination in groundnut seed from small size pods from Linganpalli farmer's fields

S.No	Farmer name	Farmer practice		Improved practice	
		A. flavus infection(%)	Aflatoxin (μg/kg)	*A. flavus* infection(%)	Aflatoxin (μg/kg)
1	Chenna Reddy	0.00	19.7	1.85	16.7
2	Govinda Reddy	2.78	38.1	0.00	812.5
3	Raghava Reddy	1.39	0.0	6.94	6.8
4	Narasimha Reddy	0.00	0.0	0.46	58.2
5	Bayyapu Reddy	22.69	545.9	0.46	0.0
6	Pedda Narayana	2.78	786.6	3.24	15.6
7	Chinna Narayana	0.46	570.4	6.94	11.3
8	Pedda Sanjanna	2.78	1968.7	0.00	9.2
9	Venkata Reddy	0.00	18.5	0.46	11.9
10	Ramachandra Reddy	1.39	1410.3	1.39	9.3
	Mean	3.43	535	2.18	95
	SE	2.17	217	0.85	80
	CV (%)	200	128	124	265

Table 13a. Estimation of aflatoxin in groundnut seed from insect damaged pods from Pampanur

S.No	Farmer name	Aflatoxin (µg/kg)	
		Farmer practice	Improved practice
1	Pedda Sardanappa	9.2	14.5
2	H. Narayana	7.3	8.7
3	Akkampalli Narayana	5652.4	1330.9
4	G. Naramma	25.7	9.2
5	G. Sreeramulu reddy	6.7	6.2
6	Edamala Ramanna	13.8	7.7
7	Meenaga Narayana	522.9	207.4
8	G. Ranga Reddy	5.7	3.8
9	Potte Ramanna	6.0	5.3
10	Potte Rajanna	10.8	5.7
11	Vadde Adinarayana	12.3	32.2
12	Kuruvu Akulappa	1487.0	6.0
13	Kummari Thimmappa	7.0	147.1
14	G. Lakshmi Devamma	4.1	NT
15	M. Mallarayudu	5.1	6.5
	Mean	518	128
	SE	380	94
	CV (%)	284	275

Table 13b. Estimation of aflatoxin in groundnut seed from insect damaged pods from Linganpalli

S.No	Farmer name	Aflatoxin (µg/kg)	
		Farmer practice	Improved practice
1	Chenna Reddy	13.0	28.6
2	Govinda Reddy	5.0	8.6
3	Raghava Reddy	155.9	3.5
4	Narasimha Reddy	108.3	685.3
5	Bayyapu Reddy	4231.7	4.3
6	Pedda Narayana	8203.9	6734.4
7	Chinna Narayana	15.5	NT
8	Pedda Sanjanna	NT	10.6
9	Venkata Reddy	61.5	13.9
10	Ramachandra Reddy	24.1	NT
	Mean	1424	936
	SE	964	832
	CV (%)	203	251

Table 14. Recovery of AFM1 from artificially contaminated milk samples as determined by ELISA.

S. No	Concentration of AFM1 used for spiking (ng/ml)	Concentration of AFM1 estimated (ng/ml)[a]	Percent recoveries of AFM1 in spiked samples[b]
1	0.25	0.26 ± 0.1	104 ± 7.8
2	0.5	0.47 ± 0.1	94 ± 7.0
3	1	0.97 ± 0.1	97 ± 7.5
4	5	4.53 ± 0.4	93 ± 8.3
5	10	9.43 ± 0.8	94 ± 7.8
6	25	27.4 ± 1.4	108 ± 7.4
7	50	48.1 ± 2.2	95 ± 3.1
8	CRM <0.05	0.07 ± 0.2	140 ± 3.1
9	CRM 0.76	0.79 ± 0.1	97 ± 2.2

[a] Each sample was spiked with a known concentration of AFM1, extracted in 70% methanol and assayed. Data represent mean of three replications ± SD. [b] Determined by the formula, Detected AFM1 (ng/ml) divided by the concentration of AFM1 used for spiking and multiplied by 100. Values are Means ± SD

Table 15. Incidence and range of aflatoxin M1 in milk samples

S.No	Sample type	Total no.of samples	%Samples with >0.5ng/ml	No. of samples with AFM1 content (ng/ml) in the range of				
				0-0.5	0.6-15	16-30	31-45	48
1	Raw milk (peri urban)	116	93	8	59	37	11	1
2	Raw milk (rural)	236	34	155	74	3	4	0
3	Milk packets	44	36	28	11	5	0	0
4	Powered milk (g of dry milk/ml of solution)	10	50	5	5	0	0	0
5	Milk products (g of dry milk/ml of solution)	10	30	7	3	0	0	0

Table 16. Groundnut aflatoxin levels in storage samples in Anantapur

S.No	Source	Total no. of samples	No of samples with aflatoxin (μg/kg)				
			<10	10-30	31-100	100-500	>500
1	Farmer storage	50	42	1	4	2	1
2	Traders storage	229	160	23	13	27	6
3	Oil millers storage	233	169	32	15	8	9
4	Insect damaged	48	28	9	2	1	8
5	Groundnut cake	56	1	10	0	43	2
6	Pod with haulms	80	56	15	7	0	2

Table 17. Aflatoxin content in groundnut samples inoculated with *A. flavus* isolated

S.No.	Isolate No.	Identity	Aflatoxin (μg/kg)
1	AF 02	AF 2	3592
2	AF 03	AF P-39	58
3	AF 06	AF S3	3680
4	AF 07	AF 90-2	42
5	AF 08	AF 92	16
6	AF 09	AF 8-3-2A	17
7	AF 11	AF K-137	33
8	AF 15	AF 3	11
9	AF 17	AF Non-tox	3327
10	AF 18	NRRL 3000	2512
11	AF 19	V 3734/10	115
12	AF 22	ARS 46	8
13		F 5(ICGS)	8
14	AF 8		17
15	AF 9		8
16	AF 11		19
17	AF 16		6091
18	AF 16-1		2146
19	AF 19-1		4327
20	AF 19-3		2797
21	AF 11-4		9581
22	AF 16-5		20
23	AF 6-5	TMV 2 A'Pu	6178
24	AF 10-1	TMV 2 A'Pu	7371
25		G 10 seed	20
26		AP nor-NK	140
27	AF 4	AF T-915	623
28	AF 4-1	Soil; A'pur	2395
29	AF 8-1	Soil; A'pur	12
30	AF 8-2	Soil; A'pur	13
31	AF (Tiru)		26

Table 18. Isolates purchased from the Food Science Australia (AFISC).

Species	**QUB isolate code**	**ICRISAT isolate code**	**B1 Toxin Prod.**
Aspergillus flavus	Afnt1	Af 9	N
Aspergillus flavus	Afnt2	Af 24	N
Aspergillus flavus	Afnt3	Af 4086*	N
Aspergillus flavus	Afnt4	Af 4288*	N
Aspergillus flavus	Aft1	Af 10-1	Y
Aspergillus flavus	Aft2	Af 11-4	Y
Aspergillus flavus	Aft3	Af 2746*	Y
Aspergillus flavus	Aft4	Af 4473*	Y
Aspergillus flavus	Aft5	I-1	Y (300 μg kg^{-1})
Aspergillus flavus	Aft6	I-2	Y (300 μg kg^{-1})
Aspergillus flavus	Aft7	I-3	Y (1500 μg kg^{-1})
Aspergillus flavus	Aft8	I-4	Y (200 μg kg^{-1})
Aspergillus flavus	Aft9	I-5	Y (150 μg kg^{-1})
Aspergillus flavus	Aft10	I-6	Y (500 μg kg^{-1})
Aspergillus flavus	AfA	AfA	Not tested
Aspergillus flavus	AfB	AfB	Not tested
Aspergillus parasiticus	Apnt1	Ap 16-5	N
Aspergillus parasiticus	Apnt2	Ap 01	N
Aspergillus parasiticus	Apnt3	Ap 4467*	N
Aspergillus parasiticus	Apnt4	Ap 4468*	N
Aspergillus parasiticus	Apt1	Ap 16	Y
Aspergillus parasiticus	Apt2	Ap16-1	Y
Aspergillus parasiticus	Apt3	Ap 2501*	Y
Aspergillus parasiticus	Apt4	Ap 2745*	Y
Aspergillus parasiticus	Apt5	Ap 2756*	Y

Table 19. Percentage infection of two lots of kernels with *Aspergillus flavus* and *A. niger*

	Infection (%)	
Sample	*A. flavus*	*A. niger*
A (500 kernels)	<1.0	2.8
B (200 kernels)	1.0	3.0

Table 20. Effect of RH on kernel moisture content (%MC) after 21, 70 and 150 d in storage [Experiment 1]

	RH (%)					
Harvest	13	25	43	57	75	SED
21 d	5.2	6.5	10.3	12.6	14.9	0.76***
70 d	4.5	4.7	5.4	7.0	10.4	0.21***
150 d	3.1	3.8	4.9	5.7	7.9	0.08***

Table 21. Aflatoxin contamination (μg kg^{-1}) in dry and wet kernels at three temperatures after 7 and 42 d in storage [Experiment 1]

Temperature (°C)	7 d			42d		
	Dry	Wet	Mean	Dry	Wet	Mean
24	4678	3639	4158	4114	4116	4115
30	3850	1360	2605	4281	4073	4177
36	5098	244	2671	3681	3564	3623
Mean	4542	1748		4025	3918	
SED Moisture		270.1***			214.2	
SED Moisture × Temperature		468.8***				371.1

Table 22. Kernel moisture content (%MC), % infection with *A. flavus* and aflatoxin contamination (μg kg^{-1}) in dry, intermediate and wet pods stored for 7 and 105 d [Experiment 2]

	Dry	Intermediate	Wet	SED
Initial %MC	8.4	15.5	22.7	-
%MC at 7 d	7.9	7.9	8.1	0.23
%MC at 105 d	7.2	7.1	7.2	0.26
Infection (%) at 7d	36	46	70	3.1***
Infection (%) at 105 d	49	52	70	2.5***
Aflatoxin (μg kg^{-1}) at 7 d	547	924	2435	304.7***
Aflatoxin (μg kg^{-1}) at 105 d	3799	4179	4768	210.2***

Table 23. Kernel moisture content (%MC), % infection with *A. flavus* and aflatoxin contamination (μg kg^{-1}) in pods stored at different RH for 7 and 105 d [Experiment 2]

	RH (%)				
	30	50	70	90	SED
%MC at 7 d	4.1	5.6	7.5	14.5	0.77***
%MC at 105 d	5.0	5.3	6.1	12.3	0.44***
Infection (%) at 7 d	43	43	47	67	6.9
Infection (%) at 105 d	40	38	54	98	8.8*
Aflatoxin (μg kg^{-1}) at 7 d	204	574	684	3747	
Aflatoxin (μg kg^{-1}) at 105 d	986	403	725	14880	

Table 24. Parameters to be included in preliminary and full analyses of aflatoxin contamination at harvest (μg kg^{-1})

	Parameter	Units
Preliminary	Pod yield	Kg ha^{-1}
	Proportion of small pods at harvest	%
Full		
As above plus:	*Aspergillus flavus* colonies at flowering	Cpu
	Aspergillus flavus colonies at harvest	Cpu
	Wealth ranking of farmers	Catagories
	Mean soil temperature	^{O}C
	Number of dry days during pod-filling	D

Table 25. Summary of the difference in farmer and improved production practices at Linganapalli and Pampanur

	Linganapalli		Pampanur		
	Farmer	Improved	Farmer	Improved	P
Pod yield (kg ha^{-1})	297	334	398	494	<0.01
Aflatoxin (μg kg^{-1}	536	95	13	17	<0.001
Small pods (%)	16.5	16.5	9.9	10.6	<0.05
Dry spell duration (d)	42		35		
Soil temperature (°C)	28.4		27.2		

Table 26. Groundnut pod yield against different treatments of aflatoxins management trail at ICRISAT-patancheru center during 2002 rainy season

Treatments	Pod yield (kg/ha)			
	Variety JL 24		Variety J 11	
	Control	Treatment	Control	Treatment
Compost	706.4	741.7	571.4	702.2
Cereal residue	793.9	849.7	768.1	783.6
Gypsum	885.6	778.9	640.0	716.7
Bio-control	863.6	820.8	773.3	726.7
Compost + Cereal residue	718.3	624.4	648.6	595.3
Compost + Gypsum	789.2	875.6	718.3	593.9
Compost +Bio-control	867.8	846.9	719.2	688.1
Cereal residue + Gypsum	914.7	731.9	751.4	621.4
Cereal residue + Bio-control	887.8	687.2	730.0	726.4
Gypsum + Bio-control	814.4	926.7	705.0	760.8
Compost + Cereal residue + Gypsum	743.6	776.4	685.3	632.8
Compost + Cereal residue + Bio-control	725.8	585.3	606.4	548.1
Cereal residue + Bio-control + Gypsum	758.9	783.9	632.8	651.7
Gypsum + Bio-control + Compost	748.9	796.9	718.3	764.2
Compost + Cereal residue + Gypsum + Bio-control	853.3	663.6	699.7	629.4
SE 66.07 CV (%) 11.4				

Table 27. Pre-harvest *Aspergillus flavus* infection and aflatoxins contamination in groundnut samples collected from on station trail at ICRISAT-Patancheru center during 2002 rainy season

Treatments	Control JL 24		Treatment JL 24		Control J 11		Treatment J 11	
	A.flavus inf.(%)	Aflatoxin (μg/kg)	*A.flavus* inf.(%)	Aflatoxin (μg/kg)	*A.flavus* Inf.(%)	Aflatoxin (μg/kg)	*A.flavus* inf.(%)	Aflatoxin (μg/kg)
Compost	0.00 (0.00)	5 (0.692)	0.33 (1.91)	43 (1.321)	0.67 (3.83)	2774 (2.568)	0.67 (2.71)	34 (1.171)
Cereal residue	1.00 (4.62)	73 (1.291)	0.67 (3.83)	6 (0.801)	0.67 (2.71)	106 (1.001)	1.67 (7.33)	3 (0.549)
Gypsum	1.00 (4.62)	1263 (1.891)	1.00 (4.62)	183 (1.447)	3.00 (7.82)	214 (1.612)	1.00 (4.62)	10 (0.908)
Bio-control	8.00 (15.49)	1067 (1.982)	1.67 (4.31)	23 (1.173)	2.00 (6.56)	25 (1.003)	1.00 (3.32)	330 (1.439)
Compost + Cereal residue	3.33 (8.44)	5021 (2.730)	2.00 (7.95)	183 (1.471)	1.67 (6.03)	2 (0.376)	2.33 (8.47)	348 (2.250)
Compost + Gypsum	1.33 (5.24)	759 (1.394)	6.00 (8.37)	63 (1.515)	0.33 (1.91)	2 (0.411)	8.00 (13.71)	267 (1.923)
Compost + Bio-control	1.33 (3.85)	4 (0.518)	15.33 (18.00)	1466 (2.555)	2.00 (4.73)	11 (0.796)	2.00 (6.56)	253 (1.614)
Cereal residue + Gypsum	3.00 (7.39)	12 (0.945)	4.67 (12.36)	56 (1.323)	3.00 (7.39)	489 (2.444)	2.33 (7.17)	108 (1.316)
Cereal residue + Bio-control	1.33 (5.42)	45 (0.887)	1.33 (5.24)	2258 (2.096)	0.67 (3.83)	3835 (2.040)	0.67 (2.71)	154 (1.060)
Gypsum + Bio-control	6.33 (13.02)	282 (1.782)	2.00 (6.22)	10 (0.611)	0.00 (0.00)	29 (0.987)	1.33 (6.54)	2 (0.445)
Compost + Cereal residue + Gypsum	5.67 (12.68)	7 (0.801)	3.33 (9.74)	245 (1.648)	2.00 (6.65)	46 (0.866)	4.00 (10.71)	3 (0.638)
Compost + Cereal residue + Bio-control	2.67 (7.63)	200 (2.147)	3.33 (9.74)	73 (1.532)	0.67 (2.71)	21 (1.283)	1.00 (3.32)	22 (1.063)
Cereal residue + Bio-control + Gypsum	3.00 (9.35)	560 (2.761)	1.00 (4.62)	5081 (2.688)	1.00 (3.32)	81 (1.308)	4.33 (11.76)	29 (0.977)
Gypsum + Bio-control + Compost	2.33 (7.17)	1811 (1.661)	3.67 (8.53)	49 (1.150)	2.33 (7.02)	3381 (1.748)	2.00 (4.73)	6 (0.814)
Compost + Cereal residue + Gypsum + Bio-control	0.67 (2.71)	625 (1.446)	0.33 (1.91)	2170 (1.871)	1.00 (3.32)	3 (0.608)	0.67 (2.71)	20 (1.134)
A. flavus infection: SE 2.37 (3.60) and CV (%) 129 (70) Aflatoxin contamination: SE 1120 (0.61) and CV(%) 296 (70)								

Figures in parenthesis are angular and Log 10 transformed values for *A. flavus* infection and aflatoxins contamination respectively

Table 28. *Aspergillus flavus* infection and aflatoxins contamination in groundnut seed from large size pod collected from on station trail at ICRISAT-Patancheru center during 2002 rainy season

Treatments	Control JL 24		Treatment JL 24		Control J 11		Treatment J 11	
	A.flavus inf.(%)	Aflatoxin (μg/kg)	*A.flavus* inf.(%)	Aflatoxin (μg/kg)	*A.flavus* Inf. (%)	Aflatoin (μg/kg)	*A.flavus* inf.(%)	Aflatoxin (μg/kg)
Compost	0.00 (0.00)	2 (0.341)	0.00 (0.00)	5 (0.709)	0.33 (1.91)	3 (0.435)	3.67 (6.46)	6 (0.548)
Cereal residue	0.33 (1.91)	1 (0.144)	1.00 (3.32)	1 (0.235)	0.00 (0.00)	0 (0.121)	0.00 (0.00)	0 (0.107)
Gypsum	2.00 (4.73)	2 (0.327)	1.00 (4.62)	3 (0.472)	4.00 (6.76)	2 (0.282)	0.33 (1.91)	2 (0.365)
Bio-control	3.67 (8.53)	1 (0.23)	2.67 (7.44)	4 (0.493)	0.33 (1.91)	1 (0.208)	3.00 (7.82)	5 (0.487)
Compost + Cereal residue	4.00 (8.37)	1 (0.133)	7.33 (9.32)	116 (0.847)	4.33 (7.04)	3 (0.441)	4.00 (6.76)	1 (0.138)
Compost + Gypsum	1.00 (4.62)	0 (0.00)	2.67 (9.08)	1 (0.301)	0.33 (1.91)	1 (0.177)	1.67 (4.31)	102 (0.943)
Compost + Bio-control	5.67 (8.12)	1 (0.154)	1.00 (4.62)	0 (0.114)	6.00 (10.57)	2 (0.269)	0.33 (1.91)	1 (0.138)
Cereal residue + Gypsum	13.33 (16.14)	0 (0.00)	12.67 (16.21)	0 (0.00)	5.33 (12.49)	1 (0.208)	5.00 (9.75)	0 (0.00)
Cereal residue + Bio-control	0.00 (0.00)	0 (0.00)	0.00 (0.00)	0 (0.00)	0.67 (3.83)	0 (0.00)	0.67 (2.71)	0 (0.00)
Gypsum + Bio-control	0.33 (1.91)	771 (1.121)	0.00 (0.00)	1 (0.269)	0.33 (1.91)	1 (0.283)	0.00 (0.00)	11 (0.697)
Compost + Cereal residue + Gypsum	3.33 (6.14)	1 (0.138)	1.67 (5.76)	5 (0.694)	1.33 (3.85)	1 (0.164)	3.00 (5.82)	1 (0.314)
Compost + Cereal residue + Bio-control	0.33 (1.91)	0 (0.00)	0.33 (1.91)	2 (0.318)	2.00 (7.95)	0 (0.107)	0.67 (3.83)	0 (0.00)
Cereal residue + Bio-control + Gypsum	0.67 (2.71)	1 (0.159)	1.33 (5.24)	1 (0.208)	1.67 (6.03)	851 (1.268)	0.00 (0.00)	0 (0.00)
Gypsum + Bio-control + Compost	0.33 (1.91)	0 (0.00)	0.67 (2.71)	1 (0.227)	0.00 (0.00)	0 (0.00)	0.00 (0.00)	0 (0.127)
Compost + Cereal residue + Gypsum + Bio-control	1.00 (4.62)	0 (0.100)	0.33 (1.91)	0 (0.00)	0.33 (1.91)	1 (0.214)	0.00 (0.00)	0 (0.00)
A. flavus infection: SE 2.80 (4.10) and CV (%) 150 (102) Aflatoxin contamination: SE 150 (0.29) and CV(%) 812 (182)								

Figures in parenthesis are angular and Log 10 transformed values for *A. flavus* infection and aflatoxins contamination respectively

Table 29. *Aspergillus flavus* infection and aflatoxins contamination in groundnut seed from medium size pod collected from on station trail at ICRISAT-Patancheru center during 2002 rainy season

Treatments	Control JL 24		Treatment JL 24		Control J 11		Treatment J 11	
	A.flavus inf.(%)	Aflatoxin (μg/kg)	*A.flavus* inf.(%)	Aflatoxin (μg/kg)	*A.flavus* Inf. (%)	Aflatoin (μg/kg)	*A.flavus* inf.(%)	Aflatoxin (μg/kg)
Compost	0.33 (1.91)	1 (0.315)	0.33 (1.91)	3 (0.437)	0.33 (1.91)	1 (0.303)	2.67 (7.44)	1 (0.239)
Cereal residue	0.33 (1.91)	1 (0.235)	0.00 (0.00)	672 (1.578)	1.00 (4.62)	1 (0.310)	0.00 (0.00)	1 (0.154)
Gypsum	2.00 (4.73)	13 (0.764)	0.00 (0.00)	1 (0.297)	8.00 (11.47)	2 (0.425)	1.00 (5.74)	2 (0.318)
Bio-control	1.00 (4.62)	2 (0.330)	1.67 (5.76)	2 (0.480)	0.00 (0.00)	124 (1.057)	3.67 (8.06)	3 (0.583)
Compost + Cereal residue	0.67 (2.71)	0 (0.000)	0.33 (1.91)	41 (1.101)	0.00 (0.00)	0 (0.107)	1.33 (5.24)	378 (1.454)
Compost + Gypsum	1.67 (4.31)	1 (0.234)	1.00 (4.62)	80 (1.086)	0.67 (2.71)	6 (0.432)	0.00 (0.00)	1 (0.149)
Compost + Bio-control	3.67 (8.06)	2 (0.412)	0.33 (1.91)	129 (0.863)	9.33 (10.65)	539 (2.033)	1.00 (4.62)	1 (0.133)
Cereal residue + Gypsum	4.00 (8.37)	1 (0.164)	3.00 (9.54)	6 (0.434)	1.00 (4.62)	1 (0.244)	1.67 (5.76)	0 (0.133)
Cereal residue + Bio-control	0.00 (0.00)	1 (0.303)	0.00 (0.00)	2 (0.402)	0.33 (1.91)	832 (1.389)	0.00 (0.00)	1 (0.290)
Gypsum + Bio-control	1.00 (4.62)	1 (0.233)	1.67 (6.03)	1 (0.168)	0.33 (1.91)	1 (0.181)	1.67 (7.15)	1 (0.304)
Compost + Cereal residue + Gypsum	6.67 (11.44)	0 (0.000)	2.00 (6.56)	4 (0.492)	5.33 (12.70)	0 (0.114)	2.33 (7.17)	1 (0.278)
Compost + Cereal residue + Bio-control	1.33 (5.42)	3 (0.486)	0.00 (0.00)	2 (0.501)	1.67 (7.15)	3 (0.514)	0.00 (0.00)	1 (0.282)
Cereal residue + Bio-control + Gypsum	5.00 (9.24)	1 (0.305)	1.00 (4.62)	1 (0.233)	4.33 (7.04)	3 (0.351)	0.67 (3.83)	1 (0.256)
Gypsum + Bio-control + Compost	2.00 (6.56)	595 (1.233)	0.33 (1.91)	1 (0.230)	1.00 (5.74)	654 (1.098)	0.67 (2.71)	136 (1.423)
Compost + Cereal residue + Gypsum + Bio-control	0.00 (0.00)	1 (0.316)	0.00 (0.00)	13 (0.730)	0.67 (2.71)	421 (1.154)	0.33 (1.91)	1 (0.168)
A. flavus infection: SE 2.16 (3.44) and CV (%) 152 (91) Aflatoxin contamination: SE 128 (0.41) and CV(%) 475 (149)								

Figures in parenthesis are angular and Log 10 transformed values for *A. flavus* infection and aflatoxins contamination respectively

Table 30. *Aspergillus flavus* infection and aflatoxins contamination in groundnut seed from small size pod collected from on station trail at ICRISAT-Patancheru center during 2002 rainy season

Treatments	Control JL 24		Treatment JL 24		Control J 11		Treatment J 11	
	A.flavus inf.(%)	Aflatoxin (µg/kg)	*A.flavus* inf.(%)	Aflatoxin (µg/kg)	*A.flavus* Inf. (%)	Aflatoin (µg/kg)	*A.flavus* inf.(%)	Aflatoxin (µg/kg)
Compost	1.33 (5.42)	1 (0.159)	4.33 (9.78)	986 (2.111)	2.33 (6.64)	305 (0.987)	1.33 (6.54)	0 (0.000)
Cereal residue	3.00 (7.82)	0 (0.000)	0.67 (3.83)	0 (0.000)	0.33 (1.91)	1031 (1.532)	1.00 (4.62)	0 (0.000)
Gypsum	24.67 (21.48)	2 (0.280)	1.33 (6.54)	87 (1.024)	21.33 (17.71)	29 (1.100)	1.33 (5.24)	112 (0.843)
Bio-control	3.00 (7.82)	2718 (2.835)	4.67 (11.85)	48 (0.719)	0.67 (2.71)	1471 (2.061)	1.33 (3.85)	1031 (2.126)
Compost + Cereal residue	17.6 (20.65)	1528 (2.531)	4.33 (11.24)	719 (1.111)	5.00 (10.08)	1055 (2.856)	3.00 (9.60)	1158 (1.180)
Compost + Gypsum	5.00 (10.87)	0 (0.000)	4.00 (10.71)	0 (0.000)	1.33 (5.24)	14 (0.548)	2.00 (4.73)	0 (0.000)
Compost + Bio-control	14.33 (15.38)	0 (0.000)	2.67 (7.03)	0 (0.000)	2.33 (7.17)	18 (0.896)	3.00 (7.82)	0 (0.000)
Cereal residue + Gypsum	1.33 (5.24)	0 (0.000)	8.33 (13.74)	702 (1.108)	1.00 (4.62)	0 (0.000)	1.67 (7.15)	0 (0.000)
Cereal residue + Bio-control	1.00 (4.62)	2 (0.295)	0.33 (1.91)	0 (0.000)	0.33 (1.91)	889 (1.712)	1.33 (3.85)	1578 (1.339)
Gypsum + Bio-control	2.67 (7.63)	0 (0.000)	3.00 (9.35)	0 (0.000)	0.33 (1.91)	0 (0.100)	0.67 (3.83)	0 (0.000)
Compost + Cereal residue + Gypsum	13.00 (17.51)	8 (0.472)	9.00 (13.10)	620 (1.090)	3.67 (8.96)	24 (1.043)	3.33 (8.19)	4 (0.371)
Compost + Cereal residue + Bio-control	0.67 (3.83)	493 (1.868)	0.67 (2.71)	2 (0.266)	1.00 (4.62)	0 (0.000)	1.33 (5.24)	3 (0.318)
Cereal residue + Bio-control + Gypsum	1.33 (6.54)	0 (0.000)	3.33 (8.44)	2 (0.271)	3.33 (9.30)	52 (0.732)	0.33 (1.91)	158 (0.892)
Gypsum + Bio-control + Compost	1.67 (5.76)	0 (0.000)	0.67 (3.83)	1040 (1.852)	1.33 (5.24)	2601 (2.346)	0.00 (0.00)	102 (0.830)
Compost + Cereal residue + Gypsum + Bio-control	1.00 (4.62)	85 (1.382)	3.33 (10.40)	0 (0.000)	0.00 (0.00)	0 (0.000)	0.67 (3.83)	143 (0.877)
A. flavus infection: SE 2.37 (3.60) and CV (%) 129 (70) Aflatoxin contamination: SE 1120 (0.61) and CV(%) 296 (70)								

Figures in parenthesis are angular and Log 10 transformed values for *A. flavus* infection and aflatoxins contamination respectively

Table 31. Aflatoxins contamination in groundnut seed from damaged pod

Treatments	Aflatoxin (µg/kg)			
	Control		Treatment	
	JL 24	J 11	JL 24	J 11
Compost	745 (2.381)	1769 (2.651)	1680 (2.713)	758 (1.820)
Cereal residue	40 (1.588)	1713 (3.183)	581 (2.353)	1621 (3.089)
Gypsum	313 (1.945)	611 (2.484)	1142 (1.744)	88 (1.689)
Bio-control	1492 (2.543)	699 (2.156)	16 (1.207)	908 (2.073)
Compost + Cereal residue	1145 (2.790)	618 (2.472)	340 (2.202)	881 (2.630)
Compost + Gypsum	1521 (2.518)	962 (1.604)	567 (2.220)	704 (2.019)
Compost +Bio-control	1970 (2.722)	152 (1.581)	988 (2.486)	101 (1.591)
Cereal residue + Gypsum	335 (1.802)	1266 (2.536)	1501 (2.351)	216 (1.765)
Cereal residue + Bio-control	232 (1.855)	949 (2.730)	241 (1.102)	983 (2.915)
Gypsum + Bio-control	12 (1.097)	431 (2.156)	988 (2.293)	392 (1.987)
Compost + Cereal residue + Gypsum	129 (1.178)	484 (2.161)	383 (1.370)	6 (0.656)
Compost + Cereal residue + Bio-control	552 (2.027)	406 (1.339)	612 (2.162)	50 (1.466)
Cereal residue + Bio-control + Gypsum	596 (2.221)	1774 (2.615)	1686 (2.726)	290 (1.991)
Gypsum + Bio-control + Compost	1497 (2.645)	1190 (2.660)	2227 (2.669)	1598 (2.747)
Compost + Cereal residue + Gypsum + Bio-control	1155 (2.502)	949 (2.085)	1080 (2.330)	944 (2.297)
A. flavus infection: SE 2.37 (3.60) and CV (%) 129 (70) Aflatoxin contamination: SE 1120 (0.61) and CV(%) 296 (70)				

Figures in parenthesis are Log 10 transformed values for aflatoxins contamination

Table 32. Aflatoxin contamination in market samples

S.No.	Particulars	Total No. of samples	% samples with >10 μg/kg	Aflatoxin range μg/kg	No. of samples with aflatoxin in the range (μg/kg)				
					<10	11-30	31-50	51-100	>100
1	Maize	74	43	0-806	43	14	6	6	7
2	Sorghum seed	8	0	0-2	8	0	0	0	0
3	Soy bean cake	19	89	7-81	2	11	5	1	0
4	Groundnut cake	17	100	18-1007	0	2	0	2	13
5	Groundnut seed	67	27	0-1776	53	6	2	4	12
6	Cotton cake	9	100	11-43	0	5	1	0	0
7	Poultry feed	10	40	3-34	6	3	1	0	0

Table 33 *Aspergillus flavus* population (000 cfu / g. soil) in on farm trials as influenced by management practices

Farmer	At flowering		At harvest	
	IP	FP	IP	FP
P.Sardanappa	5.75 (3.76)	6.8 (3.83)	82.0 (4.91)	46.5 (4.67)
K.Thimmappa	5.35 (3.73)	3.30 (3.52)	71.5 (4.85)	10.0 (4.00)
Y.Ramanna	2.95 (3.47)	0.35 (2.54)	47.0 (4.67)	49.5 (4.69)
M.Narayana	9.00 (3.95)	3.55 (3.55)	66.5 (4.82)	69.5 (4.84)
G.Rangareddy	7.55 (3.88)	5.50 (3.74)	09.0 (3.95)	22.0 (4.34)
P.Rajanna	4.35 (3.64)	3.75 (3.57)	16.5 (4.22)	16.0 (4.20)
V.Adinarayana	5.20 (3.72)	4.65 (3.67)	17.0 (4.23)	26.0 (4.41)
P.Ramanna	2.55 (3.41)	2.05 (3.31)	17.0 (4.23)	09.0 (3.95)
K.Akkulappa	1.10 (3.04)	5.15 (3.71)	31.0 (4.49)	31.0 (4.49)
G.Lakshmidevamm	5.70 (3.76)	1.85 (3.27)	31.5 (4.50)	12.0 (4.08)
H.Mallarayudu	1.35 (3.13)	0.90 (2.95)	09.0 (3.95)	21.5 (4.33)
H.Narayana	1.25 (3.10)	2.05 (3.31)	66.0 (4.82)	81.0 (4.91)
G.S.Reddy	2.65 (3.42)	7.30 (3.86)	43.5 (4.64)	93.0 (4.97)
A.Narayana	6.25 (3.80)	9.85 (3.99)	59.5 (4.77)	44.0 (4.64)
Mean	4.4 (3.56)	4.1 (3.49)	40.5 (4.42)	37.9 (4.47)
SEm	0.07		0.05	
CD 5%	NS		NS	

Table 34 *Aspergillus flavus* population as influenced by supplemental irrigation and management practices

	A.flavus population ('000 cfu/g)	
	Flowering	**Harvest**
Irrigation		
Supplemental	1.64 (3.72)	132.40 (5.12)
Rainfed	9.19 (3.76)	82.12 (4.83)
SEm ±	0.21	0.03
CD 5%	NS	0.18
Management		
Control	9.97 (3.63)	155.00 (5.10)
Seed treatment	8.26 (3.75)	76.00 (4.86)
Gypsum	9.42 (3.86)	94.65 (4.85)
LLS	8.94 (3.85)	74.35 (4.83)
Trichoderma	(3.62)	136.30 (4.84)
SEm ±	0.41	0.14
CD 5%	0.62	0.41

- **Figures in parantheses indicate log transformed values**

Table 35. *Aspergillus flavus* infection and aflatoxin contamination in pre-harvest groundnut seed samples collected from Pampanur (Anantapur) farmer fields during 2002 rainy season

S.No	Farmer name	Farmer practice		Improved practice	
		A. flavus infection(%)	Aflatoxin (μg/kg)	*A. flavus* infection(%)	Aflatoxin (μg/kg)
1	Pedda Sardanappa	1	0.0	2	0.0
2	H. Narayana	0	2.4	1	2.2
3	Akkampalli Narayana	9	1.9	3	2.5
4	G. Sreeramulu reddy	2	0.0	5	16.2
5	Edamala Ramanna	1	2.8	2	496.9
6	Meenaga Narayana	6	5.8	0	1.4
7	G. Ranga Reddy	0	3.3	2	2.3
8	Potte Ramanna	4	1.7	0	0.0
9	Potte Rajanna	4	4.7	1	2.7
10	Vadde Adinarayana	5	52.4	3	11.7
11	Kuruvu Akulappa	6	3.3	6	6.1
12	Kummari Thimmappa	0	0.0	2	0.0
13	G. Lakshmi Devamma	9	1.0	6	0.0
14	M. Mallarayudu	6	3.0	3	3.0
	Mean	3.79	5.88	2.57	38.93

Table 36. Pod and haulm yield (kg/ha) of groundnut as influenced by different management practices

Farmer	Pod yield		Haulm yield	
	IP	FP	IP	FP
P.Sardanappa	511	421	967	880
K.Thimmappa	337	296	623	531
Y.Ramanna	487	375	770	584
M.Narayana	435	381	802	765
G.Rangareddy	587	483	1096	785
P.Rajanna	281	265	460	320
V.Adinarayana	221	192	360	303
P.Ramanna	221	207	381	315
K.Akkulappa	408	392	744	700
G.Lakshmidevamma	296	286	390	319
H.Mallarayudu	255	216	337	301
H.Narayana	509	500	990	860
G.S.Reddy	333	325	577	404
A.Narayana	437	419	723	650
Mean	380	341	630	552
SEm	6.7		20.8	
CD 5%	20		64	

Table 37. Pod yield of groundnut (kg/ha) as influenced by supplemental irrigation and management practices

Treatment	Irrigated	Rainfed	Mean	
Control	407	252	330	
Seed treatment	468	252	360	
Gypsum	467	252	360	
LLS management	412	268	340	
Trichoderma	427	229	328	
Mean	436	251		
	Irrigated	Management	I at M	M at I
SEm	10.41	17.14	43.13	24.24
CD 5%	63	NS	154	NS

Table 38. Haulm yield of groundnut (kg/ha) as influenced by supplemental irrigation and management practices

Treatment	Irrigated	Rainfed	Mean	
Control	758	409	583	
Seed treatment	732	408	570	
Gypsum	766	408	587	
LLS management	693	407	550	
Trichoderma	686	376	531	
Mean	727	406		
	Irrigated	Management	I at M	M at I
Sem	12.06	12.48	47.99	17.65
CD 5%	73	37	198	73

APPENDICES

Staad

Report – 1

Socio- Economic Determinants of Farmers Practices and Perceptions in Groundnut Based Livelihood Systems in Andhra Pradesh – An Analysis of Their Implications for Reducing Aflatoxin Contamination.

Of the project on

Strategies for reducing aflatoxin levels in groundnut-based foods and feeds in India:

A step towards improving health of humans and livestock

For the

International Crops Research institute for the Semi-Arid Tropics (ICRISAT)

and

Natural Resource International, UK.

Prepared by

Rama Devi Kolli

Socio-economic advisor

Andy Hall

SOCIETY FOR TRANSFORMATION, AGRICULTURE AND ALTERNATIVES IN DEVELOPMENT

Socio- Economic Determinants of Farmers Practices and Perceptions in Groundnut Based Livelihood Systems in Andhra Pradesh – An Analysis of Their Implications for Reducing Aflatoxin Contamination.

I. Introduction

Solving the problem of aflatoxin contamination in groundnut is not an end by itself. It is a signal to researchers that it is only a tip of the iceberg. To get to the bottom of the problem one needs to understand the underlying reasons that had triggered off this problem.

Groundnut is grown extensively in Ananthapur and Chittoor districts of Andhra Pradesh primarily as a rain fed crop. It is cultivated by all types of farmers (rich/ poor, small/ big, etc), in different types of soils. Groundnut cultivation in this region is therefore constrained by factors such as weather, labor availability, credit, mechanization, marketing practices, social structures that govern power relations between rich and poor, institutional support for knowledge, skills etc. Farmers' crop management practices and their market behavior patterns hence, depend upon a range of socio-economic factors that seem to have implications for aflatoxin contamination.

Aflatoxin contamination is an unknown phenomenon in the farming systems of the study region. Farmers, as producers of groundnuts and consumers of groundnut products, are not aware of aflatoxins and their ill affects on the health of people and animals, and hence do not perceive aflatoxin contamination as a problem. Aflatoxin contamination is neither visible to them nor do they have any wide spread experiences to perceive its ill effects on their livelihood systems. It is not perceived as an economic risk, since neither sale of the crop nor its prices get affected due to aflatoxin contamination. Farmers thus, may not feel the necessity to use aflatoxin reducing technologies as the market does not provide any incentives for supplying aflatoxin free groundnut crop nor are there any penalties on aflatoxin contaminated produce.

This study is a part of the project that aims to *reduce aflatoxin contamination by developing and (applying) a set of farmer validated management strategies / technologies suitable for adoption by small-scale farmers (Project document 2000)*. However, it is important to realize, that simply generating technologies and expecting them to provide the desired results with out examining the perceptions, constraints and opportunities of the farmers that pattern their current farm practices may have the risk of the technologies either not being adopted or ignored.

In this study, we present an argument that, the existing farm practices are a result of the constraints and opportunities available to the farming community that are determined both by the socio-economic factors that underpin their livelihood systems and the physical and biological factors in crop production. It is pertinent to understand how the various factors affect the existing pre and post harvest crop management practices so as to integrate the development and adoption of farmer validated technologies. Since the project aims to generate farmer validated technologies, it is important to ensure that the farming community is sufficiently induced to generate greater levels of awareness, incentives and willingness for adoption of technologies in order to improve their livelihood systems.

Therefore, the key objective of this study is to understand how the socio-economic factors impinge upon the current practices of groundnut production, which in turn may contribute to aflatoxin contamination.

The specific objectives of the present study are to:

1. Assess the existing pre and post harvest groundnut cultivation, handling and storage practices of the farmers from the context of aflatoxin contamination with specific reference to the farmers' opportunities and constraints in Ananthpur and Chittoor districts of Andhra Pradesh,
2. Assess farmers' perceptions and awareness of the importance of quality of groundnut and the risks associated with aflatoxin contamination, and
3. Understand the socio economic context and identify factors constraining and determining these practices in Ananthpur and Chittoor districts of Andhra Pradesh and their potential implications for aflatoxin contamination.

II. Framework for Analysis of Farm Practices:

Available literature (Mehan V. K. et al. 1991, Waliyar. F. 1997) indicates that *Aspergillus flavus* infection of groundnut occurs under pre harvest, post harvest handling and post harvest storage conditions. Apart from Biological and physical factors, farmers' practices that were mentioned as potential reasons for Aflatoxin contamination can be summed up as:

- Absence of sorting practices by the farmers before marketing,
- Use of damaged and loose shelled kernels as seed,
- Delayed harvesting after physiological maturity
- Retention of high quantities moisture in pods
- Inadequate protection from rain, pest and disease attacks

Literature review therefore reiterates that aflatoxin management should start in the farmers' fields with proper crop production management and handling, post harvest storage, followed by marketing, and processing conditions. Therefore, this study proposes to examine the socio-economic factors patterning the pre-harvest, post-harvest, storage and marketing practices of the farmers that are potential causes of aflatoxin contamination in groundnut. A separate study is undertaken to understand the marketing practices of the various players in the groundnut trade, the levels of awareness to aflatoxin contamination among the market players, and the reaction of the market to aflatoxin contamination

Concept and Hypothesis

It is important to understand initially whether farmers are aware of aflatoxin contamination and their perceptions about it as a problem. It is also important to review their management practices with a perspective to understand the constraints, opportunities and implications of these practices on afaltoxin contamination. Only after we understand the determining factors of the existing cultivation practices to the aflatoxin contamination, we will have an opportunity to develop and test more suitable technology options that will help in production and supply of aflatoxin free groundnuts.

Preliminary investigations in Ananthpur district provided clear indications of the range of socio-economic factors that seem to influence the behavior patterns of the farmers. These factors relate to the farming systems under which farmers manage their groundnut crop and/or due to the influence of some external factors, which are a result of the dynamics of various formal and informal institutions in the system.

We therefore surmise that farmers are constrained to undertake groundnut crop management practices due to the socio-economic factors prevalent in the region, even though various technical options might be made available to them and that:

a) Unless awareness is generated among farmers to perceive aflatoxin contamination as a problem that needs to be solved, together with providing suitable market incentives, introduction of crop management measures for the reduction of Aflatoxin contamination may not be easily acceptable to the farmers.

b) It is essential for the farmers to over come the socio-economic constraints and build-up suitable opportunities before they can undertake crop management measures for the reduction of Aflatoxin contamination.

The role and influence of each of these socio-economic factors that influence crop management practices are hypothesized as under.

Labor availability

Labor shortages, especially during critical operations that have implications for aflatoxin contamination, pose a major problem to the farmers.

Credit mechanisms

While, lack of access to and timely availability of credit impinges on the ability of the farmers to undertake appropriate and timely crop management practices, the linkage between crop production and debt repayment undermines the farmers' incentive to take care of the quality of groundnut.

Market behavior

Lack of quality incentives in general and an absence of price differentiation for variations in quality make the farmers indifferent to the quality of the crop, which has implications for aflatoxin contamination.

Mechanization

Introduction of mechanization is likely to add new and complex sets of options relating to the quality of crop, accessibility, shifts in operation time charts, reorientation of labor time, market acceptability, the associated incentives and value addition which may have implications for aflatoxin contamination.

Institutions for knowledge access

Improved and sustained access to knowledge about new technologies would lead the farmers into adopting better management practices that may have positive implications for preventing aflatoxin contamination.

Social factors

a) Socio-Economic stratification: social structures and power relations

Differences in access to resources, markets, institutions and other opportunities that lead to variations in the opportunities available to the different socio economic categories of farmers. These differences among different categories of farmers will have varied implications for developing strategies for reducing aflatoxin contamination.

b) Gender

Increasing women's awareness and perceptions about quality will be able to influence the use of better crop management practices leading to maintaining quality of groundnuts and better adoption of new technologies.

Awareness

Lack of awareness pertaining to the incidence of aflatoxin and its correlation to agro-climatic, economic, biological and physical aspects as well as the health risks associated with consumption of aflatoxin contaminated products leads to indifference in the selection of crop management practices among the farmers.

The results and discussion of these hypotheses are presented in the following sections. After the methodology section, an over view of the current groundnut crop management practices of the farmers in the study area and the variations in these practices between the six case study villages is described in section IV. This is followed by an analysis of the socio-economic determinants of crop management practices and their implications for aflatoxin contamination in section V. In this section the specific implications of each of the socio-economic determinants i.e., Labor, credit, mechanization, marketing practices, institutional access, socio-economic variations due to social structures and power relations among the farming communities and gender perspectives are examined. Farmers' awareness on aflatoxins, the related effects, and their perceptions of quality of groundnut are discussed in section VI. Finally, the conclusions from the study along with specific recommendations for further action research are presented.

III. Methodology

Participatory Rural Appraisals (PRAs) using various techniques have been conducted to study farmers' practices and behavior in groundnut production systems and the influence of various socio-economic factors mentioned above. Village case studies following this approach were undertaken in six villages in the state of Andhra Pradesh in the Deccan Plateau, India. Pampanur, Gantapuram, Lingannapalli, and Jalalapuram villages in Ananthapur district and Nagulakunta and Thoti Harijanawada in the Pileru area of Chittoor district were selected for the study. The PRAs were conducted during Nov 2000 to Feb 2001 in Ananthapur district and during April – May 2001 in Chittoor district. Table-1 sums up the various PRA techniques used for understanding different socio-economic aspects of groundnut farmers' behavior.

Village selection process

Two locations were chosen to conduct PRAs that represent two agro-climatic situations that are supposedly conducive for alfatoxin contamination. Anantapur district and Pileru area of Chittoor district of Andhra Pradesh in the Deccan Plateau are the two locations selected, where groundnut crop is predominantly grown under purely rainfed conditions. While the former represents 'drought stress' conditions the latter represents 'moisture conditions' at the time of harvest due to North-East monsoon rains, both thus creating congenial condition for aflatoxin contamination of the groundnut crop.

Groundnut based cropping systems constitute an important source of livelihood for the farmers in these areas and hence raising a 'good crop' in each year of cultivation is considered critical as groundnut pods provide the much needed cash income and the haulm, a valuable source of fodder throughout the year.

Table – 1: PRA Techniques Used in the Study

Socio-economic Aspects	**PRA Techniques Applied**
Crop management Practices	Case studied, group discussions, Seasonal Calendar.
Labor availability	Seasonal activity calendar, Pair-wise ranking of problems.
Credit mechanisms	Case studies, Pair-wise ranking of problems.
Market behavior	Case studies, Seasonal calendar.
Mechanization	Social map, Case studies, Seasonal activity calendar.
Institutions for knowledge access	***Venn diagram, Focus group discussion.***
Social factors ▪ Socio economic stratification-power relations ▪ Gender	Social mapping, Wealth ranking, Seasonal activity calendar, Pair wise ranking of problems.
Quality perceptions and Awareness	Matrix scoring of groundnut varieties, Case studies, Group discussions with men and women farmers.

Exploratory surveys were conducted initially to identify villages for case studies that have varied socio-economic conditions, groundnut crop management practices and institutional interventions/support. Four villages were selected in Ananthapur district. Technological interventions by Andhra Pradesh Agricultural University under on-farm demonstration and extension program in dry land agriculture in general and awareness demonstrations on aflatoxin contamination were conducted in two of the villages. In the other two villages, development interventions were provided by an NGO (Rural Development Trust - RDT), where farmers were introduced to either land-based activities that lead to watershed development or other general development programs. Pampanur and Lingannapalli villages represent the first situation while Gantapuram and Jalalpuram represent the second situation.

Table – 2: Details of Study Villages

Area	Name of the village	Name of Mandal	Total No of Households covered by PRAs	No of Case Studies carried out in each village	Cropping Pattern	
					Rainy Season (Kharif)	Post Rainy Season* (Rabi)
Ananthapur	**Pampanur**	Atmakur	142	13	Groundnut – with Pigeon pea/ Castor/ Green gram -Others-Paddy/ Sun flower	Groundnut Paddy
	Lingannapalli	Rapthadu	95	10	Groundnut – with Pigeon pea/ Castor/ Sorghum/ Sesamum --Others- Grapes / Sweet Oranges/ Vegetables	Groundnut Paddy
	Gantapuram	Battelapalli	139	14	Groundnut – with Pigeon pea/ cow pea Others- Paddy/ Sun flower/Grapes / Sweet Oranges/Vegetables/ Marigold/ 'kanakambaram' (flower)	Groundnut Paddy
	Jalalapuram	Battelapalli	121	12	Groundnut – with Pigeon pea/ Castor/ Green gram/ Horse gram Others-Paddy/ Sun flower/ Mulberry/ Papaya Sweet Oranges/Vegetables	Groundnut Paddy
Pileru	**Nagulakunta**	Yerravari-palem	24	9	Groundnut – with Pigeon pea/ Castor/ Horse gram/ Sorghum/Pearl millet Others-Paddy/ Flowers/Marigold/ Vegetables/ Onion	Paddy
	T.Harijanwada	Yerravari-palem	20	5	Groundnut – with Red gram/Castor/ Horse gram/Sorghum/ Cow pea/ Green gram --Others – Paddy	Paddy

(Source: Social Mapping, Seasonal Calendars, Group discussions)

* Post rainy season crop are grown by farmers who have irrigation facilities.

In Pileru, the second location, two villages were selected for PRAs. Improved groundnut cultivation practices were introduced to the farmers in one of the villages (Nagulakunta) under participatory technology development (PTD) activity organized by Agriculture Man Ecology (AME), an Indo-Dutch bi-lateral program. The PTD activity was introduced through the Andhra Pradesh Rural Reconstruction Movement (APRRM) an NGO. Though APRRM has its presence in the second village, (T.Harijanawada) its activities are restricted to watershed development programs. Details of the study villages are provided in Table-2.

IV. Overview of Current Groundnut Crop Management practices

Researchers attribute the crop management practices of the farmers as one of the main reasons for generation and perpetuation of aflatoxin contamination in the groundnut crop. It is therefore important to understand these practices in the study region and examine them for their role in aflatoxin contamination. Groundnut is grown under purely rainfed conditions with relatively low external inputs and under riskier environments like recurring droughts, erratic rainfall, etc. An overview of the crop management practices that are being undertaken by the farmers in the six case study villages is given in Table-3.

Crop production practices show similar patterns in all the case study villages with minor differences related to use of inputs and extent of mechanization except for Nagulakunta village in Pileru. In this village farmers follow the Participatory Technology Development (PTD) methods of cultivation under the guidance of AME, which include use of non-chemical based inputs. However, variations are observed between the practices of the rich and poorer farmers within each of these villages.

Farming operations begin with the onset of the monsoon and are usually done manually. Ploughing, harrowing, inter-cultivation and sometimes harvesting are some of the operations that are generally undertaken manually with the help of animal drawn implements. Farmers are also increasingly using tractors instead of animals for the general operations and threshers for pod stripping activity.

Groundnut is typically cultivated in the study region by application of farm yard manure (FYM), on a rotation basis between the plots, and 2-3 ploughings, followed by cleaning the field of pods and crop residues from previous crop, harrowing and finally leveling with a heavy wooden plank drawn by animals. Pods retained from the previous crop or ones that are procured from various sources are manually shelled and the seed (kernel) mixed with seed treatment chemicals. Sowing is usually done with a seed drill (bullock drawn) and small quantities of chemical fertilizers are applied simultaneously as basal dose (usually a bag of DAP or complex fertilizer). Inter-cropping with pulses and/or sorghum is normal practice (castor is a recently introduced inter-crop). See Table 3.

Though TMV-2 is the most popular variety in the region for quite some time, farmers also use other popular varieties such as JL-24 and K-134 to a certain extent. A few farmers are also trying out newly introduced varieties such as Tirupathi-1 and 2 and Polachi Red.

Earthing up of soil around the root zone is done as an inter-cultivation cum weed control practice with animal drawn implements, and is usually followed by manual weeding at least twice during the crop season. Pest and disease control is usually restricted to a maximum of 2-3 sprayings of commonly available chemicals when visible symptoms of crop damage by the commonly known pests and diseases such as red hairy caterpillar, white grub, leaf miner, leaf folder, helicoverpa, leaf spot, rust, bud necrosis are observed.

At around 100 to 110 days of sowing and irrespective of the pod maturity status, farmers begin harvesting as soon as rains bring in the required soil moisture for easy pulling of the crop manually. At this stage, farmers cannot risk to wait for total maturity of crop. Availability of moisture is more critical and generally gets greater importance in the decision to undertaking the harvesting operation. Under unavoidable circumstances of insufficient moisture or absence of rainfall, farmers use tractors or animal drawn implements to uproot the crop more as an exception than as a rule. After uprooting, the crop is kept for drying in small upturned clumps for 2-3 days in the field. Farmers pray that it does not rain during this time, as it is likely to spoil a good crop.

After drying, the crop is transported to the common farmyards (small groups of farmers own these yards for threshing and storage of crop residues) where the crop is stacked awaiting threshing. With the availability of labor and/or threshers (generally within 15 days to a month) or whenever the farmer is ready, separation of pods from the plants (threshing/ pod stripping/ pod separation) is done either manually or mechanically. Well formed pods are selected and set aside for seed purpose for the next crop in gunny bags at the farmers' homes and the rest of the crop is either sold or traded for credit obtained earlier. Those farmers who can afford to wait for better prices store the produce in closed rooms within their homes in lose heaps or in jute bags.

Farmers are in the habit of spreading gammaxene at the time of stacking the crop to control a highly virulent pest that eats away the kernel inside the pods, locally called 'nuvvu maliga'. They also use gammaxene to control another similar type of storage pest, locally called 'ouzu', that sucks away the oil content in the kernel while the kernel is still in the pods during storage. Fumigation (by fumigating tablets such as Celphos) is sometimes undertaken when farmers store the pods in gunny bags as control measures against the storage pests.

<u>Variations in crop production practices:</u>

While almost all the crop production practices are similar in all the case study villages, a few interesting practices that are exclusive to certain villages require mention. The variations in the practices between the villages are largely due to their differences in access to credit, labor, implements, machinery, etc., apart from local ingenuity and resources. In Pampanur village, as against the common practice of using available animal drawn ploughs at the time of first tillage, farmers generally tend to use tractors for ploughing when there is a delay or failure of the first monsoon showers, to save cropping time and moisture. See Table 3.

Harrowing is generally done by an animal drawn implement called 'Guntaka' in the region. In Gantapuram and Jalalapuram villages however, the 'guntaka is sometimes arranged to be drawn by tractors instead of animals by farmers who have access to tractors. No valid reason was attributable to this action. Perhaps it could be deduced that there is a shortage of draught animals in the area and so farmers use spare tools and tractor time effectively and get the work completed faster instead of spending money on costly tractor drawn equipment like the disc harrows.

There is a large variation in use of own seed between the villages. It is observed that in Pampanur and Ghantapuram villages farmers are increasingly selling off their entire crops at harvest time and resorting to purchase of seed material at the time of sowing compared to Lingannapalli and Jalalapuram villages where almost all the farmers retain their own seed from the previous crop.

While applying basal doses of fertilizers (irrespective of the quantities), is common to all farmers in all the villages, a few farmers apply top dressing of urea under favorable conditions during the early stages of crop growth. This practice of applying top dressing of urea is not found among the farmers of Lingannapalli village. Farmers of Gantapuram and Jalalapuram villages are better informed about the usage of fertilizers such as potash and phosphates. While it is common to use pest and disease control measures including soil applications, in Ghantapuram, 'small farmers' have a trend of using 'neem oil' for controlling certain kinds of pests.

A typical feature observed in Lingannapalli village is that the animal drawn 'guntaka', is arranged to be drawn by a tractor for undertaking harvesting operation especially when the soil moisture conditions are not favorable for an extended harvesting period. This is an ingenious way of using the nearly two feet wide blade of the 'guntaka' as a groundnut digger thereby saving time, money and above all valuable moisture.
In Nagulakunta village, farmers apply 'Mussorie Phosphate' (rock phosphate, a non chemical fertilizer) along with FYM as basal dose of plant nutrient, rhizobium culture, trichoderma, phospho-bacteria, nilgiri leaf extract and gypsum as per the new methods of cultivation developed under the PTD program as a comprehensive package of chemical free cultivation. They also undertake sampling procedures to identify, separate and destroy diseased plants in order to reduce further spread of diseases such as bud necrosis.

V. Socio-economic Determinants of Crop Management Practices and Implications for Aflatoxin Contamination

The groundnut management and marketing practices described in section IV gives us an overall scenario of the current practices followed by the farmers in the study area. Information from the PRAs and discussions with the farmers however reveals that they encounter a number of constraints during the production of groundnuts. The various constraining factors indicated by the farmers are as follows.

- Irregularity/ delay in the first monsoon showers and non-availability of agricultural implements to the poor farmers delays timely ploughing and consequently affects land preparation.
- Delay in supply of seeds (especially by the Government agencies) and non-availability of funds for purchase of seeds and other inputs, delays sowing operations.

- Weeding gets affected as the poor farmers have to contend with working on their own farms and also on others' fields as wageworkers while the rich farmers face labor shortages. The operation is further burdened when higher frequency of rains results in increases in the incidence of weeds, further delaying the weeding operations.
- Expensive, adulterated and ineffective pesticides/ chemicals together with shortage of finances / credit leverage and lack of technical knowledge in identification and/ or application of specific control measures lead to improper pest and disease control measures.
- Severe labor shortages, prohibitively expensive labor at harvest time, difficulty in uprooting due to lack of timely rains, damage to pods due to harvesting by tractors or ploughs and requirement of extra labor for collection of left over pods due to difficulty in harvest are some of the major impediments during harvesting operations.
- Occurrence of rain during field drying inhibits the ability of the farmer to save a good harvest.
- Shortage of labor supply and transport facilities for undertaking stacking operations are major constraints to the farmers. Presence of high levels of moisture, occurrence of rain or excessive fog during stacking period and pest attack on stacked crop affects the ability of the farmer to ensure good quality produce.
- Severe shortage of labor and threshers leading to prolonged stacking and faulty thresher operations during pod stripping activity damages the produce.
- Lack of efficient storage facilities / structures inhibits the farmers from being able to store good seed material for next crop due to very high incidence of storage pests leading to desperate purchases of inferior seed during subsequent sowing.

An analysis of the underlying reasons for these constraints hence, indicate that there are certain socio-economic factors that influence the crop management practices described above. Unless the processes that govern these factors are understood, it is difficult to develop suitable technologies and convince the farmers about the need to control and reduce aflatoxin contamination. The socio-economic factors that determine the crop management practices are discussed here under.

a) <u>Labor availability</u>

The dynamics of labor availability and demand were captured through agricultural calendars drawn by the farmers in the 6 study villages and are summed up in Table-4. The scores indicated in the table are purely based on the perceptions of the farmers while conducting the PRAs and hence should be viewed in qualitative terms rather than in absolute terms. The variations in the scores between the villages could be to a certain extent based on the differences in expression (number of beans). Overall, the patterns expressed in the calendars do indicate the reality of the situation.

Labor Dynamics

Agricultural labor consists of landless labor as well as small and marginal farmers who work for wages to supplement their incomes. The extent of labor in the population composition of the village as well as their outward mobility for wage labor have a strong bearing on the labor demand and supply positions for critical crop operations. Jalalapuram and Lingannapalli are villages with low labor composition while Pampanur, Nagulakunta and T. Harijanawada have a larger proportion of labor population and Ghantapur has a good mix of both farmer and labor populations (the small farmers group has larger holdings compared to the other villages).

Discussions with farmers and a study of the agricultural calendars derived from the PRAs indicate that carrying out certain crop production operations within a specified time have implications on the productivity and quality of groundnut crop. As most of the groundnut operations are carried out manually or by animal power in the study area, timely availability of labor in required quantities becomes very critical.

It is observed from Table - 4 that demand for labor peaks up whenever the crucial operations need to be performed. Farmers expressed that there is a shortage of labor during such operations and are therefore left with no choice but to compete for the available labor, pushing up labor costs. Those at the weaker side of the competition end up with delayed operations leading to losses in productivity and crop quality.

While this is so with the farmers who require hired labor for their operations (usually the rich or medium farmers), the case of small and marginal farmers who work their own fields and also need to work at others' fields for the much needed additional income, have a different kind of problem. They have a choice. They either can work on their own fields first, bring home a valuable crop and then go to others for wages, by which time peak wages would have dropped losing valuable income or go for work first, get the benefit of peak wages and risk losing a crop.

Labor Shortages

As per the seasonal calendars, sowing, weeding, harvesting (uprooting), drying, transporting, stacking and threshing (pod separation) are the critical operations with implications for loss in productivity or crop quality due to shortages in the availability of labor (see Table - 4). Maximum shortages are felt during the harvesting and threshing season for both men and women labor. Though there is an exclusive demand for women labor during the weeding season, shortages of labor is less critical. Though sowing operations also have a higher demand for labor, both men and women, it is comparatively lower than the demand during the weeding, harvesting and post harvesting operations. It is also pertinent to know here that labor is also employed, during this period, in the activities of other cash earning crops such as sunflower, vegetables and paddy that do create additional demand for labor.

i) Sowing

Farmers require to capitalize on whatever soil moisture is available. There is therefore a significant demand for labor right from the first monsoon showers. Shortages in supply of labor are felt due to the intensity of the activity since majority of the farmers begin operations simultaneously. Nevertheless, farmers in the study area do not perceive labor shortages during this period as a major constraint. Analysis of the responses of farmers indicated that, during the land preparation and sowing operations (May-July), only farmers in Pampanur had a slight difficulty in getting labor for their operations during the entire period. In Ghantapuram and T.Harijanawada demand for labor is reported to be slightly higher during the first ploughing (May). Scarcity of labor is more severely felt in Nagulkunta and T.Harijanawada during the sowing operations (July). In all the other cases labor shortages are not indicated. However, farmers did admit that instances of delayed sowing do occur in these villages amongst farmers who fail to access labor early on.

ii) Weeding

Weeding is an important activity in August – early September and the demand for women labor is high. Though farmers feel the pressure of labor shortages during this period since the overall quantum of women labor requirement is high, it is not considered too critical. Depending upon the incidence of weeds and the economic situation of the farmers, weeding activity is either neglected (especially the poorer farmers) or is undertaken with marginal delays and to inadequate/ incomplete levels of weeding. The pressure for availability of labor is therefore still not at its peak.

In Jalalapuram and Lingannapalli villages, where the labor populations are small, the demand for labor is at its peak even during this period and so labor is imported from neighboring villages. On the other hand labor shortages are felt in Nagulkunta and T.Harijanawada villages since laborers from these villages go to the neighboring villages for work. After weeding there is a short period during September when there are no activities except for some pest control activities and top dressing of fertilizers.

iii) Harvesting (uprooting)

Harvesting is the most critical operation that needs to be undertaken at a precise time. From about early October, farmers constantly check the crop for pod maturity and harvest immediately upon receiving sufficient rainfall. While labor may be idle till it rains, the sudden demand for labor upon rainfall is so intense that labor rates shoot up to two to three times the regular rates. This severe shortage of labor leads to delays in harvesting the crop. This is a universal phenomenon in the study area and there are no exceptions. Only Pampanur, which has a large labor population, exhibits a marginal deviation in that, the pressure is not very high in the early stages, but peaks up during late October early November. This pressure for labor continues till the drying, transporting, stacking and threshing operations are completed.

iv) Drying, Transporting and Stacking

As the crop is left for drying in the field for 3 to 4 days, the process of gathering the uprooted crop into small heaps for the night (for protection from possible rains) and spread out during the day for drying needs labor. Improper drying of the crop due to labor shortages or if the crop gets affected due to intermittent rains, fungal growth may develop even before the crop is transported to the stacking area or while the crop is kept stacked awaiting pod stripping.

Transporting and stacking the crop are contiguous activities that also require labor during the peak harvesting season. Therefore, the farmer is continuously under pressure to complete all these activities in time while the demand for labor is still at its peak. Availability of labor is very low and the wage rates are still very high. The entire study area has the highest demand for labor without exception as the harvesting, drying, transporting and stacking activities go on simultaneously.

v) Threshing (pod separation)

Pod separation is a slower operation and is carried out at convenience as the crop has reached home and is safely stacked. Though the pressure for labor is still on the higher side, since a majority of the small and marginal farmers and a few medium/rich farmers are under pressure to dispose of the crop for repayment of credit, demand for labor comes down to below critical levels for this operation. While it is presumed that stacked groundnut crop is comparatively safe from infections, it is still possible for the crop to get damaged even at this stage. Under situations when farmers are sometimes constrained to stack the crop while it is still not sufficiently dry (when rains threaten to inundate harvested crop) or under conditions of heavy fog and rainfall during the stacking period, moisture that either seeps in to the stacks or is already present helps generation of fungal growths that are likely to damage the crop. During such a situation demand for labor continues to be high.

It is only for two months during October to December that laborers in the study area and especially those of Ghantapuram and Pampanur find them selves in very high demand and get high wages. While the landless laborers of these villages have no option but to opt for work at any period of time, the small and marginal farmers need to weigh the consequences of going for wages as against harvesting their crop first. Under circumstances of insufficient or excessive rainfall during the harvest to threshing period, the dilemma is even greater. If these small and marginal farmers realize that the yield potential of the crop is low they undertake wage labor activity for better earnings and take chances with their small crop or vice versa. Neglecting the crop may enhances its susceptibility to aflatoxin contamination and when this crop finally enters the supply-utilization chain affects the quality of the end products derived from groundnut.

The scenario of the labor dynamics presented by the farmers indicates certain critical situations of non-availability of labor for carrying out crucial timely operations that have a bearing on the productivity and quality of the groundnut crop. Here, we sum up the operation wise implications of labor shortage during the various pre and post harvest groundnut crop production practices of the farmers in the study region, that have a bearing on either the initiation or spread of aflatoxin contamination in the crop.

Implications for aflatoxin contamination

- Delayed sowing due to labor shortages may lead to early and immature harvests (conditioned to availability of moisture at harvest time) that may have implications for Aflatoxin contamination.
- Bottlenecks in labor supply and/ or high costs may lead to either incomplete/ inadequate weeding or abstaining from weeding. While the direct implications of improper/ inefficient weeding to aflatoxin contamination are not clear, it does indicate that shortages (labor and money) can force the farmers to leave their fields untidy.
- Delay in harvesting may lead to over-maturity, germination of seed before harvest and/or damage to crop due to intermittent rains, which could provide conditions suitable for aflatoxin contamination.
- Improper field drying or wetting due to rains may cause development of diseases that may generate aflatoxins during the stacking period. Labor availability during field drying therefore is very critical.
- Threshing, if delayed leads to the crop being retained in stacks for longer periods, get exposed to rain and fog leading to further damage, generate infections and possible aflatoxin contamination.

b) Credit mechanisms

Farmers in the study villages seem to have well-organized credit linkages, as observed from Table -5. The most common sources of credit are the commercial, co-operative and rural banks. Other major sources of credit are the groundnut traders, self help thrift groups (SHGs) and non-government organizations (NGOs). The traditional moneylender seems to be the least opted source. An emerging and interesting phenomenon is the interdependence of farmers among themselves for credit. Discussions with farmers revealed that farmers are helping each other by lending to each other in cash so as to avoid exploitation by professional moneylenders and traders. They are doing this mainly to avoid being tied up to groundnut traders for forced sale of their produce.

Even though there are fairly good sources of credit in the study villages, according to farmers, credit is still not easily available. It is interesting to note that farmers of all wealth categories in Lingannapalli village make it a point to obtain credit from banks and avoid moneylenders and groundnut traders. Though such banking facilities are available to most farmers of the other study villages, not all farmers have access to banks since some small, marginal, sharecropping or tenant farmers either lack or have insufficient collateral securities. Hence, in most of the study villages a part of the credit requirements are being met through self help groups (SHGs). These SHGs are operational mostly among the small and marginal farmer groups. SHGs have their limited circle of farmers and loans are available in rotation only, leaving some of them to look for other sources as well. Those of the marginal farmers of the study villages (except Lingannapalli) as well as the small farmers of Nagulakunta and T. Harijanawada villages who are not members of SHGs or miss out due to the rotation of credit from the SHGs obtain the much needed easy credit from NGOs like AME, APRRM and RDT. The richer categories of farmers have created a new phenomenon of organizing credit transactions (in cash) among themselves in Gantapuram & Jalalpuram villages.

Failure of a crop puts the farmers under the risk of default in repayment of loans. Banks do not provide subsequent loans if the first one is not repaid. Defaulters are not given access to future loans with NGOs like the RDT. SHGs also shun defaulting member farmers as the credit is mostly on rotation basis and other members get affected due to defaults in repayments. So crop credit is not likely to be available to the entire farming community as and when they require.

Under such conditions, some farmers do need to take credit from other sources. The easiest credit is available in the form of seed or other inputs from the groundnut traders, and most times the credit is linked to repayments in kind – in this case the crop. Case studies with farm households have revealed that, it is usually the poorer class of farmers who are generally dependent for credit from such tie-ups. Apart from the poor, some of the middle category of farmers of Jalalapuram, Pampanur and Nagulakunta villages also obtain such input credit. Moneylenders are another source of credit, but they demand mortgages, which are not easily available with the farmers. It is observed that only the middle (read - rich) and marginal farmers of Pampanur and the rich farmers of Ghantapuram take loans from the moneylenders. Farmers are under severe pressure to repay credits. Banks withhold ownership documents if loans are not cleared in time and so further loans are not possible. Traders exert pressure on the farmers to repay credits immediately on harvest of crop so as to ensure low procurement prices.

In order to reduce the enormous interest burden on their high cost loans, farmers are under pressure to sell the crop immediately upon harvest. Members of the SHGs are also constrained to repay their rotating loans due to peer pressure. The rich and middle category farmers of Gantapuram & Jalalpuram villages who have credit transactions among themselves are also under pressure to repay their loans immediately upon crop harvest due to the fact that both parties – the creditors and borrowers – being farmers are always short of money. This being a new trend with just a few transactions the pressure for repayments is understandable.

<u>Implications for aflatoxin contamination:</u>

Groundnut crop in the study region is a high-risk crop, as it is mostly cultivated under rain fed conditions. Farmers are perennially dependent on credit, usually at high rates of interests. Farmers therefore tend to reduce their debt burden as much as possible especially since credit, under most circumstances, is available only on the conditions of repayments immediately upon harvesting the crop. Groundnut crop production practices in this region therefore, are primarily dictated by the type of credit available and the pressure of repayment of credit, be it in cash or kind.

Seed being the most expensive input farmers compromise on the quality of seed as its procurement is essentially dependent on credit due to the cash crunch by the sowing period. Farmers are constrained to use the seed provided by or through the moneylenders'/ traders' sources irrespective of its quality or the dormant infections that they may be carrying due to the pressure of credit supply.

Farmers generally desist from undertaking operations such as pest and disease control, adequate/ extended weed control measures, etc., that involve additional cash expenditures than the bare minimum required. Due to the pressure of repayment of credit (especially those tied up to repayments in kind) farmers tend to sell their groundnut crop without undertaking the necessary post harvest management practices and care, such as removal of refraction material and proper drying to reduce the moisture content. This indifferent attitude of farmers towards post harvest management of the crop could lead to avoidable contamination during transport, trading and pre-processing storage periods. Though farmers carefully select seed material from their own crop to avoid expensive borrowing for purchase of seed, it cannot be guaranteed that their own seed is free from infections.

c) *<u>Farmers' Marketing Practices</u>*

Basically, across all study villages, it is the local brokers and traders through whom farmers have the greatest access to the markets. Those who have access to decorticating units and oil millers (like a few farmers from all the four Ananthpur villages) exercise their options of sale that includes selling to the Andhra Pradesh Co-operative Oil Seed Growers Federation (Oil Fed) or at the closest market yards. On the other hand, Tamilnadu traders dealing in confectionery, seed and export quality kernel and the Kalahasti (Chittoor District) Seed traders approach (from Ananthpur, where they camp during the season) farmers of Pampanur, Ghantapuram and Lingannapalli villages through their personnel or agents. It is the quality of produce that attracts the specialty and higher premium traders to the farmers. Farmers of these villages are normally eager to sell their produce to these traders as they are paid a small premium (10 - 20% more than the prevailing prices) in order to pick up the best materials from the early harvests and arrivals to avoid disappointment at the end.

It is observed from Table - 6 that farmers of all wealth categories across all the study villages have equal access to all categories of traders. Farmers of the study villages indicated that, brokers, professional creditors, traders and representatives of specialty traders visit them at the time of harvest and start negotiations. However, small and marginal farmers mostly have weaker negotiating capacity due to their ignorance of the tricks of the trade or have little say in the bargaining or negotiations due to their dependency on the more influential, richer or dominating farmers / farmer brokers and the roles played by them. Once dependent, they are either forced to sell at lower prices or made to wait for longer periods (sometimes up to 4 months as in Lingannapalli village the previous year) by the time their produce is sold, though instances of such long waiting are rare.

Table – 5: Credit Sources & Input Linkages in Groundnut Production

Name of the Village	**Wealth** Category	*Sources of Credit for Farmers*					
		Banks	**RDT**	**ºSHGs**	Money lender	G.Nut trader	**Among themselves**
Ananthapur		Mode of Transaction					
Pampanur	Middle	Cash	--	--	Cash	In kind	--
	Small	Cash	--	Cash	--	--	--
	Marginal	Cash	* Cash	Cash	Cash	In kind	
Lingannapalli	Rich	Cash	--	--	--	--	--
	Middle	Cash	--	--	--	--	--
	Poor	Cash	--	Cash	--	--	--
Gantapuram	Rich	Cash	--	--	Cash	--	Cash
	Middle	Cash	--	--	--	--	--
	Small	Cash	--	Cash	--	In kind	--
	Marginal	Cash	Cash	Cash	--	In kind	--
Jalalapuram	Rich	Cash	--	--	--	--	Cash
	Middle	Cash	--	--	--	In kind	Cash
	Small	Cash	--	Cash	--	In kind	--
	Marginal	Cash	Cash	Cash	--	In kind	--
Pileru (Chittoor)			**APRRM**		**AME**		
Nagulakunta	Middle	Cash	Cash	Cash	Cash & Kind	In kind	Cash
	Small	Cash	Cash	Cash	Cash & Kind	In kind	Cash
	Marginal	Cash	Cash	Cash	Cash & Kind	In kind	Cash
T.Harijanawada	Small	Cash	Cash	Cash	---	In kind	Cash
	Marginal	Cash	Cash	Cash	---	In kind	Cash

Constraints / Remarks
• Default in repayment of bank loan obtained for a previous crop is a disqualification for obtaining fresh loan • Moneylenders demand property/gold mortgage towards security. • Groundnut traders provide credit by ensuring repayments through product purchase tie-ups at his terms of improper weighing procedures and unfair rates. • For SHG members (among small & marginal farmers only) loan is not available to all of them at the same time as money keeps rotating among themselves and may even be delayed. • Credit transactions among the rich farmers ensures greater pressure to repay. • AME gives technical advice, conducts and field demonstrations and supplies critical inputs through a revolving fund through APRRM. • Sometimes repayment may be in the form of labor when debt it among the villagers themselves

(Source: Case Studies, Pair wise ranking, General Group discussions)

° Women self help groups engaged in thrift and credit activities

*** RDT with drew from Pampanur – provides credit to poor farmers on a selective basis.**

Farmers' practices of holding and marketing of their groundnut produce, deduced from the case studies and presented in Table - 6, indicates that a large segment of farmers, especially the debt-ridden farmers irrespective of wealth categories, sell off their groundnut produce immediately after harvest (within a month) and most times at less than market prices. Only a few rich farmers wait for better prices, sometimes up to five months. Farmers of the villages that do not have proper access to markets sell their produce at less than the market prices as very few traders approach them for purchase. Under such conditions of constrained selling, farmers generally do not have any incentive for producing or marketing good quality crop. Quantity is the main focus here.

In the absence of any regulations relating to marketable crop standards, farmers sell their produce as it suits them or as per whatever produce they harvest. Sorting the produce is a rarely followed / not a common practice. Both, the good and the inferior pods are disposed off through brokers, traders and other channels of the market. While, specialized traders involved in export and seed supplying activities procure the best of

Table – 6: Farmers' Practices of Ground nut Storage & Marketing: Ananthapur & Pileru

Name of Village	Wealth Category	Storage period	Selling Point
Ananthapur area			
Pampanur	Middle	0 to 4 months	Local trader / Decorticators / Oil Millers - ATP Tamilnadu trader
	Small	Within 1month	Local trader / Tamilnadu trader
	Marginal	Within 1month	Local trader
Linganna Palli	Rich	3 to 5 months	Local trader / Tamilnadu trader
	Middle	2 to 3 months	Local trader / Tamilnadu trader
	Poor	0 to 4 months	Local trader / Decorticators / Oil Millers - ATP Tamilnadu trader
Ganta-puram	Rich	Within 1month	Local trader / Tamilnadu trader
	Middle	***Within 2 months***	Local trader
	Small	Within 2 months	Local trader / Tamilnadu trader / Pileru / Kalahasti traders
	Marginal	Within 2 months	Local trader / Decorticators / Oil Millers - ATP ***Pileru / Kalahasti traders***

Jalala-Puram	Rich	Within 3 months	Decorticators / Oil Millers - ATP Pileru / Kalahasti traders
	Middle	Within 2 months	Local trader / Decorticators / Oil Millers - ATP
	Small	Within 3 months	Local trader / Decorticators / Oil Millers - ATP
	Marginal	Within 1month	Local trader
Pileru area			
Nagula-Kunta	Middle	Within 1month	Local trader
	Small	Within 1month	Local trader / Trading through APRRM
	Marginal	**No information due to crop failure**	
T.Harijanawada	Small	Within 1month	Local trader
	Marginal	Within 1month	Local trader

(Source: Case Studies)

produce at higher prices, the general category of produce is procured by the oil industry and the decorticating units at standardized rates.

The market channels follow a basic type of grading of the groundnut pods, purely for the purposes of price fixation. It should however be noted that grading here does not involve segregation of any damaged material. A price is fixed after evaluation and allocation of a grade (including the damaged material) for the entire lot of material desired to be sold by the individual farmer. Procurement rates are offered by the traders based on the three parameters of shelling percentage, refraction and moisture content after analysis and verification on the spot.

Though better quality material fetches higher prices, and the poorer quality produce is marketable only up to certain bottom line standards. Farmers do not get any additional incentives from the market for supply of infection / defect free groundnut produce. This way even the best of produce is likely to carry some defective material as no farmer undertakes to clear the lots of marginal defects. Very poor quality produce is rejected by the traders at the market yards and also by the standard traders. Such rejected material is also sold - to small local oil crushing units locally known as 'rotaries'. The oil from such rejected material, with all its toxicity and impurities if any enters the consumer market.

Implications for aflatoxin contamination:

Farmers' marketing practices and their relationship to the various marketing channels with which they trade their produce clearly indicates that they need not account for aflatoxin contamination as a prerequisite / criteria for sale of their produce. Hence, they have no mechanism to look up for aflatoxin contamination during the pre and post harvest management of the crop. On the other hand, the market is also ignorant of and indifferent to aflatoxin contamination in groundnut. Farmers do not get any additional incentives from the market for supply of infection / defect free groundnut produce either.

d) Mechanization

Mechanization of groundnut cultivation is an emerging phenomenon in this region, and is still at the rudimentary levels. Tractors and small crop threshers, hand sprayers for plant protection activity and small decorticating machines for shelling the pods are the only machines that are used by farmers in the region. Majority of the farmers however hires most of the machinery and equipment, as it is expensive for them to purchase and maintain them.

Table – 7: Mechanization of Groundnut Threshing in Ananthapur

No. of households

S. No.	Name of the Village & Wealth Category	Total No. of Households	Threshing Methods	
			Mechanized	Manual
	Pampanur:			
1.	Middle	35	25	10
2.	Small	27	21	06
3.	Marginal	80	36	44
	Lingannapalli :			
1.	Rich	21	20	01
2.	Middle	38	30	08
3.	Poor	36	09	17
	Gantapuram:			
1.	Rich	08	01	07
2.	Middle	56	10	46
3.	Small	54	01	53
4.	Marginal	21	00	21
	Jalalapuram :			
1.	Rich	15	08	07
2.	Middle	37	10	27
3.	Small	38	06	32
4.	Marginal	31	04	27

(Source: Social maps, wealth ranking exercises)

Tractors are mostly used for ploughing and harrowing and sometimes for uprooting the groundnut crop during shortage of soil moisture at harvest time. As it increasingly becoming difficult for the farmers to maintain draught animals, more and more farmers are beginning to use mechanical power for their cropping operations. It is interesting to note from the case studies that even small and marginal farmers in Ghantapuram are taking the help of tractors extensively in field preparation, sowing, uprooting and transportation activities while in Jalalapuram they use tractors for field preparation activities only. Hybridization of the tractor with the country made 'guntaka' for harrowing, field leveling and uprooting of groundnut crop is an interesting feature in Ananthapur area.

The latest trend in mechanization in Ananthapur region is the use of crop threshers for stripping groundnut pods from the plants as is evident from Table - 7. The Pileru area is yet to catch up with their use. Threshers are becoming increasingly popular in Ananthapur region due to labor shortages during the harvesting and threshing season (the period also coincides with paddy harvesting) and consequent high labor wages. They are also in demand since stripping operation is done much faster than with labor. Farmers are therefore in a position to meet the demands of the Tamilnadu traders for early supplies and quickly encash on the higher rates during the early crop arrivals period. They also help save time and avoid damage to the stacked crop from storage pests ('nuvvu malliga') and rain. Another major reason why an increasingly large number of farmers are using the thresher for pod stripping is that they need not undertake cleaning operations separately to eliminate waste material and the lighter semi filled pods.

However, all farmers are not in a position to use the threshers. There are a number of constraints that need to be over come before a farmer can use the thresher. Access is one of the biggest constraints. Since threshers are single operation equipment, they seem very expensive for the farmers to buy them. Most of the richer category of farmers also cannot afford to buy one purely for their own use. Only a few rich farmers or traders in some villages own and hire them out.

Since only a few units are available, demand for these machines is high and so only those who are in a position to use them immediately get precedence for use as the crop needs to be dry and ready for threshing. Any leftover moisture or wetting of crop due to rain causes hindrances to the threshing operations. The richer category of farmers has an advantage for allocation of machine time compared to the poorer farmers as the thresher operators prefer larger quantities for continuous and longer operations while it is not economical for small farmers to hire them for threshing their smaller lots.

Farmers need to hire 8 to 10 laborers per day to keep the machine running, a proposition that is not easily possible for the small farmers, especially due to the shortages of labor during the harvesting season and it works out to be expensive (Table - 8). Hence, most small and marginal farmers who normally use their family labor or share labor with other farmers continue to strip the pods manually (Table - 7). The rare occasions when this category of farmers use the thresher is when they get their produce threshed in lieu of wages for working as labor at the threshing operations of the other farmers or when they have the opportunity to either stack their produce along side that of a richer farmer or when they have the option to join up with others.

Table – 8: Mechanization in Groundnut - Constraints & Perceived Effects on Quality

Type of Machine	*Agricultural* Operation	Pampanur			Lingannapalli			Ghantapuram				Jalalapuram			
		Mi	S	Ma	R	Mi	P	R	Mi	S	Ma	R	Mi	S	Ma
Constraints in use of Machinery – Wealth Category wise															
Tractor	Hiring is costly	4	-	-	4	4	-	4	-	-	4	4	4	4	4
	Not Available in time	-	-	-	-	-	-	-	-	4	4	4	4	4	4
	Transporting is costly	-	-	-	-	-	-	-	-	4	-	-	-	-	-
Thresher	Heavy rush	4	4	4	4	4	-	4	4	4	-	-	-	-	-
	Hiring is costly	-	-	-	-	4	-	-	-	-	-	-	-	-	-
Quality Deterioration due to Mechanization – Wealth Category wise															
Tractor	Damage to Pods while uprooting	4	-	-	4	4	-	4	-	-	4	4	-	-	4
	Transport delay may degrade quality	4	-	-	4	4	-	4	-	-	-	-	-	4	-
Thresher	Cracking of Pods	4	4	4	4	4	-	4	4	4	-	-	-	-	-

Source: Case Studies
R : Rich – Mi : Middle – S : Small – Ma : Marginal - : No report / did not report

A major operational problem with the threshers is that they require large open areas at the stacking point to allow for heaping of pods, stover and dust separately, each away from the other. It is also difficult for the threshers to be positioned in the interior fields as they need to be towed by other vehicles and so have restricted mobility. Breaking and splitting of pods while stripping is another problem that farmers need to reconcile with in order to use the services of the mechanical threshers.

It is evident from Table - 7 that farmers of Pampanur village are using threshers more intensively as compared to the other three villages. Threshers are used by all wealth categories in this village with the rich using more intensively than the poor. A reason for such extensive use of threshers could be due to the fact that though Pampanur village has large labor population, most of the labor force out-migrates from the village for work. In the other three villages of Ananthapur area, mostly the rich use threshers.

A few farmers use the services of the local decorticating units for shelling the pods in Lingannapalli and Jalalapuram villages as these units are located within or close to the villages. The kernel is either retained for seed purposes or sold for better prices to traders depending up on the quality of the produce.

Implications for aflatoxin contamination:

While mechanization has its advantages, working with machines has a few implications for damages and consequently for possible aflatoxin contamination. According to farmers, harvesting with tractors, stripping of pods with threshers and shelling of pods with decorticators causes physical damage and injury to the pods and kernel. Since the farmers are interested in selling entire produces without losing much as wastage, they generally do not segregate the damaged material as it gets counted in the shelling percentages for price fixation. Farmers in fact select some of the blown out damaged and ill filled pods from the threshers and mix them up with the rest of the produce and get benefited.

Mechanization of crop activities helps farmers in completing the harvest and post harvest activities quickly, thereby reducing the risks of pest and disease infections during these activities. Yet, due to the insensitivity of the market to contaminated produce, mechanically damaged and other defective material (automatically segregated by machinery) is added back to the produce, increasing the risks of contamination. Rushing with threshing activity as and when threshers are available may shorten field drying activity leading to increasing susceptibility to aflatoxin contaminations, while lack of threshers extend the stacking period thus enhancing the potential for damage due to pest attack and exposure to rain and fog.

e) Institutions for knowledge Access

Information on crop production techniques and input support is available to the farmers of the study villages through the activities of either the state agricultural university (ANGRAU), the state departments of agriculture (DoA) and horticulture (DoH). The Rural Development Trust (RDT) in Ananthapur area and Andhra Pradesh Rural Reconstruction Movement (APRRM) with the active support from (Agriculture Man Ecology) AME in Pileru area which also provide technical information to the groundnut farmers are considered by farmers as important sources of institutional support in the study villages. While the DoA and DoH are expected to be available to the farmers on a continual basis, ANGRAU and RDT are present in some of the villages in the region based on project activities. The various institutional support accessed by farmers derived from Venn diagrams is outlined in Table - 9.

Farmers of Lingannapalli and Jalalapuram villages have indicated that they interact more closely with the DoA and DoH from where they obtain some input supplies and basic technical information. Farmers of Lingannapalli and Pampanur villages, where ANGRAU conducts its dryland agriculture extension program, expressed that they are receiving good technical support through the activities. Farmers in the villages where ANGRAU has its programs have rated it as the best source of access to knowledge. The RDT, as an NGO involved in village development activities in Ananthapur region, undertakes watershed development activities and as a part of this activity provides technical support to the farmers in soil improvement and moisture conservation aspects. They also facilitate access to technical information on crop production to a limited extent. In Pileru area, farmers of Nagulakunta village consider AMEs' participatory technology development (PTD) program as an important source for technical support, particularly for groundnut crop and also appreciate the financial support rendered through a revolving fund for their self help groups. Farmers of T. Harijanawada appreciate the role of APPRM in the watershed development programs of their village.

Though it seems that there is a good amount of technical support available to the farmers of the study villages, the support is neither comprehensive nor extensive. The DoA and DoH are expected to provide total technical support free of cost as well as certain input supply activities such as good seeds, fertilizers, pesticides, small farm machinery and other products at cost with associated subsidies if any. Yet, as accessibility of technical staff of the DoA and DoH to the farmers is limited to the highly erratic and rare periodic visits to the villages by the staff or their erratic availability at their stations, they do not serve any purpose to the farmers. Support from the ANGRAU is available only on contact and demonstration basis for a few willing farmers for some time and not on a sustainable or continual basis. Therefore, diffusion and dissemination of technical knowledge is limited.

Table – 9: Institutional Support for Knowledge Access to farmers

Agency	**Villages**	**Activity**	**Remarks**
Ananthapur area			
1. ANGRAU	Pampanur Lingannapalli	Conducting on farm demonstrations (OFD), technical advises, input supply, package of practices, Agricultural implements on subsidy Farmers participation in Kisan melas	Limited Technical services and input support, new dryland agricultural techniques
2. RDT	Gantapuram Pampanur	Involvement in Watershed development and its allied activities	Soil improvement, water harvesting, alternative methods of land use
3. Agriculture Dept	Lingannapalli Jalalapuram	Technical advises through Raitu sadassu. Suggestions on seed treatment, plant protection measures etc	Technical information and input supply support
4. Horticulture Dept.	Lingannapalli Jalalapuram	Providing package of practices for cultivation of fruits & flowers	Technical information and input supply support
Pileru area			
5. AME	Nagulakunta	Encouraging better yields through PTD package, providing loan/revolving fund & critical inputs	Technical information and input supply support
6. APRRM	Nagulakunta T.Harijanawada	Watershed program, Agrl. Technology through PTD practices	Supports AME's PTD in Nagulakunta only

(Source: Venn diagram, General Group discussions)

The poorer category of farmers is usually not in a position to benefit from such activities due to their preoccupation with their livelihood activities. RDT on the other hand, involves farmer participation across a larger section of farmers (most of their activities have a group approach) in limited areas of technical support. However, though the support is limited only to certain aspects of technical knowledge, their project activities and project period are programmed for capacity building among the farmers with an overall development approach. Farmers of Nagulakunta village get technical support specifically for groundnut crop production technologies by AME. This support is limited to improving productivity and capacity building on technical issues and to a certain extent build up their managerial abilities. Issues such as aflatoxin control have not yet been addressed by the current program.

It is therefore evident that, though some technical information reaches the farmers through all these sources and certain amount of capacity building is taking place, information on issues such as aflatoxin contamination, is not available to the farmers. The complexity in identification of aflatoxins, ambiguity in the identification of definite paths of contamination and lack of comprehensive understanding on aflatoxin contamination among the information providers are some of the reasons for the deficiency of information on aflatoxin among the farmers. Conscious efforts are required to correct this situation of deficiency of comprehensive information on aflatoxin among the information providers. Further, it is important for these information-providing institutions to identify the incentive structures that will ensure farmers produce aflatoxin free groundnuts for the market and advocate the importance of producing such contamination free products to the farmers. They also need to provide advocacy to concerned organisations for policy initiatives to arrest the food-fodder spread of aflatoxin contamination.

<u>Implications for aflatoxin contamination:</u>

Information on issues such as aflatoxin contamination is simply not available to the farmers. The complexity in identification of aflatoxins and lack of clear perspective about its control measures among the information providers leads to this deficiency of information on aflatoxins among the farmers.

f) ***Social factors***

i) Socio-Economic stratification and power relations

Wealth ranking exercises in the study villages led to farmers identifying themselves as belonging to different socio-economic categories primarily based on socio-economic criteria. These criteria relate mostly to the assets they own including land and other resources. The main criteria that emerged were size of land holding owned, ownership of livestock, machinery and equipment, sources of irrigation, capacity to hire labor and extent of physical labor used on own farm activities. The socio-economic criteria used by farmers along with their wealth classification are presented in Table - 10.

Table – 10: Socio-economic Stratification: Wealth Categorization by Farmers

Categories	Rich	Middle	Small,	Marginal
Village	**Criteria Used for Wealth Categorization**			
Pampanur	**Farmers refused to be classified as rich since no farmer owns more than 20 acres of land**	• Own > 6 acres • Traditional landlords • Secondary occupations • Hire labor also • Own irrigation sources	• Own 3 - 5 acres • Work on own field • Work for wages • Rain fed farming	• Own < 2 acres • Work on own field • Wage earnings are main income • Rain fed farming
Lingannapalli	• Own > 20 acres • Secondary occupations • Hired labor only • Own irrigation sources - > 4 bore wells • Own or hire Tractors	• Own 5 - 19 acres • Work on own field • Hires labor also • Own irrigation sources – 1- 3 bore wells • Own > 4 pairs bullocks • Sometimes hire tractor	*Farmers insisted on being categorized as Poor* • Own < 4 acres • Work on own field • Hires labor when critically required • No irrigation sources • May own < 1 pair bullocks • Hire Bullocks	
Ghantapuram	• Own > 20 acres • Work on own field • Hire labor • > 5 acres under summer irrigation sources -2 wells • Own or hire Tractors • Threshers, jeeps, etc.	• Own 10 – 19 acres • Work on own field • Hire labor also • 2-3 acres under summer irrigation sources-1/2 wells • Own > 5 buffalows – sell milk for livelihood • Sometimes own tractor	• Own 3 - 9 acres • Work on own field • Work for wages • Hire labor also • No irrigation sources • Own 3-4 buffalows / cows – sell milk for livelihood	• Own < 2 acres • Work on own field • Wage earnings are main income • No irrigation sources • Own 1/ 2 buffalows / cows – sell milk for livelihood
Jalalapuram	• Own > 20 acres • Hired labor only • > 5 acres under summer irrigation sources - 2 /3 wells • Own > 5 buffalows – • May own Tractor	• Own 6 - 10 acres • Work on own field • Hire labor also • > 3 acres under summer irrigation sources – 1 well • Own 3- 4 buffalows – or few sheep	• Own 3 - 5 acres • Work on own field • Hire labor also • < 3 acres under summer irrigation sources – 1 well • Own 1- 2 buffalows – or few sheep	• Own < 2 acres • Work on own field • Wage earnings are main income • No irrigation sources • No livestock
Pileru Area				
Nagulakunta	**Farmers refused to be classified as rich**	• Own > 5 acres • Employed • Mango orchard (2 acres) • > 3 Livestock • up to 1½ acres paddy (1 well) • Has pucca house • Sheep rearing	• Own 3 - 4 acres • Basket weaving activity • 2 - 3 Livestock • < ¼ acres paddy • No irrigation sources • Sheep rearing	• Own < 2 acres • Wage earnings are main income • 1 or no livestock • No irrigation sources
Thoti Harijanawada	**Farmers in the entire village preferred to be categorized as small and marginal categories only.**		• Own >3 acres • Lease land > ½ acre • Employed • > 3 Livestock • No irrigation sources • Sheep rearing (> 5)	• Own < 2 acres • Lease land < ½ acre • Wage earnings are main income • > < 3 Livestock • No irrigation sources • Sheep rearing (<5)

(Source: Social maps and wealth ranking exercises) *AME carries out farmer PTD activities in this village

Through a pair wise ranking exercise, men and women farmers were asked to rank the problems in groundnut crop production and marketing activities as per their perceived priorities. In Pampanur, Nagulakunta and T. Harijanawada villages, farmers of all the wealth categories preferred to do this exercise together while Ghantapuram, Jalalapuram and Lingannapalli farmers desired to form into two different groups – the richer and poorer – to conduct this exercise. The ranks thus obtained are listed in Table - 11.

It is evident from Table - 11 that, while some problems are ranked equal by all the categories, their perceptions differed in a few cases indicating the variations in their priorities. For example across villages and wealth categories, unfavorable climate figured as a top priority problem while a problem like pest and diseases in Ghantapuram fetches a fourth rank by the rich while the poor classify it as a high second rank problem. Similarly, lack of technical know-how is ranked by the poor farmers of Ghantapuram as a top constraint, while the rich farmers of the village did not consider it as major constraint and so ranked it at third place.

Again in Lingannapalli and Jalalapuram villages, the rich consider non-availability of labor a lowly sixth ranking problem, while the poor do not perceive it as a problem at all. Credit though is a ubiquitous problem for the entire farming community; the rich have classified it at slightly lower ranks of fours and fives while the poor ranked them at higher twos and threes. One interesting and yet a major problem is the wild boar menace in Pileru region. Farmers in this area ranked this problem at a high Two while farmers in Ananthapur region have no such problem at all.

Table – 11: PROBLEM ANALYSIS MADE BY GROUNDNUT GROWERS OF ANANTHAPUR and PILERU

S No.	Problems in Groundnut Processing & disposal	Ranks given by farmers of								
		Mixed group			Rich & Middle			Poor		
		Nagula kunta	T. Hari janawada	Pampa Nur	Ganta puram	Lingan napalli	Jalala puram	Ganta Puram	Lingan napalli	Jalala puram
		PILERU AREA		ANANTHAPUR AREA						
1	Unfavorable climate (Inadequate rains)	1	1	1	1	2	1	1	1	1
2.	Market problem (No rate)	3	3	4	6	1	3	--	2	1
3.	Pests/ diseases	5	5	4	4	3	2	2	3	1
4.	Weeds	7	6	5	5	5	7	5	5	4
5.	Non-availability of Labor	--	--	7	3	6	6	4	--	--
6.	High costs of inputs	6	--	--	--	4, 8♣	4	4	3, 4♣	2
7.	Debts & Financial constraints	4	2	2	4	4	5	3	3	3
8.	Non availability of thresher	--	--	6	--	7	--	--	--	--
9.	Lack of Irrigation	--	--	3	--	--	4 @	--	--	--
10.	Lack of Technical Know how	--	4	4	3	--	--	1	--	--
11.	Adulterated pesticides	--	--	--	2	--	--	--	--	--
12.	Wild Boar menace	2	2	--	--	--	--	--	--	--

(Source: Pair-wise ranking of problems in groundnut production and sale)

Note : Lower figures indicate higher severity of the problem.
♣ Denotes non availability / high hiring charges of agricultural implements.
@ Denotes electricity problem.

Discussions in the earlier sections have clearly indicated that different categories of farmers have differential opportunities due to differential access to resources, bargaining capacity and their livelihood options and constraints with regard to groundnut cropping systems. The differences mainly relate to accessibility to credit, labor, mechanization and markets. As is evident from the discussions in the earlier sections of this report, the poorer categories of farmers generally lack access to credit and inputs to plan out cropping operations.

While credit tie-ups inhibit the ability of the poor to produce better product, lack of proper access to market affects their perceptions on producing quality product due to lack of incentives. They also lack access to machinery and equipment through which timely operations can be conducted quickly and efficiently so as to be able to utilize all available opportunities for producing quality product. (See relevant sections on credit, markets and mechanization).

Due to the limitations in access to resources, farmers' perceptions of their constraints differ among the categories. Such differing perceptions among the farming community lead to variations in the crop management practices. The differing opportunities and constraints on the other hand are also likely to create hurdles in following uniform crop management practices. The lesser the opportunities and options to carry out proper crop management practices the higher are the chances for susceptibility to contamination. However, it is difficult at this stage to attribute which of the categories of farmers, perceptions, constraints, opportunities or options are likely to contribute to the incidence and spread of aflatoxin contamination.

<u>Implications for aflatoxin contamination:</u>
Different categories of farmers have differential opportunities and constraints that are likely to create hurdles in following uniform crop management practices. The lesser the opportunities and options to carry out crop management practices as desired, the higher are the chances for susceptibility to contamination.

ii) Gender Perceptions

Activity calendars show that women actively participate either exclusively or along with men in various groundnut crop production operations, important among them being seed management, seed treatment, sowing, manual weeding, harvesting, pod separation, shelling and storage (see Table - 4).

Such extensive involvement of women brings in a different set of observations that are likely to be either different or add a new dimension of information from those of the men farmers. Group discussions exclusively with women farmers indicate that their perceptions about prioritizing the problems vary from those of the men farmers. According to them, field pests and diseases (especially 'nuvvu malliga' at harvesting time), storage pests (Oozu), weeds and drought are the major problems faced by the groundnut farmers. They also realize that heavy rains leading to water logging can lead to poor pod development and damage the crop, while improper drying before stacking of crop reduces crop quality as it can lead to fungal growth. These observations clearly indicate that it is essential not to undermine the role of women farmers during dissemination of technical information on crop production activities.

Since women work more closely with the groundnut pods and kernel, and their observations concerning quality of seed, pod and kernel have greater significance compared to that of the male farmer. The various aspects of good quality groundnut as described by the women farmers of the study villages are summed up as following.

- Healthy seed, pods or kernel need to look neat, properly rounded, fully formed without spots, blackening or fungal growth and contain more oil.
- The kernel not only has to be whitish in color(light colored), it has to have a good taste (some bitter tasting kernel may also look whitish).
- The variety of groundnut needs to be pest and disease resistant.
- While selecting seed material it is important to select only fully filled pods even if shelling is difficult compared to partly filled pods that may be easy to shell.

From these observations it can be implied that women do have very close association with the pods and kernel as well as their care during storage and therefore are aware of the qualities that are required to constitute good quality groundnut. Similarly, they are the ones who sort out the inferior pods and kernel and sell them to oil rotaries while keeping the best for seed purpose. This potential of women can be utilized to advantage in the identification and reduction of aflatoxin contamination in groundnuts, as they are mostly involved with seed management, storage and consumption of groundnuts. However, their reluctance to use of fumigation (by celphos tablets) of seed and other produce within their households, due to the side effects of the chemicals, during extended storage requirements requires considerable attention.

The debate is strong in the sense that, while handpicking and storage of good pods and kernel for seed and household consumption is an extremely preferred activity, inhaling of toxic fumes of fumigation chemicals during fumigation by the household is an equally detestable preference. While the farmers either do not have the means to purchase fresh seeds every new crop or are not assured of good quality seed material whenever required by them, what other options do they have but to digest the fumigation chemicals?

Implications for aflatoxin contamination:

Women work more closely with the groundnut pods and kernel. This association of women with the groundnut crop can be utilized to advantage in the identification and reduction of aflatoxin contamination in groundnuts, as they are mostly involved with seed management, storage and consumption of groundnuts.

VI. Farmers' Awareness of Aflatoxin Contamination and Perceptions on Groundnut Quality

An awareness survey*(ANGRAU. 1999) conducted by the Acharya N.G.Ranga Agricultural University (ANGRAU – the erstwhile Andhra Pradesh Agricultural University -APAU) in 8 villages of Ananthpur district of Andhra Pradesh shows that irrespective of the size of farmers' holding or literacy levels, farmers' knowledge on aflatoxin is very low. About 90 % of the big farmers themselves (leave alone the small and medium farmers) had not heard of aflatoxin. None of the oil millers and about 50% of commission agents know that some forms of fungus develops on groundnut pods and kernels. As far as aflatoxin contamination is concerned, only the very experienced commission agents who assess quality of the produce had heard of it, while very few oil millers had any knowledge about aflatoxin contamination.

PRAs conducted with farmers in this study clearly indicate, as shown in Table - 12, that they are not aware of aflatoxin per se, and consequently do not have any means of identification or mechanisms to detect it. The reason for such a situation is that nowhere in their production and disposal process do they come across a situation when they are asked to check or verify for aflatoxin contamination. None of the marketing channels where they dispose their groundnut production has any restrictions on the sale of aflatoxin-contaminated products.

The only time when farmers (in two of the study villages) ever heard about aflatoxins was when ANGRAU conducted an awareness campaign on aflatoxin contamination. It has remained as a simple piece of information with those few farmers, who attended the meeting, as no sustained follow up action was initiated to bring in any necessary changes in the farmers management practices. It shows here that, just being aware is not a sufficient condition for addressing problems such as aflatoxin contamination because farmers have several constraints in groundnut crop production and marketing aspects (discussed earlier in this report) which need to be addressed first. Even in Nagulakunta village, where farmers are involved in the participatory technology development program for groundnut crop production the trend is similar.

Farmers normally are concerned about good quality seed material and good marketable produce. Their perceptions of good quality material is based on the general perceptions of fully formed big, bold, spotless pods with high oil content, clear color, good taste and high shelling percentage, etc, (Table - 12). Pods and kernel that taste bitter, have fungal growth, are rotten or sprouted and have bad odour are considered unfit for consumption and so discarded. However, small quantities of inferior quality material such as discolored, shriveled, bitter tasting, broken shelled and other deformed form of kernels and pods are sold along with the rest of the good quality material. Farmers are also aware that improper drying of produce, dried pods getting wet in rain, presence of moisture in stacks, and leftover pods retrieved from the fields after the harvesting period being mixed with the better lot are some of the reasons that affect the quality of groundnuts.

Perceptions of farmers across the villages and across wealth categories are found to be similar with regard to the quality of produce. Pods and kernel that show fungal growth or are discoloured are definitely discarded. Yet, there is a good chance that some of the discardable ones may escape through the market channels into the consumer market. The entire exercise is based on the farmers' knowledge and perceptions on good and bad materials and related visual observations. Aflatoxin contamination on the other hand is an unknown entity for them. They neither have any indication of what is aflatoxin nor any means of identifying or detecting it, and so they are oblivious to it.

Table – 12: Farmers' Perceptions on Quality of Groundnut and Awareness about Aflatoxin – Ananthapur and Pileru.

Name of Village	*Quality Perceptions*			
	Good Quality	Inferior Quality	**Discardable**	**Awareness about Aflatoxin**
Ananthapur area				
Pampanur	• Fully formed pod • Spotless pod • White colored pods • More oil content • Big bold pod	• With fungal growth • Shriveled kernels • Red /Black color • Discolored • Bitter to taste	• Bitter taste • Fungal impression • Tasteless	• Few farmers heard of the term during ANGRAU scientists visit.
Linganna Palli	• Heavy kernel • Good taste • Spotless pod • White colored pods • More oil content • Big bold pod	• White fungal growth • Rotten look • Rough appearance • Red /Black color • Discolored • Bitter to taste	• Bitter to taste: kernel • Damaged pods • Rotten look • Fungal impression on pods/ kernel	• Few farmers heard of the term during ANGRAU scientists visit.
Ganta Puram	• More out turn • Good taste • More oil content • White, big, bold pods • Spotless pod • White colored pods • More oil content • Big bold pod	• White fungal growth • Shriveled kernels • No oil content • Red /Black color • Discolored • Bitter to taste	• Sprouted kernel • Bitter to taste	• Not aware
Jalala Puram	• Healthy look of pod • God taste :kernel • More outturn/size • Vigorous kernel • Spotless pod • White colored pods • More oil content • Big bold pod	• No oil • Pod shell is hard • Fungal growth • Sprouted kernel • Broken shell • Shriveled kernel • White fungal growth • Red /Black color • Discolored • Bitter to taste	• Bitter to taste • Broken pods • Sprouted kernel • Fungal impression • Pods with bad odor	• Few progressive farmers are aware of the term only through the media.
Pileru area				
Nagula Kunta	• Fully formed & healthy seed • Good taste • More outturn • Spotless pod • White colored pods • More oil content • Big bold pod	• Thin/shriveled • Split cotyledons • wrinkled, damaged • Non-germinating • Less out turn • Red /Black color • Discolored • Bitter to taste	• Bitter to taste • Fungal impression • Rotten kernel	• No idea

T.Harijana wada	• Healthy & vigorous/ fully formed Viable seed • Good taste • Spotless pod • White colored pods • More oil content • Big bold pod	• Red/black/ discolored • broken cotyledons • sprouted • Red /Black color • Discolored • Bitter to taste	• Bitter to taste • Fungal impression	• No idea

(Source: Group discussion on Quality aspects, matrix exercise on Varieties vs. traits and case studies)

VII. Conclusions and Recommendations

Conclusions

It is clear from the study that farmers are not aware of aflatoxins, and so do not perceive aflatoxin contamination as a problem in their groundnut production systems. They are oblivious to 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 may carry aflatoxin contamination since, neither the groundnut prices are influenced due to aflatoxin contamination nor are there any market restrictions on its sale. They also do not have information on the health risks involved in consumption of aflatoxin contaminated products.

Groundnut crop production and post harvest methods as being practiced by the farmers of the study area are constrained and/or conditioned by the various socio-economic factors prevailing in the region.

Farmers are indifferent to crop quality due to several conditions such as the pressure to clear their high cost credits at the earliest, labor/ machine availability, etc. The prevailing management practices do indicate that they provide favorable conditions for the development and propagation of aflatoxin contamination.

The groundnut market is not oriented to either rejecting the contaminated produce or providing incentives to contamination free produce and therefore, quality of the crop is not a hindrance for the sale of groundnuts in the market. Finally, as there is no resistance from the ultimate consumer of groundnuts and groundnut products against aflatoxin contamination, reducing aflatoxin contamination in groundnut production may not be considered vital for continuity of production and marketing.

Apart from this general scenario of production, the constraints and opportunities of wealth categories indicate different power relations in terms of access to resources, bargaining capacity and livelihood options indicating the existence of a social structure where the poor emerge as the disadvantaged. The small and marginal farmers do not have the same opportunities and perceptions as the rich farmers with respect to issues such as access to and availability of credit, timeliness of credit, labor, quality of inputs, mechanization, information and access to markets. For example, while the poor farmers are more heavily burdened with credit-output tie-ups when compared to the rich, labor shortages for crucial operations is an equally bigger problem for the rich farmers.

Such differences lead to variations in management practices between the wealth categories and hence could have different implications for aflatoxin contamination. For example, the poor farmers resort to inadequate drying and post harvest care due to the pressure of credit-output tie-ups or livelihood options, problems of managing labor may dissuade the rich from undertaking proper care of weeding, post-harvest handling of the crop, etc., thus giving scope for the spread of aflatoxins.

The specific division of labor, between men and women involved in the groundnut production systems leads to specific gender perceptions concerning different aspects of crop management practices and crop quality. Such differential experiences may lead to management practices that are likely to have an impact on aflatoxin contamination. For example women's involvement with seed management activities may have considerable influence on maintaining the seed quality and its consequent effect on aflatoxin contamination while men's experience with groundnut marketing is likely to influence their perception about crop quality in general.

Overall it appears that, in the dry-land groundnut environments, the socio-economic context indicates that the constraints faced by the farmers are many more than the opportunities available to them, to improve quality and productivity of the crop. However, a conscious intervention with a good understanding of the underlying reasons for these problems (discussed in this paper) is necessary for evolving farmer validated technologies for reduction of aflatoxin contamination in groundnut.

Recommendations

The findings of the study suggest that one cannot just begin addressing the problem of aflatoxin contamination by simply introducing improved management practices. The present scenario suggests that the role of the farmers in the whole system is more on the receiving end as 'passive subjects' rather than 'active stakeholders' despite the fact that groundnut crop constitutes one of their main sources of livelihood in this region. Farmers' socio-economic conditions indicate a complex situation where several factors are at interplay. Strategies for interventions to reduce aflatoxin contamination in groundnut need to be evolved to fit the process of technical change into the livelihood systems of farmers at large while improving their living conditions. This requires a closer examination of the role of the various institutions and the actors that are involved with the entire supply chain of groundnuts and their products.

We therefore recommend that –

- Technological change will not take place unless a series of interventions that can give necessary incentives are provided to the farmers and other stake holders.

- As farmers work under several socio-economic constraints, which are likely to become their primary concerns 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.

- 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 seed free from contamination irrespective of the sources of supply.

- We have to build coalitions of interests 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 legislative action are required simultaneously to enforce prevention of trade in aflatoxin contaminated products.

- Mass awareness campaigns are required to educate the farmers, traders, processors and the consumers of groundnuts and groundnut products regarding the ill affects of aflatoxin contamination. For this purpose, alternate approaches to marketing need to be developed such that the whole supply chain is ultimately integrate into a single system.

- Providing incentives to farmers, health concerns, building up of consumer demands for aflatoxin-free groundnuts, trader responsiveness and appropriate action research for technical change should be the operational focus of interventions. Research institutions, government agencies, marketing agencies, consumer groups, NGOs, farmers groups and lobbies should be organized into becoming joint stake holders and collaboratively evolve strategies that will address the problem of aflatoxin contamination at a systemic level. Farmers have to be made stakeholders and become accountable to and be the beneficiaries/partners of an aflatoxin free groundnut crop production system.

- The small and marginal farmers do not have the same opportunities and bargaining capacity as the rich. Blanket recommendations for all the groups may in fact adversely affect the poor while benefiting the rich. It is extremely important to take care that interventions do not leave the poor worse off while making the rich better off. Similarly, perceptions of men and women involved in crop production activities need to be ascertained for optimizing the validation of technologies and interventions based on their experiences.

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Table – 3: Overview of Management Practices in Groundnut: Ananthapur and Pileru Areas

S. No.	Agricultural Operations	*Management Practices / period Common to all villages*	*Management Practices different fro*			
			Pampanur	**Lingannapalli**	*Gantapuram*	*Jalalapu*
I.	Land Preparation	Plough twice with country plough / tractor. Manual removal of left over pods/stubbles. Harrowing with *Guntaka (bullock drawn), leveling with a wooden plank, FYM incorporated into the soil during land preparation / May to June	Tractors are used for ploughing if first showers are inadequate		Harrowing with *Guntaka (bullock / tractor drawn)	Harrowing w *Guntaka (bu tractor drawn
II	Sowing Operations	Keep the seed ready by manual pod shelling in April Treat the seed with Thiram @ 2.5 to 3 gm/kg seed (few), Line sowing with bullocks or power drawn seed drill/ in July	Less than 50% use own seed	Shelling in May Majority farmers use own seed	Shelling in May Majority farmers buy seed	***Shelling (2 weeks before sowing) Majority farm own seed.***
III.	Fertilizer Application	Manually apply Urea & DAP as basal dose July – Aug – Sept	Top dressing 30 days after sowing.		SSP/ MoP/ DAP / Complex; as basal d : ½ as basal rest as top dressing 35 to 4 after sowing	
IV	Inter cultivation & weed control	2 Manual weedings with 15 to 20 days interval. Earthing up the soil around the plant / in Aug- Sept		2-3 weeding manual or by metla guntaka.		
V	Pest Control^{o}	Spray Chemicals for pests and diseases with the sprayer – Celphos tablets for storage pest control. Aug / Sept – Oct		dust phorate granules	Neem oil : is used by small farmers only	Negligible sto pest problem
VI.	Harvesting Uprooting, Field drying & Stacking	Manual / tractor uprooting depending upon rains, field drying for 2-4 days & stacking in the farm yard for 15-30 days. / Oct – Nov		Guntaka drawn by tractor is sometimes used for uprooting groundnut crop		
VII.	Threshing	Manual and mechanized threshing November / December/ January	Mechanized threshing by majority farmers.	Mechanized threshing by majority farmers.	***Manual threshing by majority Few rich / medium opt threshers***	Manual thres majority Mechanized threshing opt the richer clas
VIII	Storage	Pods stored in gunny bags or left in heaps in closed rooms / December – February				
IX	Marketing	Farmers have credit input linkage with money lenders. Traders approach the farmers to purchase the produce January – February	All wealth category have credit output links	Only poor farmers have credit output links	***Few marginal farmers have credit output links***	Few farmers categories exc rich) have cr input linkage money lender

Popular Varieties used : TMV 2, JL 24, K 134, and Polachi red in the order (Source : Seasonal Calendo

o Most common pests and diseases: Red hairy caterpillar, white grub, leaf folder, leaf spot and bud necrosis; Post harvest pest 'nuvvu maliga'; Storage pest 'oozu'.Guntaka – Local wooden implement with metal blade drawn by bullocks used for breaking clods / harrowing.

Table – 4: Labor demand and supply for different Agricultural Operations in Kharif Groundnut : Anatapur & Pileru

Name of Village	**Month-wise Scores Given by Farmers on Labor for Different Agricultural**							
	May	**June**	**July**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**
Ananthapur area								
Pampanur	M:5 F:5 - Ploughing - **Field cleaning**	***M:6 F:4*** - FYM - ***Harrowing*** - ***Leveling***	M:5 F:8 - Seed treat - Sowing - Fertilizers	***M:8 F:8*** - ***Inter cultivation*** - ***Weeding***	M:8 F:6 - 2nd weeding - Pesticides	M:8 F:8 - Pesticides	M:10 F:10 - Uprooting - Field drying - Stacking	M:10 F:6 - Threshing - Sieving - Bagging
Lingannapalli	--	--	M:2 F:2	M:10 F:10	M:5 F:5	M:10 F:10	M:8 F:8	

	- Ploughing - Field cleaning	- FYM - ***Harrowing*** - Leveling	- Sowing - Inter–cultivation - Pesticide	- ***Harrowing,*** - Manual weeding - 2^{nd} spray of pesticides	- 3^{rd} spray of pesticide (depending on need)	- ***Uprooting*** - ***Drying*** - ***Transporting*** - Stacking - Threshing	- Threshing - Bagging	
Gantapuram	M:6 F: 0	M:4 F:4		M:9 F:9	M:2 F:2	M:10 F:10		***M:10 F:10***
	- Ploughing	- Harrowing - Sowing - Inter cultivation		- Intercultivation - Weeding - Pesticides	- Pesticides	- ***Uprooting, - Field drying*** - Transporting - Stacking - Picking up leftover pods		- Uprooting - Threshing **Rabi G-nut** *activities*
Jalalapuram	--	***M:2 F:2***	***M:4 F:4***	M:10 F:10	M:10 F:10	***M:10 F:10***	M:10 F:10	
	- Land preparation	- Sowing - ***Fertilizer***	-Late sowing - ***Inter cultivation***	- Pesticide - Weeding	- Pesticide	- ***Early uprooting***	- late uprooting - Field dryin - Stacking - Threshing - Bagging	
Pileru (Chittoor) area								
Nagulakunta	--	--	M:9 F:7	M:10 F:10	M:3 F:3	M:10 F:10	M:8 F:10	M:2 F: 0
	- Land preparation	- FYM	- Bio-fertilizers - Sowing	- Gypsum - Weeding	- Pesticide	- Uprooting - Field drying - Stacking - Threshing - 2^{nd} drying - Bagging		- Marketing - Paddy operations
T.Hari-janawada	***M:6 F:6***	M:3 F:2	M:9 F:8	M:10 F:10	M:6 F:5	M:10 F:10	M:10 F:9	M:9 F:8
	- ***Land preparation***	- FYM, - fertilizer	- Sowing - Inter-cultivation	- weeding	- 2^{nd} weeding	- Uprooting - Field drying - Stacking - Threshing - 2^{nd} drying - Bagging		- Paddy operations

Note : M -Male labour : F - Female labour -- Represents no demand for hired labor during those months (Source : Seasonal Activity Calendar)

Nos indicate the scores given by farmers using beans to represent the demand for labour – higher numbers indicate greater demand and scarcity of supply

Scale:

0-2	3-4	5-6	7-8
Surplus labor available within village	labor available within village	Just sufficient labor with in village	Labor not available for work as and when require
Low demand for labor	Moderate demand	Moderately high demand	High

Staad

Report - 2

Marketing and Processing Practices and Quality Perceptions in Groundnut Disposal
An Analysis of the Factors Concerning Aflatoxin Contamination In Ananthapur and Chittoor districts of Andhra Pradesh.

Of the project on

Strategies for reducing aflatoxin levels in groundnut-based foods and feeds in India:

A step towards improving health of humans and livestock

For the

International Crops Research institute for the Semi-Arid Tropics (ICRISAT)

and

Natural Resource International, UK.

Prepared by

Rama Devi Kolli

Socio-economic advisor

Andy Hall

SOCIETY FOR TRANSFORMATION,
AGRICULTURE AND ALTERNATIVES IN DEVELOPMENT

Marketing and Processing Practices and Quality Perceptions in Groundnut Disposal

An Analysis of the Factors Concerning Aflatoxin Contamination In Ananthapur and Chittoor districts of Andhra Pradesh.

Introduction

Aflatoxin contamination is a complex phenomenon. Aflatoxin contamination cannot be detected by visual observation. It requires specific diagnostic tools to establish its presence. Under these circumstances the issue of aflatoxin contamination has remained as an unknown entity in the food chain in India in general and the groundnut scenario in particular. Neither the farmers, nor the traders and the other market agencies involved in the groundnut production and marketing chain have an idea about its occurrence and spread.

In this report we argue that the reasons for the spread of aflatoxin contamination are mainly due to the non-responsive behaviour of the market, in providing incentives for the production of aflatoxin free groundnuts, in the absence of necessary regulations and monitoring process. We show through this report how merely bringing in awareness about the aflatoxin problem is not enough to bring in reduction in the levels of aflatoxin contamination in the groundnut crop, but requires a more holistic approach.

Study of aflatoxin contamination in groundnut crop production does not end with understanding the production patterns at the farmers' level. The processing and market channels also are potential sources and carriers of contamination. With the absence of any institutionalized regulations on the permissible levels of aflatoxin content in edible products it has become imperative to study how the formal and informal sectors of the market react to aflatoxin contamination in the groundnut crop. This exploratory study is undertaken as part of the main study - An Analysis of Socio- Economic Constraints and Opportunities for Reducing Aflatoxin Contamination in the Deccan plateau.

This study envisages to picturise/ understand how the post-production market reacts to aflatoxin contamination in groundnut. It explores the existence of any formal and informal regulations/ mechanisms, deterrents/ disincentives/ penalties within the market systems. It is also planned to understand the role of the different players in the market and the processing industry, their practices and perceptions on aflatoxin contamination.

Case studies were carried out with a cross section of market players by tracking them down from the information gathered through the PRAs conducted earlier with farmers of Ananthapur and Chittoor districts of Andhra Pradesh. Hence the case studies (14 in Ananthpur and 5 in Pileru) were focussed in Dharmavaram and Ananthapur (rural) areas of Ananthapur district and Pileru area of Chittoor district.

Information was gathered through questionnaires, and personal interviews with different market players and officials of the Andhra Pradesh Co-operative Oil Seed Growers Federation (Oil Fed) processing unit in Pileru and their head office at Hyderabad. Visits were also made to Dharmavaram and Ananthpur market yards to observe the product movement, grading procedures, transactions and to get information on the traders, their addresses and establish contact.

The Market Scene

The general scenario of the groundnut market is not very encouraging. The groundnut oil market is in low demand due to competition from cheaper palm oil imports. A large number of oil expelling units have either closed down or are transforming into other operational specialisations such as decortication. The largest market player, the Oil Fed whose activities are still substantially subsidized, is now performing only a fraction of the role it used to play till recently due to the enormous competition from imported oil and consequent irrecoverable losses.

Therefore, while the groundnut farmers are not getting remunerative price for their produce, the ground oil industry is constrained to procure groundnut at further lower prices, extract maximum quantity of oil by economizing expenditures on all fronts including reduction in spending on segregation of damaged material and storage pest control. In this process, the market sometimes resorts to unethical practices too. This trend has led to a situation where neither the farmers nor the market, including the oil industry is able to completely discard pest and disease affected, degenerated or bad quality material. Undesirable products are therefore entering the groundnut kernel and oil trade and consumption markets. While such is the case with the market, absence of firm regulations for production of contamination free edible groundnut products, the entire groundnut production, trade, value addition and processing chain is highly ignorant of the processes and effects of contamination like the aflatoxin leading to increases in the levels of contamination.

The Chain

Due to the strong commercial nature of groundnut, the crop enters the market even before the seeds are sown. Market operators at various levels interact with willing farmers before the start of the season for possible purchase tie-ups involving supply of inputs on credit and lifting of stocks immediately on production. Others in the field enter at various stages of the production calendar right up to the direct purchases at the market yards.

The general pattern of marketing groundnut crop produce is a maze of situations where the transactions are conducted at the farm, village, regulated and unregulated market yards, the A P Co-op Oil Seed Growers Federation (Oil Fed) warehouses, brokers' offices, traders' offices, the oil expelling units, the decorticating units, etc. The study was conducted in Dharmavaram and Ananthpur (rural) areas of Ananthpur district and Pileru area of Chittoor district. The entire chain of market activity was covered under this study except the regulated market since there are no groundnut regulated markets in this area.

The Ananthpur and Pileru areas were compared for the patterns and practices of market activity and were found to be mostly in similar form except for very minor differences in onward trade linkages. Findings of the study are therefore presented as a unified picture except for highlighting the differences in the Pileru area as compared to the Ananthpur area.

The various actors involved in the chain include brokers, agents and traders of various categories, a range of decorticating and oil expelling units, exporters, the seed market, the oil seeds federation and the solvent extraction units.

Brokers

Marketing of groundnut is generally undertaken by three types of brokers. Local farmers who have access to the other segments of the market chain are first level brokers. Small time professional brokers who facilitate trade for the local and A P traders form the second type. Brokers acting on behalf of exclusive traders from distant / inter-state traders for exclusive grades of the produce form the third group.

Traders

The ubiquitous village money lender/trader is the first level trader procuring the pods immediately on harvest. Regular traders involved in supply of agricultural produce to the oil expellers, refineries and other processing units at various places across the state and outside form the second level of traders. Exclusive product traders like the Tamil Nadu, Nizamabad, Bombay and Gujarat traders, looking for confectionery / seed / export quality product form the elite third type of traders.

Decorticating units

Defunct local oil expelling units with decorticating facilities have turned their units into value addition units by purchasing the crop either directly from the farmers/ local brokers/ local traders, shell the pods, segregate and grade the kernels and market them to their appropriate demand areas. The kernel is graded into either 'A' or 'B' grades depending upon the shelling percentage (71 – 74 % shelling – 'A' grade and 68 – 70 % shelling – 'B' grade) derived from sampling in the original lot of pods prior to decortication. The kernel is segregated to ensure that the test samples of one kilogram of kernel should not contain more than 20 grams damaged kernel / partially decorticated pods / refraction by removal / screening of the kernel to remove excessively damaged material.

Oil expelling units

Small oil expelling units such as rotaries and baby oil mills as well as the medium scale oil expelling and refining units procure groundnut pods from sources similar to the decorticating units as well as broken/ damaged/ shriveled/ inferior kernels segregated at the decorticating units. The smaller units extract oil and sell in the open markets. The bigger units send their produce to the urban consumer and refinery markets.

Oil Fed

The A P Co-op Oil Seed Growers Federation (Oil Fed) is a state sponsored organization that is mandated to increasing oil seeds production and safe guard the interests of the oil seeds growers. It is by far the biggest single purchaser of groundnut pods in Andhra Pradesh. It has its own large oil expelling cum refining units and to a certain extent controls the price structure of the groundnut and groundnut oil.

Solvent extraction units

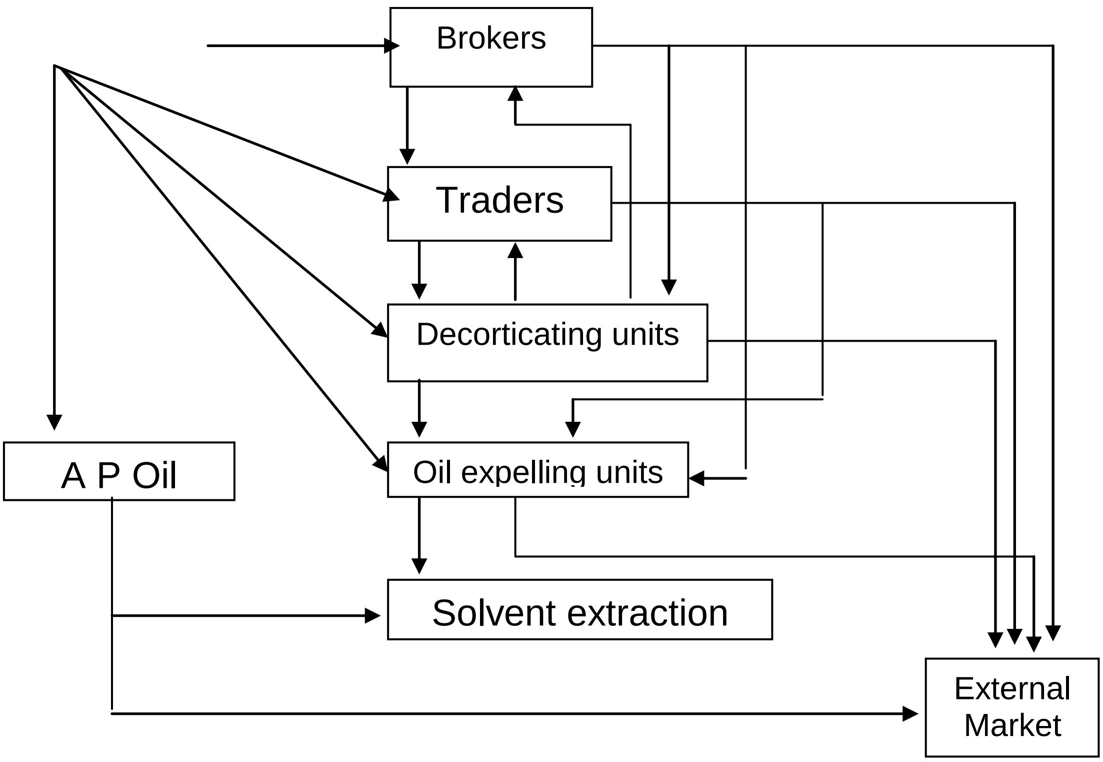
The solvent extraction units form the last link in the chain. Groundnut oil cake from the small, medium and large oil expellers is procured by these units for extraction of leftover oil in the cake.

The Market Players

In the absence of proper regulations and guidelines, each of the players in the market chain acts and functions exclusively on the market forces. Quality considerations are based only on the rudimentary physical parameters of, a) shelling percentages, b) moisture content, and c) refraction (waste material like soil adhering to pods, plant material like leaves and stems, dust, gravel etc). In the absence of any fixed parameters for fixing prices to groundnut produce that have damaged/ broken/ discoloured/ spotted/ rotten/ foul smelling/ pest ridden/ diseased/ immature pods, traders offer their prices based on the visual observations and their quality and quantity requirements. An example that requires mention here is the groundnut crop harvested from the fields with the recent large-scale attack of bud necrosis. Very low prices were offered to the produce since the pods showed a typically stunted feature that was a very clear visual symptom to the traders. The market however has neither the knowledge nor the facilities for grading of groundnut depending up on infections or contaminations such as aflatoxin.

Fig: Flow chart of the movement of groundnut produce and processed product among the various market Players

Farmer



A graphic representation of the product movement is shown in figure above, while table 1 below gives a clear picture of the market channels, value addition and product conversion points of the groundnut market.

Brokers

For convenience we term the earlier mentioned three categories of brokers as 'farmer Brokers', 'local brokers' and 'speciality brokers'.

Farmer Brokers

A few educated, affluent and/or knowledgeable farmers act as liaison agents for traders of all categories, especially the credit supplying input dealer/trader and local money lender/trader, for a small percentage of the price or on a fixed commission. Being local people they have extensive information on the yields and crop condition of the local farmers. They also have considerable influence within the village and hence persuade the small and marginal farmers into selling their small quantities of produce at less than the market rates and into giving away extra produce under pretexts of weighment procedures and quality considerations etc. The volume of produce handled by this category of brokers as shown in Table 1 indicates that they mobilize considerable volumes to the market and yet do have any say in the market prices as they operate as individuals and do not have control over the produce (such as being able to hold till the prices raise etc). Some of them also act as traders by buying small quantities of good produce from the farmers (at low rates) and sell in the market for higher profits.

Local Brokers

This category consists of local people from the villages or nearby towns who either act independently or are employed by brokerage offices or traders on a commission or salary basis. They move around in the villages spotting farmers who are willing to sell their produce to specified traders at predetermined prices or existing market rates. This category is always seen with suspicion and the brokers have very few chances of exploiting the farmers. They generally act only as liaison agents between the farmers and the traders, decorticators and oil expellers. Except for the very highly experienced ones, they normally do not have any role in price fixation or quality evaluation. This group of brokers handle large quantities of produce (volumes were not available from the survey as the respondents were reluctant to give figures). It is rare for this category of brokers to become even small time traders.

Speciality Brokers

The speciality brokers are normally independent brokers from nearby villages and towns with good perception of quality, grading, shelling percentages and refraction. They normally act as liaison agents on commission basis between the farmers and up-market traders or their agents for procuring high quality produce for specialised markets such as for seed, confectionery and export purposes. They also play an important role in price fixation due to their knowledge and experience. This is a small group of brokers who individually have large volumes though the overall product movement is small. The most common linkage this category provides is between the farmers and the Tamil Nadu traders.

Traders

Village level trader

Local moneylenders, and traders of agricultural inputs who supply farmers requirements on credit accounts, agricultural input suppliers of the nearest small town, other local traders and sometimes even rich farmers form this group of traders. Small and marginal farmers who procure their agricultural requirements on regular credit accounts are under pressure to relinquish their crop to the credit suppliers/traders immediately upon harvest and at prices determined by these traders. The terms of trade are almost always at a disadvantage to the farmer. While inputs are issued at rates higher than the market prices, exorbitant interests are charged during the lending period, the produce is paid less than the market rates and finally extra produce is taken towards various discounts such as weighing practices. The advantage of getting groundnut crop at low prices after getting exorbitant interests for the credit automatically makes traders out of these creditors.

Groundnut collected by these traders is sold to larger traders, exporters, decorticators, oil expellers and quality permitting even to the up-market traders like the Tamil Nadu traders. These traders, like all the other players handle equally large volumes between them.

Regular traders

This group consists of professional traders who operate through brokers or through direct contact with farmers. They are generally located at the market yards or local markets. In order to attract farmers and their produce, they provide small loans for various farmers' requirements at varying rates of interest which acts as a binding on part of the farmers into bringing their crop produce to the specific trader only. These traders sell the groundnut pods to other large scale traders, decortication units and oil millers across the state.

Exclusive traders

Exclusive product traders like the Tamil Nadu, Nizamabad, Bombay and Gujarat traders, looking for good quality groundnut pods (refer Table 2 for quality descriptions and grading criteria) for use in the confectionery industry, as seed material or for export are the most sought after traders. This category of traders seemingly pay a very good price considering the local market trends; however the price is definitely for very good quality product (75% shelling, 2-4% moisture and nil refraction) that can be obtained from a healthy crop and that too after further sorting and cleaning. They are non-resident traders and procure their requirements through the speciality brokers and other agents only during the harvest season when they make temporary stay in the towns, make spot purchases for cash payments and transport the product almost immediately. The product is invariably exported to other states or countries and may even be brought back as value added products or as seed material at very high rates. This segment of traders procures groundnut only from Ananthapur area, as they believe (reasons not known) that the quality of crop from Pileru area (Chitoor district) is not suitable to their requirements. Information on the volumes handled by these traders is not available.

Table 1: Marketing channels and points of product conversion.

S.No	Player	Quantity per year	Product dealt	Source	Market	Product sold
1	**Farmer**	Good Pods / Kernels from damaged pods	--	Own	Brokers /Traders Decorticators Oil expellers Oil Fed	Good Pods And Kernels from damaged pods
2	**Brokers**					
2a	**Farmer Brokers**	Pods	1,000 – 4,000 bags of Pods	Own and Farmers	Speciality Brokers Village level trader Regular traders	Pods

2b	*Local Brokers*	Pods	N.A	Farmers	Village level trader Regular traders Decorticating Units Oil Expellers	Pods and kernel
2c	Speciality Brokers	Good quality Pods	1,000 – 3,000 bags of Pods	Farmers & Local Brokers	Exclusive Traders	Good quality pods and kernels
3	**Traders**					
3a	**Village level trader**	Pods	1,000 – 3,000 bags of Pods	Farmers, Farmer Brokers & Local Brokers	Regular traders Decorticating Units Oil Expellers	Pods
3b	*Regular traders*	Pods Kernel	1000 – 6,000 bags of Pods	Farmers, Farmer Brokers, Local Brokers & Village trader	Decorticating Units Oil Expellers Exclusive Traders	Pods and kernel
3c	**Exclusive Traders**	Good quality Pods and kernels	N.A.	Speciality Brokers Traders	External Markets	Good quality Pods and Kernel
4	**Decorticating units**	Pods	1,000 – 28,000 bags of Pods	Farmers, Farmer Brokers, Local Brokers & Village trader	Oil Expellers Exclusive Traders	Kernel
5	**Oil expelling units**	Pods and Inferior quality kernels	500 – 1,000 bags of inferior kernel	Farmers, Farmer Brokers, Local Brokers & Village trader Decorticating Units	Local and External oil and oil cake markets & Solvent extraction units	oil and oil cake
6	**Oil Fed**	Pods	3,50,000 – 4,00,000 bags of Pods	Farmers and Sometimes Traders	External oil and oil cake markets Solvent extraction units	oil and oil cake
7	**Solvent extraction units**	Oil Cake	5000 – 5500 MT of oil cake	Oil Expellers & Oil Fed	Oil and de-oiled cake markets	Oil and de-oiled cake

Decorticating units

With the import and open distribution of large quantities of palm oil, large number of local groundnut oil expelling units were forced to shut down as trade in groundnut oil had become a risky proposition. A few oil-expelling units with decorticating facilities have turned their units into value addition units by shelling the pods, segregating and grading the kernels and marketing them to their appropriate demand areas. This trend has resulted in the emergence of exclusive decorticating units which now buy groundnut pods directly from the farmers, the local brokers and traders and in turn act as traders of groundnut kernels.

Depending upon the financial strengths, quality of crop procured, condition of the machinery, and onward contacts, these units dispose off the good quality kernels at premium prices. The next lower grades are sold to the larger oil expellers and local confectioners while the damaged, inferior (pest and disease affected), shriveled and broken kernel along with semi shelled pods and pod residue is sold to local oil rotaries and baby oil mills. The shelled husk is purchased by the farmers for generating crop residue manure.

Table 2: Grading and Prices of Groundnut Pods and Earnings of Various Players in the Groundnut Marketing Chain.

S. No	**Player**	**Grading**	**Price(In Rs/Q)**		
			Purchase Prices	**Commission/ Profit Range**	**Selling Rates**
1.	**Farmer**	Shelling % - 65 – 75 Moisture % - 4 - 12 Refraction % - 2 - 4	His own	--	900/- to 1350/-
2.	**Broker:**				

2a	Farmer brokers	Shelling % - 70 –72 Moisture % - 4 – 8 Refraction % - 2 – 4	1100/- to 1250/-	3.50 to 4/-	1100/- to 1250/-
2b	Local brokers	Shelling % - 65 – 70 Moisture % - 4 – 8 Refraction % - 2 – 4	900/- to 1100/-	10/- to 15/-	910/- to 1,115/-
2c	Specialty Brokers	Shelling % - 72 - 75 Moisture % - 2 – 4 Refraction % - 0	1200/-	100/- to 125/-	1325/-
3.	**Traders**				
3a	Village level trades	Shelling % - 65 – 72 Moisture % - 4 – 8 Refraction % - 2 – 4	900/- to 1175/-	45/- to 120/-	1220/-
3b	***Regular traders***	Shelling % - 68 – 72 Moisture % - 4 – 8 Refraction % - 0 – 4	1000/- to 1200/-	50/-	1050/- to 1250/-
3c	Exclusive traders	Shelling % - 72 – 75 Moisture % - 2 – 4 Refraction % - 0	1325/- and above - ?	100/- to 125/-	N.A
4.	**Decorticating units**	Shelling % - 68 – 74 Moisture % - 4 – 8 Refraction % - 2 – 4	900/- to 1200/- (pod)	65/- (Kernel)	Kernel 1586/- to 1593/- B grade 1900/- to 1916/- A grade
5.	**Oil expelling units**	Shelling % - 65 – 70 Moisture % - 4 – 8 Refraction % - 2 – 4	Inferior kernels- 1400/- to 1550/-	330/- to 380/-	Oil –3150/- to 3450/- Cake: 750/- to 780/-
6.	**Oil Fed**	Shelling % - 72 Moisture % - 8 Refraction % - 2	Fair produce- 1220/- (pod)	To NAFED at 2% commission	Oil - 3600/- to 3800/- Oil cake - 900/- to 1050/-
7.	**Solvent extraction plants**	Oil Cake from Oil expelling units	900/- to 1000/-	135/- (S.E Oil)	S.E oil : 3200/- De-oiled cake : 850/-

Oil expelling units

The few remaining oil expellers are the small rotaries and baby oil crushers and the medium scale oil expelling and refining units. Their infrastructure levels, financial strengths and financial viability are very low. Hence these units normally procure low-grade groundnut pods and kernels at cheaper rates (so as to ensure lower oil extraction costs) to be financially viable and sustaining. They procure the required raw materials from the decorticating units and from farmers. The smaller units extract oil and sell in the open rural markets and also to the refineries. The cake is sold to the solvent extraction unit. The bigger units send their produce to the urban consumer and refinery markets.

Oil Fed

The Oil Fed procures groundnut directly from the farmers at the market yards or at their co-operative warehouses. It procures pods with a minimum 72% shelling, maximum of 8% moisture and 2% refraction at a base price of Rs. 1220/- per quintal which is the minimum support price offered by the Government for the year 2000 -2001. Better quality pods are paid higher prices as per quality parameters.

Even though the groundnut oil business in the open market is not very lucrative, pod procurement prices are fairly stable due to the procurement policy of the Oil Fed. However, produce that does not meet Oil Fed specifications, is open to the vagaries of the market players.

Solvent extraction units

Being the last link in the chain, and needing only the leftovers (oil cake) of the main players, these units do have a very small and insignificant role in the market dynamics.

Marketing and Storage Practices and Quality Perceptions

In Andhra Pradesh, about eighty five percent of the groundnut crop is produced during the rainy season. The confectionery and the oil industry procure and store the pods or kernels in sufficient quantities when fresh crop reaches the market rather purchasing stored products. A few farmers store the crop for short periods and sell during the off season period at higher prices. However, majority of the annual stocks required by the various industries and trading players is procured during the season, depending upon the market demands, their marketing strategies and financial strengths and stored as per their conveniences (Table 3).

In order to achieve their quantity targets market players procure groundnut pods and kernel of all grades. The rate payable to the individual lot and the quantity are the only considerations for procurement. While, such is the situation of the market, cultivation of groundnut crop itself is carried out under diverse conditions. Quality parameters required by end users are of no consequence to the farmers. They prefer to sell in the market what ever they produce rather than produce what ever the market wants. The requirements of the end users too are very ambiguous – there are no guidelines for uniform quality standards. While, FPO standards are prescribed by the Government, unlimited quantities of inferior quality products are sold in the semi-urban and rural areas without any controls. In such a complex situation, tracing out the whereabouts of aflatoxin contamination is another complex phenomenon by itself (Table 3).

Groundnut crop is usually stored before it is converted into its product forms and stored groundnut pod is susceptible to various pest (locally called *nuvvumalliga, oozu, chekka purugu & nusi purugu)* and disease (various types of fungus) attack. Additional processing costs will have to be incurred by the already burdened processing industry if they undertake segregation of such storage pest and disease affected material apart from loss in weight. While this being the case with the organized groundnut oil producing industry, concerns for controlling possible losses, do not seem to be of primary value in the production to utilization chain in the unorganized sector in the rural areas especially since there are no penalties for lack of quality concerns nor are there incentives for producing quality product. Reviewing the roles of each of the market players gives a picture of their involvement in generation and control of aflatoxin contamination and their understanding of the importance of such contamination vis-à-vis consumption of such products by the human and animal population.

<u>Brokers</u>

Brokers are almost always only liaison persons and do not hold any stocks of groundnut. They spot the best pods available in the village as preferred by the trader, update themselves with external market situations and fix groundnut prices depending upon the quality. The produce is immediately sold out to the party and there is no storage at the broker's end, and so there is no need for adopting or even having knowledge of any control measures for safeguarding the produce from pest and diseases.

Though the brokers do not understand the terms aflatoxin and aflatoxin contamination and its consequences, they are paid to detect inferior quality or otherwise damaged pods. They also are in a position to identify any visible damage by commonly occurring pest and diseases such as bud necrosis, pod borers etc. They are permitted to allow up to 1 kg of damage pods per bag of 40 kgs, at a price reduction of Rs. 10/- to 30/- per bag for a base price-range of Rs. 480/- to 500/- per bag. They have to reject the material if damaged pods are in excess of 1 kg per bag. They do understand that improperly dried crop when stored in heaps before pod stripping leads to fungal growth, which they can observe visually even on the pods.

Traders

Traders purchase pods directly from farmers or through the brokers and sell it to the next set of users. Depending upon the market conditions and individual capacities, traders maintain stocks of groundnut pods up to a maximum duration of six months. The groundnut market does not react by the terms aflatoxin and aflatoxin contamination. Though there is a section of traders that know or have heard of them, the market being oblivious to such terms, they ignore the criteria in selecting their pods for onward trade.

However, the entire markets reacts to the presence of visibly damaged or inferior quality pods (broken/ discoloured/ spotted/ rotten/ foul smelling/ pest ridden/ diseased/ immature) in the lots, and so the traders scrupulously follow the rules of reducing the prices of such material. It is to cater to such of the market situations that the traders acquire an understanding of the situations in which groundnut pods can get affected. Therefore, they know that groundnut pods can be damaged if the pods contain high levels of moisture or due to soaking in rain while in storage, and at the farmer level during stacking of crop before stripping of pods and improper drying before stacking. Traders who are involved in regular medium to long-term (15 days to 6 months period) storage business do follow rudimentary control measures such as storing in properly covered storage areas (as against the normal practice of storing in gunny bags out in the open) and dusting or spraying gammaxene.

Based on the type of trade they are involved in, traders have their individual quality considerations while procuring groundnut pods. Traders from Tamil Nadu do not entertain even the slightest quantity of visually observable inferior or damaged pods. Traders from other regions permit a minor quantity of such material for a price consideration. There are the others who, for a price consideration, procure groundnut pods irrespective of the extent of such material in the lots, for onward sale to local oil mills.

Decorticating units

The decorticating units are more specific in what they buy. Only 'A' & 'B' grade pods with 71 to 74% & 68 to 70% of shelling respectively are purchased as A grade kernels will be extracted from A grade pods and so on. It is important for them to grade their out puts very scrupulously failing which their product may be rejected by their main purchasers the Tamil Nadu traders, the big wholesalers, the bigger oil companies, etc. Their entire stock is rejected if it is observed that more than 2 % of the kernels are damaged / spoilt. The husk is locally sold to farmers @ Rs 1000/- per tractor load for use as manure.

The decorticating units have enough storage facilities in the form of godowns where they store the pods up to a maximum of 4 months. They purchase the produce directly from the farmers or brokers in pod form. The pods are also stored sometimes in gunny bags heaped one above the other in the open (with in the compound and out side the decorticating unit) for up to 2 to 3 months. Use of proper pest control measures on the pods depends upon the individual units' financial capacity and storage requirements. While some of them use fumigation tablets into the jute bags for control of storage pests like *nuvvumalliga*, *chekka purugu & nusi purugu*, some manage only with gammaxene and the rest do not have any control measures. They do know that storage of pods can lead to infestations. The decorticating units are not sure whether the government rule restricting storage of more than 600 bags of pods per unit is still in force.

The decorticating units concurrently decorticate the pods as & when purchased and sell the kernel with out long storage. While they follow some storage pest control measures for the pods they procure, it is surprising to note that they do not follow any specific control measures for the kernels extracted in the units even if the kernels need to be stored up to 6 months under unavoidable circumstances. However, they do not allow sprinkling of water on the pods before decortication for fear of attracting diseases.

Decorticating unit owners have some basic information about aflatoxin through the media only (one owner has read about aflatoxin contaminated pods from India which were rejected in the international market saying they were unfit for consumption). They had no idea about the harm it could cause when consumed by humans or livestock. They do know that occurrence of rains during stacking and improper field drying lead to the origin of inferior quality kernels that are brown, red or black, bitter in taste and have fungal growth. They are given to realize that oil produced from contaminated kernels gives off smell and froth on boiling and may cause some health ailments to human beings. They relate the contamination to the presence of free fatty acids (FFA) in the oil.

Oil expelling units

Business being what it is with the oil expelling units, especially the smaller units, cheap and inferior pods and kernels sold by farmers, traders and sometimes the decorticating units are used to extract oil and sold in the local market, sometimes adulterated with the cheap palm oil. Oil cake is sold to poultry units / cattle owners as feed as well as to the solvent extraction units. There is no grading of oil except filtering with an ordinary cloth. Oil after extraction is stored in iron or plastic drums with no specific control measures to maintain hygiene.

Fortunately however, there is very little scope for storage here as the kernels are crushed as & when purchased and oil extracted. Under extreme business conditions oil is retained for up to a maximum of 10 days only. It is stored in the iron drums or small tins. Neither is there any requirement to have storage control measures nor do these units follow any. So, while fresh aflatoxin contamination is not possible from these units, extracted oil as well as the oil cake may have chances of getting contaminated when damaged kernels enter the oil expelling process. This needs further verification.

The owners of Oil rotary / Baby oil mill have not heard about Aflatoxin but again like the rest of the chain also know of inferior and damaged pods and kernels. They know that such material is low

Table 3: Storage measures and awareness about Aflatoxin

S. No	Player	Product dealt	Storage period	Control measures	Awareness about Aflatoxin
1.	**Farmer**	Pods and kernels from damaged pods	May store depending on market favorability	No control measures adopted	Not heard about Aflatoxin. Knows about damaged pods.
2.	**Brokers**				
2a	Farmer Brokers	Pods	No storage activity	Not Applicable	-do-
2b	Local Brokers	Pods	-do-	-do-	-do-
2c	Special Brokers	Good quality pods	-do-	-do-	-do-
3.	**Traders**				
3a	Village level trades	Pods	15 days to 4 months	Sprinkle Gammexene on storage bags	Not heard about Aflatoxin but relates to damaged pods
3b	Regular traders	Pods/ Kernels	Up to 15 days in gunny bags	No control measures adopted	-do-
3c	Exclusive traders	Good quality pods and kernels	No storage activity	-do-	-do-
4.	**Decorticating unit**	a)Pods	May be stored for 2 to 4 months	Sprinkle Gammexene on storage bags	Doesn't know about it in detail but relates to

		b)kernel	Short storage period till kernels are sold out	No control measures adopted	damaged pods
5.	**Oil expelling unit**	Pods and inferior quality kernels	kernel: No storage as crushing is continuous l Oil: 15 to 20 days.	Kernel & Oil: No control measures adopted.	-do-
6.	**Oil seed federation**	Pods	Storage up to 20 days as decorticating, crushing and selling oil are a constant process	All controls for pest & disease including fumigation undertaken	Know about Aflatoxin through Research experts.
7.	**Solvent Extraction Plant**	Oil cake	No storage of Oil cake as it is procured as and when required. De-oiled cake is stored for short periods.	Extreme care is taken to ensure that de-oiled cake does not come in contact with moisture.	Know about Aflatoxin but not in detail.

quality and take advantage from the low price it commands. Since none of their consumers are bothered of any contamination in the oil, they blissfully continue their trade by using cheap, inferior and damaged pods and kernels and 'help' the poor farmers, traders and the decorticators sell their unsolicited produce and survive.

Oil seeds federation

The business of purchasing groundnuts, decorticating, expelling oil and selling in the highly competitive palm and adulterated oil market has brought even the government sponsored Oil Fed into irretrievable losses. In order to continue its existence oil fed is crushing groundnuts for NAFED (the national agricultural marketing federation – a Govt. of India sponsored organization) on a 2 % commission basis. Oil Fed purchases pods from the farmers at the Government support price at Rs. 1,220/- per quintal for the basic quality parameters of 72% shelling, 8% moisture and 2% refraction. Higher prices are paid for higher shelling and lower moisture or refraction parameters.

After extraction, oil is stored in huge tanks for up to a maximum of 20 days before it is packed and marketed. Depending upon the need, Oil Fed repurchases oil from NAFED and sells through its own outlets or to other supermarkets and shops in the name of Vijaya oils. Oil cake is purchased by local solvent extraction units for further oil extraction. No specific control measures are adopted to prevent the oil from any type of contamination.

Oil Fed purchases pods directly from the farmers only during kharif season (the rabi crop is small and the pod prices are higher) at its farmer co-operative warehouses or the market yards and stores in the jute bags heaped one above the other in the godowns. They have regular storage infections control program. Novan, Chloropyriphos and/or Malathion are sprayed in the godowns. Some times celphos tablets are incorporated in to the jute bags. Weekly fumigation is done under air locked conditions in the godowns.

The Oil Fed staff is fully aware of Aflatoxin, its contamination and its effects on human and animal population and therefore follows proper storage practices within its premises. However, their groundnut pod purchase guidelines and available infrastructure does not permit them to analyze pods for aflatoxin content before or after purchase.

Solvent extraction units

Solvent extraction units buy the oil cake from Oil Fed and other oil expeller units of all sizes. Oil cake is procured depending on the daily consumption capacity of the unit so as to have very low storage inventories. Similarly extracted oil is also disposed off as soon as possible for quick recoveries. This way, the need for providing expensive storage facilities and the need to maintain laborious storage and control measures is eliminated. The de-oiled cake however is stored in jute bags with no specific pest and/or disease control measures but extreme care is taken to prevent it from exposure to moisture that may affect its quality due to fungal growth. The crude oil is sold to oil refineries, while the de-oiled cake is sold to poultry units. It is believed that contaminated oil cake, on consumption, reduces egg-laying capacity of the birds, but awareness about aflatoxin is very low among the Solvent extraction unit owners.

Pricing and Penalties

It is very intriguing to realize from the information provided by the respondents of the case studies that there are no substantial tangible benefits for producing excellent quality groundnuts compared to poor quality or even inferior material. While it is common belief that Tamil Nadu buyers pay handsome prices for the best quality product - be it pod or kernel - the actual price differences are between 4 and 5% over the next lower grade which tends to indicate that there is virtually no premium for the top grades.

Oil Fed is the major purchaser of groundnut pods in Andhra Pradesh. Since it is a government sponsored agency, it adheres to the minimum support prices announced by the government from time to time. This price is based on a minimum of 72% shelling ratio, 8 % of moisture content in the pods and 2 % of refraction (wastes) material. Prices of pods are either increased or decreased at proportionate values for every percentage raise or fall from the three basic parameters. However, Oil fed does not purchase groundnut pods that have less than 68 % shelling, more than 12% moisture and 4 % refraction. Pods with inferior percentages are rejected outright. They do not have any parameters to qualify material based on the levels of inferiority or damage to the pods. Kernel of every size, shape, texture, colour, maturity stage etc have to be considered under the shelling percentage and accepted. Price structure of the groundnut pods in the markets evolves from this basic format.

Since the entire market depends on this type of price fixation, there are neither penalties nor incentives for marketing ‘infected’ or ‘infection free’ groundnut material. Therefore, one finds that there is uniformity in the value obtained for the net kernel yields from the pods irrespective of the crop variety, or grade of pods or kernel.
Transactions at the field and village level have a hidden advantage to the traders and brokers. The small and marginal farmers who produce small quantities of groundnut find it too expensive to take their produce to the market yards, and so sell to the local traders at very low prices. The rates are fixed arbitrarily and at a disadvantage to the farmers. Price fixation for the other village transactions are based on crude methods of measuring moisture and refraction and are again used to the advantage of the traders. Any premium available to the traders on quality produce is never passed on to the farmers since the entire trading is organized to the advantage of the traders who have the potential to buy and store in large quantities when the market prices are low.

Conclusions

Medium, small and micro sized oil mills that have a rural market for their produce irrespective of quality concerns; credit controlled village level trade and absence of effective regulations coupled with the effects of a highly volatile market has led to a complex market scenario that does not look for quality concerns of the end products.

Whatever quality concerns persist in the market depend up on an up market demand for confectionery, seed or export grade of pods or kernel. Here too, presence of aflatoxin is not a matter for verification. At no point in the trade channel is the produce tested for contamination of any kind. Grading is undertaken to basically fix a price to the product based on its yield potential rather than to fix any penalty parameters for the levels of toxicity or contamination in the produce. Hence, all quality concerns are restricted to the physical aspects of the produce. The produce once identified as inferior quality or damaged material reenters the edible market at various levels, through the processing industry with minor penalties in the pricing structure. Every type of produce is finally marketed and processed to reach the end users in the edible products market.

It is evident from the experiences of the various market players including the Oil Fed that while regulations for checking levels of contamination do not exist at all, storage and stocking regulations are rarely known to the players since there is virtually no monitoring or control mechanism. Therefore, storage of the produce is undertaken by the market players depending upon their perceptions of net gain only rather than the technical requirements of storage practices to avoid chances of contamination.

Creation of simple regulated markets and assuming that these markets can take care of problems like that of the aflatoxin will be sheer repetition of the existing useless regulations. It may be possible to contain aflatoxin contamination only when -

- Proper regulations are framed and a mechanism to ensure automatic surveillance and monitoring is implemented, the groundnut crop produce market is likely to continue to be complex and irresponsible to the consumer.
- A firm policy is framed and kept operational to streamline the market and processing channels of the groundnut product.
- Extensive awareness campaigns to bring a proper perspective into the entire groundnut production, processing and market system.
- Strong backup support by research institutions and extensive low cost monitoring approaches will be needed at all the stages of crop production and general marketing activity.

It is felt that, unless market incentives through consumer awareness and trade sanctions are transferred to the farmers' benefit, introduction of new management practices for the reduction of aflatoxin may not be readily accepted by the farmers.

Staad

Report on
Farmers Perceptions of Technologies to
Reduce Aflatoxin Contamination in Groundnut Based Livelihood Systems
- A Pre-Introductory Assessment for Technical Change

Of the project on
Strategies for reducing aflatoxin levels in groundnut-based foods and feeds in India:
A step towards improving health of humans and livestock (Extension Phase)

For the
International Crops Research institute for the Semi-Arid Tropics (ICRISAT)
And Crop Protection Program of the DFID
Natural Resource International, UK.

Prepared by
Rama Devi Kolli

SOCIETY FOR TRANSFORMATION,
AGRICULTURE AND ALTERNATIVES IN DEVELOPMENT

Farmers Perceptions of Technologies to
Reduce Aflatoxin Contamination in Groundnut Based Livelihood Systems
- **A Pre-Introductory Assessment for Technical Change**

Introduction

This study was conducted as a sequel to the participatory rural appraisals (PRAs) carried out earlier in Anantapur district under phase I study of the project. The earlier study helped identify/ assess the socio-economic and institutional factors that patterned the farmers' management practices that are likely to lead to aflatoxin contamination in the groundnut based livelihood systems, and helped in understanding why farmers do what they do.

It was realized that technological interventions that aim to reduce aflatoxin contamination in groundnut production should be conscious of the fact that the institutional factors like marketing, access to inputs etc. do impinge upon farmers will to adopt new practices (see STAAD reports for details). Within this scenario, it was further realized that farmers from different socio–economic backgrounds might have differential opportunities and constraints for adopting technologies. It had therefore become important to have an understanding of farmers' preparedness in technology adoption and know at the outset, which of technologies might work and which may not before the next step is taken.

Against this background, another round of PRAs were conducted in the present study, in two villages of Anantapur district, which were covered by the earlier study to get a preliminary idea about the technologies that farmers would be prepared to test and validate in their fields, the ones that may require additional resources or modifications and the technologies that are likely to be resisted. This pre-introductory evaluation of technologies by the farmers would also help address the constraints faced by them, through a range of technological options that could provide varied opportunities to different categories of farmers in the choice and selection of the technologies that are more practical to adopt.

Objective of the study

The main aim of the study was to assess farmers' perceptions and potential constraints for adopting selected aflatoxin reducing technologies for participatory testing in the coming seasons by men and women farmers of the various socio-economic categories of Ananthapur region of Andhra Pradesh in South India.

The specific objectives are -

- To study the underlying opportunities; problems and priorities and the preferences of farmers for adoption of new technologies, and
- To identify the potential socio – economic constraints for undertaking or adopting Aflatoxin Reducing Technologies of each identified group.

Methodology

The study was carried out in an iterative manner. Discussions were held at project team level initially to short list technologies that are expected to have some potential for conducting on farm research, subsequent validation and adoption by farmers. The project team put together a set of technologies that are most likely to produce aflatoxin free groundnuts and fodder.

Based on the findings in Phase I research of the project, careful consideration was given to the potential constraints of the farmers while short-listing of technologies to be proposed for on farm testing and adoption. The final list of technologies short-listed by the project team and confirmed by the ANGRAU research team at Anantapur district for discussions with farmers of the region, along with their perceived benefits and possible constraints are listed in the Table below.

Short - Listed Technologies – Potential Merits and Constraints

No	Technologies	Method	Cost	Advantages	Potential constraints
1	Seed treatment (Trichoderma)	Powder mixing with seed	Low	• Reduces root rotting and aflatoxin	• Lack of knowledge
2	Bacteria to improve manure quality	Bacteria (medium) mixing with FYM	Low	• reduces aflatoxin	• lack of knowledge
3	Application of FYM	Broad casting	No	• Preserves and increases soil moisture • Reduces free flow of rain water • Increase nitrogen in soil	• Non – availability of required quantity of FYM
4	Fungicides	Spraying fungicides along with pesticides by mixing in water	Medium	• Control leaf spot disease • Increase yields (pod and fodder) • Reduces stem rot	• Lack of knowledge • Non availability of water at field • Little bit expensive
5	Application of Gypsum	Broad casting at 30 days of standing crop (at flowering stage)	Medium	• Increases outturn, oil content in pods • Reduces stem rot	• Non – availability of required quantity of gypsum • Lack of knowledge
6	Mulching (Crop residues)	Incorporation of crop residues (lab lab; black gram; glyolicidia; dhaincha; and green manure crops) into soil	Medium	• Preserves and increases soil moisture • Increases yields (pod and fodder) • Gives micro nutrients to plant	• Lack of knowledge • Non – availability of the required quantity of crop residues
7	Compost manures	Broad coasting of manure (urban compost)	Medium	• Preserves and increases soil moisture • Increases yields (pod and fodder) • Gives micro nutrients to plant	• Lack of knowledge • Non – availability of the required quantity of manures
8	Drying techniques (wind rowing)	Drying the harvested produce in rows by putting pods up and plant down	No	• Quick drying • Reduces fungal growth and aflatoxin	• Lack of knowledge • Not in practice
9	Sorting (of damaged, small or immature pods)	Sorting of pods with winnowing and sieving	Low	• High market price (may be) • Good for health • Can be stored for long time	• Availability of labor
10	Early pod stripping / threshing - without stacking and by machines	Separating the pods from plant with machinery immediately after harvesting (2, 3 days) without stacking	No	• Reduces fungal growth and aflatoxin • Reduces the pest damage	• Labor availability and availability of machinery
11	Removal of immature/left over pods from haulms	Manual (hand picking)	No	• Healthy fodder to cattle • Reduce aflatoxin	• Expensive (labor costs) • Availability of labor
12	Improved storage methods	• Using new gunny bags • Spraying fungicides / pesticides to control oozi (storage pest) • Dipping the old gunny bags into malathion	Low	• Maintaining moisture % • Control pest damage and store for long time. • Preserve seed quality and use for seed (own) • Reduce aflatoxin	• Lack of knowledge • Lack of infrastructure for storage
13	Aflatoxin resistant varieties	Growing new varieties which are resistant to aflatoxin	Not yet known/ nil	• Good for human & animal health • High price in the market • Chance for export	• Marketing • Availability of seeds

Note No cost = No expense to adopt that particular technology
Low cost = Rs. 10/- to Rs.100/- expense per acre is involved in adopting that particular technology
High cost = Rs. 101/- to Rs.300/- expense per acre is involved in adopting that particular technology

Farmers participation

The short-listed technologies were described to various farmer groups of Lingannapalli and Pampanur villages of Anantapur district for a pre-introductory assessment of aflatoxin reducing technologies in the groundnut based livelihood systems of the region and to assess their potential to start the process of technical change.

Participatory rural appraisals (PRAs) were conducted with different farmer groups of Lingannapalli and Pampanur villages where PRAs were carried out earlier under Phase I of the project. During the present study, PRAs were mainly based on focused group discussions, matrix scoring and ranking exercises carried out with the participation of farmers groups selected from the rich, poor and women categories.

Farmer Group Selection

Farmers constituting the groups were mainly selected from the social maps of the villages drawn during Phase I study of the project based on their wealth criteria. Importance was given to selecting the same set of farmers who had participated with the ICRISAT / ANGRAU teams for on farm research activities of the project during phase I of the project.

The rich group essentially consisted of farmers of the middle and large farm (5 to 10 acres and above 10 acres respectively) category, while the poor farmer groups consisted of the small and marginal farmers (2 to 5 acres and less than 2 acres respectively). Women farmer groups were however, selected based on the social maps and their participation in self-help group activities of their respective villages and those from families of farmers who participated in the ICRISAT/ ANGRAU trials. Hence, the group consisted of women farmers of mixed wealth categories and those who actively work on the farm.

Process of Participatory Assessment

Focused group discussions were held initially with the selected groups of farmers to explain the new technologies and the various implications of adopting them. Subsequently, ranking exercises were carried out with each group of farmers separately. For this purpose, farmers listed out the various criteria that they perceived as important for adoption of given technologies that could help reduce aflatoxin. The criteria are listed and described in the Table below.

Description of Farmers Criteria/ Factors for Adoption of Technology

Criteria/ Factors	Description
Cost	Cost of inputs required for the activity under each of the proposed technologies
Labor cost	Additional labor cost input required for undertaking the activities for each of the proposed technologies
Labor availability	Possibility of availability of additional labor where required
Work load / drudgery	Process involving greater attention and/ or intensity for the activities
Yield	Increase in yields (pod and fodder) compared to current yields
Crop quality	Better crop characteristics that include field and marketable features.
Resistance	Resistance to pest and disease attack and drought conditions
Health	Reduced ill-effects on health of humans and animals
Market	Acceptability of produce in the market, better pricing and access to the markets.
Availability of machinery	Most of the machinery is hired and availability at the right time is subject to demands elsewhere. Additional or timely requirement of machine time is a constraint.
Availability of inputs	Some of the inputs required for adoption of new technologies may not be available either with the farmers or in the general market. Organizing availability of new inputs is critical to adoption of new technologies.

Each of the technologies provided by the project team were assessed against the criteria listed out by the farmer groups. Each technology thus was given a score on 0 to 10 scale against each of the criteria. The cumulative scores for each of the technologies were used to rank them in order of the preferences exhibited by the farmers. The ranking exercise was intended mainly to indicate the relative preferences of the farmers for testing and subsequent adoption of the technologies.

Farmers found it difficult to score their preferences for the technologies as most of the technologies differed in the methods of operations, cost implications and their potential benefits. The ranks presented in the matrices thus indicated a general order of preference rather than a strict hierarchy of ranking for each of the technologies.

Analysis and Discussion

Farmer Preferences for technology

It is generally observed that farmers have preferred to rank high, the technologies that have components already known to them or are perceived as easily adaptable or adoptable by them. Those that required new information and / or inputs, or required fresh adaptations by themselves or the farm labor were given the least preference. Therefore, we observe that new varieties and application of fungicides have taken top preferential spots. Farmers have grown used to trying and testing new varieties due to government subsidies and extension, and they are used to spraying chemicals for pest and disease control. Hence it was relatively easy for them to perceive to do away with the aflatoxin problem by just adopting a new variety or by spraying a fungicide along with the normal pesticides.

It is pertinent to note that, while farmers were not averse to spending a little bit more towards the cost of new seed or additional chemicals (fungicides), they were reluctant to undertake the essential crop drying activity by windrowing, an activity that requires very little new training or additional costs. This reluctance reflects farmers' apprehensions, which indicates that they are generally reluctant to do anything out of the ordinary, till they understand its method and the consequent implications of adopting it or have observed the activity first hand and are convinced.

The general pattern of farmers' order of preferences has been observed to be similar in both the villages and across the farmers groups. A few of the technologies however were ranked differently from the general trend by the different groups of farmers across both the villages. These variations in ranking mostly reflect the economic status of the farmers. Any intervention, such as application of fungicide, introduction of new varieties, windrowing or sorting of damaged and immature pods, which needs additional cash or labor input, was given a low priority by the poor farmers of Lingannapalli, irrespective of the effectiveness of the technology, clearly indicating their inability to undertake financial risks. The poor farmers of Pampanur however were not as reluctant to put in marginally higher costs.

Women farmers were more uniform in their selection of technologies across the villages. They have clearly rejected the more labor-intensive activities. Activities such as windrowing, sorting of damaged & immature pods, mulching of crop residues, improved storage methods or early pod stripping are activities that are generally relegated to women. They do not want anything to do with changing their already overburdened work style, which will require additional work on their part, even towards reducing aflatoxin that may help improve their health.

The only major disagreements in the order of preferences between women farmers of the two villages were regarding application of FYM and use of bacteria to improve manure quality. The variations in the ranks are equal and are related to their relative positions and therefore could be attributed to the availability of FYM in the village (as confirmed by the similar ranking given by the rich and poor category farmers of the respective villages) rather than real variations in perceptions.

Between the villages, the rich category farmers seem to have major disagreements in their perceptions for adoption of aflatoxin reducing technologies compared to the poor farmer and women farmer groups. The variations pertaining to use of aflatoxin resistant varieties, application of gypsum, use of bacteria to improve manure quality, early pod stripping / threshing without stacking by machines and removal of immature / left over pods from haulms seem to emerge from the variations in the general economic conditions among the rich farmer category between the two villages, rather than differences in basic perceptions of crop production activities.

The order of preference of technologies as expressed by different farmers groups in two villages are presented in a descending order in the Tables below.

Farmer's order of preference of technologies

Lingannapalli

RICH	POOR	WOMEN
Aflatoxin resistant varieties, Fungicides	Improved storage methods	Aflatoxin resistant varieties, Fungicides
Seed treatment (Trichoderma) Improved storage methods,	Seed treatment (Trichoderma)	Seed treatment (Trichoderma)
Application of Gypsum	Fungicides	Application of Gypsum
Application of FYM	Application of FYM	Application of FYM
Bacteria to improve manure quality	Application of Gypsum	Improved storage methods
Early pod stripping / threshing without stacking by machines	Aflatoxin resistant varieties	Bacteria to improve manure quality
Sorting (of damaged, small immature pods)	Bacteria to improve manure quality	Sorting (of damaged, small immature pods) Early pod stripping / threshing without stacking by machines
Mulching (crop residues and manure's)	Early pod stripping / threshing without stacking by machines	Mulching (crop residues and manure's)
Removal of immature / left over pods from haulms	Mulching (crop residues and manure's)	Removal of immature / left over pods from haulms
Drying techniques (wind rowing)	Removal of immature / left over pods from haulms	Drying techniques (wind rowing)
	Sorting (of damaged, small immature pods)	
	Drying techniques (wind rowing)	

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Farmers Order of Preference of Technologies

Pampanur

RICH	POOR	WOMEN
Fungicides	Fungicides	Seed treatment (Trichoderma)
Seed treatment (Trichoderma)	Seed treatment (Trichoderma)	Bacteria to improve manure quality
Improved storage methods	Bacteria to improve manure quality	Fungicides
Sorting (of damaged, small immature pods)	Aflatoxin resistant varieties	Aflatoxin resistant varieties
Removal of immature / left over pods from haulms	Improved storage methods	Application of Gypsum
Aflatoxin resistant varieties	Drying techniques (wind rowing)	Early pod stripping / threshing without stacking by machines
Application of FYM	Application of FYM	Improved storage methods
Application of Gypsum	Application of Gypsum	Application of FYM
Bacteria to improve manure quality	Early pod stripping / threshing without stacking by machines	Sorting (of damaged, small immature pods)
Early pod stripping / threshing without stacking by machines	Sorting (of damaged, small immature pods)	Mulching (crop residues and manure's)
Mulching (crop residues and manure's)	Mulching (crop residues and manure's)	Drying techniques (wind rowing)
Drying techniques (wind rowing)	Removal of immature / left over pods from haulms	Removal of immature / left over pods from haulms

Variations in perceptions among different categories of Farmers

Rich farmers

Management of larger sized land holdings has become a major constraint for the richer farmers mostly due to availability of labor on time and in sufficient quantities to undertake timely crop production activities. Yet the rich farmers are not rich enough to be able to procure machinery suitable to their size of operations due to the low productivity of the region. It is only that these farmers are relatively rich and are constrained to carry on the agricultural activities within the established cropping systems of the region.

Farmers expressed that it is becoming increasingly difficult for them to adopt new technologies involving labor – either by way of additional volumes or requiring additional training. Therefore, introduction of crop management techniques such as

- ***use of bacteria to improve manure quality***
- ***application of FYM***
- ***mulching***
- ***drying***
- ***sorting***
- ***removal of immature pods from haulms***

which require additional resources towards labor management are not preferred by these farmers for experimentation. The list of the technologies that found favour with farmers for experimentation and potential adoption and the associated reasons and conditions and the list of technologies that did not find immediate favour with farmers for adoption and the associated reasons are presented in the Tables below.

Most Preferred Technologies - Rich Farmers

Technology preferred	Reasons	Concerns / constraints
Aflatoxin resistant varieties,	***better price - higher yields - good for health – disease resistance***	
Seed treatment (Trichoderma)	***they are used to seed treatment less expensive - improves oil content and yields***	***- large quantities may be difficult***
Application of Gypsum	***improves oil content yields increases***	***- availability problems - laborious - labor shortage***
Application of Fungicides	***pest and disease control will give good yields***	***– even with labor shortage and non-availability of equipment – even if they have to take water in tankers to the field – concerned with out dated and adulterated chemicals***
Early pod stripping / threshing without stacking by machines		***– non-availability of machinery – shortage of labor – also believe that produce kept in stacks gives good outturn and safeguards from cyclone***
Sorting (of damaged, small immature pods)		***- if paid more prices for it***
Improved storage methods,		***- For seed purpose only***

Less Preferred Technologies - Rich Farmers

Technology	Reasons
Improved storage methods,	***-expensive - lack of infrastructure.***
Application of FYM	***- do not have - not easily available - expensive***
Bacteria to improve manure quality	***- laborious, time taking process,***
Early pod stripping / threshing without stacking by machines	***- non-availability of machinery -shortage of labor - produce kept in stacks gives good outturn - safe from cyclone***
Sorting (of damaged, small immature pods)	***- laborious - expensive***
Mulching (crop residues and manure's)	***- difficult - laborious - expensive - very less in quantity - ground shells applied the first kernel in the pod will not mature***
Removal of immature / left over pods from haulms	***- expensive - no income from it - threshing with machinery separates all pods - not feeding groundnut fodder to milch animals***
Drying techniques (wind rowing)	***- highly expensive - more labor required - plants will not stand without support - time taking process - labor shortage and labor will not accept to do***

Some important observations (fears/apprehensions) and issues expressed by the rich farmer group from their current experiences-

- ***Regarding windrowing of crop immediately after harvest, farmers expressed that it may be difficult to place the harvested crop upside down till it dries.***
- ***Few farmers felt that the first kernel of the pod will not mature due to over dosage of FYM (excess use of FYM).***
- ***Farmers believed that keeping the produce in stacks after drying the harvested crop increases. shelling percentage and thereby the yield and that is why they follow the technique since a long time.***
- ***Expressed that animals suffer with diarrhea if groundnut fodder is used in large quantities; hence limited use of fodder may not be of much consequence to aflatoxin contamination.***

Poor farmers

Groundnut crop is usually the main crop that the small farmers depend upon as their main source of livelihood, for cash requirements and to meet some of their domestic consumption requirements. Apart from working on their own fields, they also work on mutual exchange on other small farmers fields and also double up as farm workers during peak demand season to supplement their income from the groundnut crop. Under such conditions, it is extremely difficult for these farmers to introduce any crop management practice that requires additional inputs especially when the crop is grown under rain fed conditions in a perennially drought prone area like Anantapur. The reaction of this group of farmers to new technologies evokes ironic responses,

especially considering the fact that the market into which they sell their produce does not distinguish between aflatoxin contaminated and aflatoxin free groundnuts.

The willingness of this group of farmers, to adopt technologies that could reduce aflatoxin content in their groundnut crop is limited to technologies that do not require any additional inputs, either by way of cash requirements, material inputs, labor requirements or even drudgery. Technologies that found favour with poor farmers category, for experimentation and potential adoption and the associated reasons and conditions and those that did not find immediate favour with farmers for adoption and the associated reasons are listed in the Tables below.

Most Preferred Technologies - Poor Farmers

Technology preferences	*Reasons*	*Concerns / constraints*
Aflatoxin resistant varieties,	***better price - higher yields - good for health - disease resistance***	
Seed treatment (Trichoderma)	***they are used to seed treatment less expensive improves oil content and yields***	
Application of Fungicides	***pest and disease control will give good yields***	***even with labor shortage non-availability of equipment***
Improved storage methods,		***- For seed purpose only***

Less Preferred Technologies - Poor Farmers

Technology	*Reasons*
Improved storage methods,	***– do not have any produce to store.***
Application of Gypsum	***- not aware of the benefits - availability problems - laborious - drudgery – expensive***
Application of FYM	***- do not have - not easily available – expensive***
Bacteria to improve manure quality	***- difficult - laborious***
Early pod stripping / threshing without stacking by machines	***- non-availability of machinery -shortage of labor - produce kept in stacks gives good outturn - safe from cyclones***
Sorting (of damaged, small immature pods)	***– even if paid more prices for it – small quantities – is not worth it.***
Mulching (crop residues and manure's)	***- difficult - laborious - expensive - very little crop residues available for mulching - ground shells applied as manure results in the first kernel of the pod does not mature.***
Removal of immature / left over pods from haulms	***- expensive - no income from it - do not feed groundnut fodder to milch animals***
Drying techniques (windrowing)	***- highly expensive - more labor required - plants will not stand without support - very little time available during the harvesting period, so cannot spend more time on making windrows - need to work in other (rich) farmers fields***

Some important observations (fears/apprehensions) and issues expressed by the poor farmer group are -

- ***Continuous droughts have left most of them in losses: and the yields are getting worse.***
- ***Farmers are ready to spend up to Rs.700/- in addition to what they are actually spending if yields, shelling percentage, control of pest and disease etc are assured.***
- ***Operations like resistant varieties (grown on their own farm), application of gypsum, seed treatment, spraying of fungicides are done by themselves and so they do not incur extra expenditure.***

Women Farmers

Women farmers, essentially being members from both the rich and poor categories uniformly expressed their desire that, technology interventions have to ensure that women are not burdened

with additional labor or drudgery and do not face problems with accessibility to any new inputs. Their responses to the enquiries for adoption of proposed new technologies revolved round this basic theme. They were in favor of the technologies that required minimum labor but did not mind additional input costs.

Interventions such as new seed varieties, use of fungicides along with the regular pesticide applications, seed treatment, bacterial application for enriching manures, application of FYM and gypsum (typically male oriented tasks) and early threshing by machines found their favor as most of these technologies do not need additional work by women, while some of them relieve them of some of the responsibilities.

Improved storage facilities, sorting of groundnuts, windrow drying and separation of immature pods from haulms that required additional work and responsibilities on part of women received resistance from the women farmer group.

Some important observations (fears/apprehensions), suggestions and issues expressed by women group are -

- ***Women observed that groundnut haulm does not affect the health of animals but the milk gives a different smell, and hence is not favored and so most of them use green grass as fodder to milch animals.***
- ***Women expressed that they would not mind doing any sort of difficult task only if it is absolutely necessary and if it is rewarding.***
- ***Women sort groundnuts used for their seed purposes and/ or home consumption but do not sort the produce that is to be sold as it is a tedious job. They feel that health issue doesn't arise here as they always remove bad seeds when they use groundnuts for consumption.***
- ***As harvesting is now-a-days done on a contract basis, laborers may not accept to undertake windrowing method of drying the crop at harvest as it is likely to need more time and more laborious.***
- ***Women are interested to grow new varieties of groundnuts that can fetch better prices in market, and assure good health.***
- ***Women indicated that they were facing health problems during activities such as pesticide applications and chemical application during storage within their homes.***
- ***They felt that carrying water to the fields from long distances for spraying pesticides is a difficult and tedious job.***

Conclusions

The critical aspects required for adoption of technical interventions clearly spelt out by the farmers are - economic considerations like costs involved in adoption of the interventions, availability and accessibility of known and new inputs required for undertaking interventions, market acceptances of the specialized produce and premium pricing have dominated the consensus among the farmers.

However, farmers were mainly tending to resist technologies where new methods of practice are involved that appeared laborious or time consuming and those required additional labor such as in windrow drying, sorting, removal of immature pods from haulm, etc. Even though all the groups concerned were critical of this aspect of technological intervention, women farmers were particularly resistant to such interventions.

Farmers were, on the other hand were favourable to try out new technologies even if it meant marginal increases in production cost for procuring inputs such as aflatoxin resistant varieties, seed treatment with trichoderma and applying fungicides, but under the condition that they were assured of additional incomes from producing aflatoxin free groundnuts.

It is important that technologies need to be –

- Sensitive to ‘different strokes’.

Technology interventions have to be customized to suit differential preferences of the divergent groups of farmers.

- Apprehensive to workloads and drudgery.
  Farmers are apprehensive of increased workloads and drudgery associated with the interventions such as post harvest drying, sorting and storage procedures.
- Considerate to costs, availability and access of inputs (particularly new inputs).
  Preferences for adoption of technologies were based on the farmers’ experiences and perceptions of observed causes and effects or costs and savings.
- ‘Market-able’ through acceptance, accessibility and better pricing.
  Concerns for market acceptances of the specialized produce and premium pricing have dominated the consensus among the farmers especially when the current marketing practices do not distinguish aflatoxin free products from the contaminated ones.
- Perceptive to farmers’ current experiences (bovine tastes - small pods are more tasty to animals - and no perceived ill effects on health).
  Realization of the effects of consumption of aflatoxin contaminated groundnuts and haulms and the farmers did not explicitly understand its relationship to the ill effects on human and animal health.
- Conscious to the awareness of farmers to new technology interventions.
  Seeing is believing to these farmers as their farming systems are highly risk prone and hence need to be reassured of any new changes.

In conclusion

Careful attention has to be given to the approach – technological interventions as the realities indicated are complex and diverse. It is therefore essential that technological interventions should be suitable for adoption to a wide stakeholder base. Hence a group approach to reach the diverse groups of farmers is desired. Care is necessary while selecting the technologies offered for adoption so that the poor and the women farmers’ are also made stakeholders in the process of technical change.

Since the issue is complex, involving several institutional and socio-economic factors. It is important that several actors need to be involved in the process of change. Hence, the foundations for technical change needs to be based on a coalition of partnerships that will sustain processes of change holistic and sustainable.

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