# Seed System Innovations in the Semi-Arid Tropics of Andhra Pradesh

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Citation: Ravinder Reddy Ch, Tonapi VA, Bezkorowajnyj PG, Navi SS and Seetharama N. 2007. Seed System Innovations in the semi-arid Tropics of Andhra Pradesh, International Livestock Research Institute (ILRI), ICRISAT, Patancheru, Andhra Pradesh, 502 324, India. ISBN 978-92-9066-502-1. 224 pp.

## Abstract

An effective seed supply system is necessary to make good quality seed available to farmers at the right time and at low cost. Given the critical role played by improved varieties in increasing production of grain and quantity and quality of stover for livestock fodder in conventional cropping systems, agriculture decision-makers have the challenge of developing an integrated and cost-effective seed system that is capable of generating and delivering improved seed varieties to farmers. Such a system would be an important step toward ensuring seed security and enhancing livelihoods, particularly of dryland farmers.

Issues related to seed multiplication and delivery systems in India are discussed in this publication. The book outlines the development of the seed industry in India and highlights the changes made to seed policies over the years. It records the experience from an attempt to improve the local seed systems in four dryland agricultural districts that are typically representative of the semi-arid areas of Andhra Pradesh state. Using specific seed delivery models, it presents ways of strengthening seed systems to address the needs and vulnerabilities of smallholder farmers including those associated with livestock and fodder security in these areas.

This book is not an all-encompassing summary of the seed systems in Andhra Pradesh, nor does it try to provide magical solutions to constraints encountered by poor farmers. It does, however, attempt to illustrate alternative approaches to strengthen the seed systems by employing new approaches aswell as implementing tested approaches in new ways constituting innovation. Given the ever rapid changes taking place in the technological, socioeconomic and policy environments, understanding some of the processes and mechanisms involved in these changes as has been presented in this document will help in continuous development of an appropriate seed system and contribute to enhancing the livelihoods of poor farmers in the semi-arid areas of India.

## Acknowledgment

We record our appreciation of the help rendered by G Thirupati Reddy, Chief Executive Officer, Awakening People Action for Rural Development (APARD), Kurnool, and the support of Harshal Gawali, K Sanath Kumar, KV Raghavendra Rao and P Subhakar Rao in bringing out this publication. The fodder Innovation Project conducts research in India and Nigeria to enhance the livelihoods of livestock dependant poor people through increasing use of fodder. It is funded by the Department for International Development (DFID) and is implemented by the International Livestock Research Institute (ILRI) on behalf of the System wide Livestock Program (SLP).

# Seed System Innovations in the Semi-Arid Tropics of Andhra Pradesh

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## Foreword

The power of a seed is unlimited. As a powerful agent of change, seeds can be a means of overcoming production constraints, thereby making a difference in the lives of the poor and hungry. This requires seed demand and supply to be balanced by way of a secure seed supply system. This would give farmers access to adequate quantities of good quality seed of the desired type at the required time and at affordable cost.

Seeds are key components in the conservation and ownership of biodiversity. Accordingly, sustainable seed supply and implementation of seed security are among the major activities outlined in the Global Plan of Action for the Conservation and Sustainable Utilization of Plant Genetic Resources for Food and Agriculture. Seeds therefore represent hope for the future of mankind.

Throughout our history, farmers' informal seed systems have had a great influence on the evolution of modern agriculture, by practising conservation of agrobiodiversity at the gene, farmer and ecosystem levels. Within this framework, women in particular have played a crucial role, as has been identified by a recent analysis, in sustaining the informal seed sector, and more widely, in ensuring food security. However, informal seed systems are heavily dependent on local resources and inputs, and highly vulnerable to natural disasters and sociopolitical disruptions. Therefore, investing in a range of appoaches in order to strengthen local seed systems assumes great urgency.

While the formal hybrid seed industry led by the private sector has tended to focus on profit-making species and crops, the informal sector has concentrated on crops – mainly self- or open-pollinated varieties – that are crucial to local food production systems. Given such a scenario, national seed policies concludes helping to strengthen the informal sector. International support too continues to be mainly engaged with the formal sector. Perhaps matching support is required to encourage continued development of informal seed systems.

In this context, the concept of 'seed villages', which advocates self-sufficiency in production and distribution of good quality seed, is fast gaining ground. Seed villages, or village seed banks, operate under supervision and utmost transparency, inculcating mutual trust and social responsibility among farmers, thereby reducing their dependence on external inputs.

Several initiatives have been launched to revive this traditional concept, such as those initiated by the Indian Council of Agricultural Research (ICAR), the National Research Centre for Sorghum (NRCS) and state agricultural universities (SAUs). Similarly, the seed bank concept is part of ICRISAT's projects in collaboration with the Asian Development Bank (ADB), Tata-ICRISAT project in Vidisha and Guna districts of Madhya Pradesh and the Andhra Pradesh Rural Livelihoods Project (APRLP) in Kurnool district in Andhra Pradesh and other ongoing efforts in the states of Maharashtra and Karnataka.

In low-rainfall, dryland agricultural areas, cereals and legumes serve the dual purpose of providing food and income for poor farmers and fodder for their cattle. Given the critical role played by improved varieties in increasing conventional crop production, a key question arises: how do we facilitate the development of an integrated and cost-effective seed system that is capable of generating, producing and distributing improved seed varieties that meet the needs of resource-poor farmers?

This book is an attempt to review and document the existing seed multiplication and delivery systems in four dryland agricultural districts of Andhra Pradesh: Anantapur, Kurnool, Mahbubnagar and Nalgonda. While analyzing the problems associated with different seed systems in these districts, the book makes a strong case for strengthening alternative seed systems and seed delivery models that address the needs of small farmers in the context of constantly changing dynamics on the national, international, political and socioeconomic fronts.

I am sure this book will be a valuable reference source for those engaged in strengthening local seed systems as a step toward food security in the semi-arid tropics of India.

**William D Dar**
Director General
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# Part V: Seed saving and quality control

**CHAPTER IX: Developing a community based seed system**

**CHAPTER X: Quality assessment of farmers saved sorghum grain/seed in the community**

Chapter IX

# Developing a Community-Based Seed System

*The lack of scientific knowledge of seed production, quality control and innovative interventions are the main handicaps of farmer-saved seed systems, which have resulted in inferior quality seed and poor outputs. This chapter is a synthesis of knowledge that needs to be imparted to community seed systems to produce, process, treat, test, store, trade and barter and re-sow seed for food, feed, fodder and livelihood security. The mechanisms of creating and training seed growers' associations to promote seed quality are also detailed here.*

## Introduction

Farmers have for centuries selected and saved seeds to grow in the next season. They learnt to cross-pollinate plants by hand or by mixing varieties within the same field to maintain and adapt their crops. Thus they assisted in the evolution of locally adapted crops. Some of these varieties may be resistant to certain pests, and others more tolerant of salinity or drought. Some varieties can be sown or harvested earlier or later in the season. Traditional crops also provide a wide range of nutrients to the diet. The seeds of traditional crops and knowledge of their growth and use are therefore important resources and should be conserved and used.

The quality of farmer-saved seed is constrained by poor harvests, inadequate on-farm storage facilities, insufficient means to multiply quality seed and poor seed distribution systems. There is thus a need to strengthen the local capacity to produce, store and distribute seed of many crop varieties, including some landraces/farmers' varieties, which are useful in diverse and evolving farming systems.

## Steps for Strengthening Community Seed Production, Saving and Storage

(a) Appropriate policies for seed production and distribution are needed to help focus government-supported initiatives on the varietal needs of resource-poor farmers with particular attention to the needs of women farmers, and to minor crops that are inadequately covered by the private sector.

(b) Promote small-scale seed enterprises and strengthen linkages between gene banks, plant breeding organizations, seed producers and small-scale seed production and distribution enterprises.

(d) Strengthen seed quality control schemes for small-scale enterprises and provide appropriate incentives, credit schemes, etc. to facilitate the emergence of seed enterprises, paying attention to the needs of the small farming sector, of women and of vulnerable or marginalized groups.

(c) Support and strengthen farmers' organizations in order that they can more effectively express their seed requirements, paying particular attention to the needs of women and of vulnerable or marginalized groups.

(d) Provide training and infrastructural support to farmers in seed technology in order to improve the physical and genetic quality of farmer-saved seed.

(e) Develop approaches to support small-scale, farmer-level seed distribution, learning from the experiences of community and small-scale seed enterprises already in operation in some countries.

(f) Seed quality of farm-processed seed can be as good as and often better than certified seed if farmers take the first step by selecting the right variety, controlling purity with good rotation, and follow standard agronomic practices to achieve disease and weed control. They can choose a mobile seed processor that can offer the equipment, management and expertise to achieve the standard required.

## Seed Quality Guidelines for Farmers

### *a. Seed production*

- A seed is likely to give rise to a plant that has characteristics similar to its parent plants, unless the parents come from $F_1$ hybrid seeds. Therefore, seeds should be selected from strong and healthy plants.
- It is very important to remove nonhealthy or diseased plants from the field as soon as they are seen. Plants with nondesirable characteristics should be removed from the field before they flower and pollinate other plants, but after making sure that there is a diversity of characteristics in the field.
- If a farmer wants to develop or introduce specific characteristics in a plant, he can do so by controlling the pollination of plants chosen for seed production. To combine desirable characteristics, the farmer can transfer the pollen from a chosen plant to fertilize another chosen plant. For plants such as maize, which are usually wind-pollinated, the male flower should be shaken over the female flower to transfer the pollen.

- If plants are being cross-pollinated for particular characteristics, the farmer must prevent the pollination of the chosen plants by pollen from plants with other characteristics. This can be done by isolating the plants as prescribed.
- Seeds must be dried to the prescribed moisture level before storing them to improve their storage life. Moisture in the seed may encourage mold, bacteria or other pests and diseases which may affect seed viability.
- On the other hand, seeds should not be dried too much or too rapidly as they may crack or lose their ability to germinate. They can be dried in the morning sun or in partial shade, but should not be exposed to strong sunlight.
- To dry seeds, spread them out thinly on paper, cloth, flat basket or plate in a warm place off the ground. They should not be dried on metal as it may become too hot. Turn over the seed several times a day to ensure even drying. When the seeds do not feel damp or stick together, they are likely to be ready for storage.
- Any seeds that are immature, broken, diseased or pest-infested should be taken out. Stones, dirt and seeds from other plants should also be removed.
- Winnowing can remove smaller contaminants such as dust, weed seeds and dry leaves. To winnow the seeds, place them in a large flat container and toss them into the air when there is a gentle wind, then catch them in the container. The light contaminants will be blown away by the wind.

### b. Seed certification

- To encourage decentralized seed production, the "truthfully labeled" designation could be used as an alternative to the existing system of centralized public certification. In this case, no field inspection is made, producers are wholly responsible for seed quality, and are required to describe certain quality aspects on the label (Tripp and van der Burg 1997). However, under such a system there would be a need to develop enforcement mechanisms that might operate by involving individuals (possibly extension agents) who have been trained by the public certification agency in field inspections for artisan quality seed, or by shifting the responsibility for quality control to an autonomous or local public institution, including seed certification agencies. In both cases, producers should pay for the field inspection services.

### c. Seed storage

- Seeds must be stored in a way that prevents them from being attacked by pests or diseases, and that maintains their quality. Some seeds can be stored for a long time without losing their germination rate, and others for only a few months. This depends on the type of seed, the moisture content of the seed and the storage conditions. Good storage conditions for seeds are: Low moisture, low temperature, low light, protection against rodents, protection against insect pests and diseases.

- High temperature can encourage biological activity in seeds and shorten their storage life, particularly if there is any moisture in the seeds. Bright light can also be damaging to stored seeds. Seed containers should be kept in a cool area and out of direct sunlight.
- To keep rodents away, seeds should be stored in a hygienic area. The floor should be swept so there are no scraps of food that may attract rodents. Seed containers should be well-sealed and if possible kept off the ground so that rodents cannot get in. Sometimes seeds are stored in specially built huts that are raised off the ground.
- Storage weevils, fungi and bacteria can infest seeds in storage. Seeds should be free of such pests before storing them. Weevils, fungi and bacteria multiply in warm and moist conditions. To prevent this from happening, the seeds should be kept dry and cool. Appropriate pesticides/substances may be mixed with the seeds to help prevent pests and diseases. Mixing the seeds with clean, dry sand and filling the container will prevent weevils moving around.
- The quality of the seeds affects how well they will store and their ability to germinate and grow well in the field. Testing the seed before storage ensures that only good quality seeds are stored. A germination test gives an idea of the proportion of plants that are likely to grow from a certain quantity of seed, and will show how many seeds must be sown in order to obtain the desired number of plants. Use between 10 and 100 seeds for the germination test, depending on how many seeds there are.
- To test the germination rate, place the seeds some distance apart on a clean damp cloth or paper towel. For large seeds it is better to use sterilized soil. Soil can be sterilized by pouring boiling water over it to kill germs. The seeds should be placed somewhere warm, but out of direct sunlight. Keep the seeds damp, but not too wet, by sprinkling with water or covering with a clean damp cloth or paper towel.
- If none of the seeds has germinated, it may be necessary to leave them for more time, keeping them warm and damp. If most of the seeds have germinated and have healthy-looking roots and shoots, the rest of the seeds from that harvest should be viable and suitable for storage and sowing. If less than half of the seeds have germinated, or if many of them are nonhealthy, the rest of the harvest are probably also nonhealthy with a low germination rate. The farmer may decide not to store these seeds. If seed

are in short supply, these seeds may still be stored and sown, but a note should be made that they are not good quality seeds. It may be useful to test the quality of seeds before storage, and to test home-saved seeds and seeds that have been bought or exchanged, before sowing them.

## Developing a Community Seed Program

The response from farmers to development initiatives varies from one place to another. Some of the factors motivating them as seed growers include a good harvest and increased income from the sale of seed. A poor harvest in the first season can discourage them and lead to them giving up.

While some farmers do become self-reliant within a few seasons, it takes a minimum of five years to develop a sustainable community seed program. The first three years should focus on capacity building such as technical training in seed production, business skills, group dynamics, leadership and getting farmers to understand the seed production process. The next two years should concentrate on exit strategies or the final handing over of the management of seed production to the community. Some of the important activities during this last stage include taking farmers on orientation visits to places such as research stations and gene banks (for seed sources) and the State Seed Certification Agencies (SSCAs). This will acquaint the farmers with seed production and certification procedures and expenses. In addition, seed producers should visit seed companies and other service providers (NGOs, KVKs) as they may act as potential market outlets. A study visit to more experienced seed growers' associations would be of benefit to new seed growers.

## The Model

A basic model for developing a community seed program detailed below must have involvement of universality in developing community seed systems in the semi-arid tropics. A model developed for a specific area/ village/region may not yield the same result elsewhere because of the variation in the willingness of the stakeholders, the crops and varieties grown, climatic conditions, socioeconomic and perhaps biotic factors.

## Reconnaissance Survey

After identifying the areas of operation, the nongovernmental organization (NGO) or project implementing agency (PIA) should carry out a reconnaissance survey of seed needs assessment (SNA) (Ravinder Reddy et al. 2006). This is a series of participatory dialogues to engage a community in a diagnosis of the problems relating to seed and to secure the community's commitment to develop and act on its own solutions. The SNA will also identify knowledge gaps that can be corrected during training. The SNA should assist communities in developing an action plan on what needs to be done, while remembering that the role of the NGO is only to facilitate this process.

## Participatory Selection of Crops/Varieties

It is for the communities to identify the crops and varieties to be multiplied. There is a tendency for farmers to select only improved varieties at the expense of important local varieties. Facilitators should check this tendency. Farmers should be encouraged to select a good mix of crop types (crop diversity). Locally adapted varieties would be ideal in the first year. This tends to increase the chances of success since farmers already have adequate experience growing them. The NGO should be proactive in promoting farmers' participation in the selection of varieties/crops for a particular area/region/village.

## Selection of Seed Growers

Once the crops for multiplication have been identified through farmers' participatory selection, the community can select individuals who will be the seed growers. Since food legumes are known to be conserved and multiplied mostly by women, it is only appropriate and advantageous that seed production of such crops be done by them. To help farmers carefully select their local seed growers, the NGOs can help facilitate a process developing criteria for selecting seed growers. Some suggested criteria are

- He/she should be resident of the village.
- Should be a farmer with land holding.
- Must be trustworthy.
- Willing to attend training programs without fail.
- He/she should be friendly in nature and approachable to others.
- Inclination to put in sincere efforts.
- Must be willing to work in a team.
- Experienced in growing one or more of the crops intended for multiplication.
- Must be honest and willing to repay seed loans.

Having such a set of criteria reduces bias and helps farmers to choose the seed growers correctly. Experience has shown that where an NGO decides to interpose and select the seed growers, other farmers have had to secure seed for them instead.

## Capacity Building

After seed growers have been identified, technical training should follow. The seed growers are trained in basic seed production techniques including rules and regulations and seed certification methods, seed health management and seed storage management. Training is enhanced when followed by an educational tour to areas where similar programs exist. This is farmer-to-farmer learning. Farmers must be trained in business skills and some basic group dynamics and leadership.

As with all farmer training, the trainer should be conversant with principles of adult learning and facilitation skills. Training can be conducted by competent extension officers so long as they fully understand the basic seed production standards and the Seeds Act. For such innovation projects a consortium approach has yielded good results (Ravinder Reddy et al., 2006)

## Procurement of Basic Seed and Distribution

The NGO or farmers need to secure basic seed (foundation seed) for their seed production activities (Ravinder Reddy et al. 2006). Basic seed can be difficult to secure. Therefore, a proper seed source has to be found much before the start of the season. Where poor weather has affected the growing season, it would be imperative to arrange seed for the following season. It is advisable to subcontract breeders recognized by government or research organizations to produce basic seed in specified quantities. Contact arrangements may be worked out for a specific period to ensure timely supply of basic seed.

In the absence of basic seed, a seed grower can plant certified seed, but only for one season. Thereafter farmers must secure basic seed for quality seed and long-term benefits.

## Formation of Seed Growers Association

Some seed growers would certainly prefer to work as individuals but in seed growing, forming an association has the following advantages:

- Registration is cheaper for a group than for individuals. Self-help groups can take up this activity right away without any registration.

- It is cost-effective to work as a team when procuring basic seed and selling seed: There is the benefit of bulk buying and selling.
- Group contributions can be used for paying for activities such as crop inspections, seed sampling and testing.
- During the early years of seed growing the team is important for providing mutual support, encouragement and a collective voice.
- However, for farmers to work effectively as a group, needs assessment can determine whether they need to be trained in group dynamics, leadership, record keeping, conflict management and business skills.
- The seed growers association would be required, in the longer term, to mobilize funds to sustain their seed growing activities.

## Seed Marketing

The success of a community seed project lies in the ability of the seed growers to sell their produce. Some farmers have used field days, weekly village markets, village local market days as a way of advertising available seed to fellow farmers. Others have used public meetings and ceremonies in their villages to sell seed. Seed growers should be innovative in adopting ideas that are workable within their rural setup. They, however, should be careful not to price their seed beyond the local farmers' willingness to pay.

Wherever possible, help establish a credit scheme such as a revolving fund. This will enable community-based organizations to buy up seed from seed growers which will then generate new loans for resource-poor farmers. Some farmers do loan seed to other farmers, to be repaid later in the form of grain, labor or livestock.

After selling off their produce, farmers should be encouraged to save some of the income for purchasing new seed and covering other overheads in the next growing season.

Many development projects have used community-level seed production as the starting point for commercial seed development. The results have been disappointing with little commercial sustainability. The reasons for this lack of success are two fold: a lack of attention to transaction costs (for making contracts for source seed, ensuring quality control and obtaining information) and a lack of experience and resources for marketing. Community-level seed projects need more appropriate goals to be successful, such as testing and disseminating new varieties, developing farmers' experimentation capacities, and forming better links between farmers and researchers.

Chapter X

# Quality Assessment of Farmer-Saved Sorghum Grain/Seed in the Community

*Although the informal seed sector provides a dynamic and flexible system of seed supply, continuous use of nontested seed inevitably leads to degeneration of seed quality. Here we share our experience gained through an on-farm survey of the fungal profile of sorghum seed and grain collected from rural communities. Information on storage systems and options to improve the quality of molded grain is presented in detail.*

## Introduction

In many developing countries, the threat of seedborne diseases is normally ignored, and control measures are unknown or inadequate. Often the consequences are poor seed quality, dissemination and buildup of seedborne diseases and, ultimately, yields far below potential. A farmer using healthy seed is more likely to reap a big harvest. The quality of seed must be known before it is sown. However, this is not always apparent to the naked eye. Moreover, the difference between seed and grain is very thin. Seed supply from both formal and informal systems suffers from a series of problems due to the lack of investment in education, research and quality control. The main problems are low quality of seed, limited use of clean and healthy seed by farmers and seed producers, and lack of knowledge of the significance of seedborne infections in the field compared to other means of transmission, eg, soil and collateral hosts.

## Mycoflora and Mycotoxins

A pictorial guide published jointly by the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) and the Natural Resources Institute, UK (Navi et al. 1999) gives information on the identification of mold fungi on sorghum grain. However, it lacks information on the frequency of occurrence of mold in (1) samples collected from rainy- and postrainy-season harvests, (2) storage structures, (3) cultivars and (4) treatments. Hodges et al. (1999) and Navi et al. (2002) partially address this question. This chapter attempts to fill that gap and assesses the consequences of the presence of fungi on grain germination.

Sorghum is one of the most important staple food crops in the semi-arid tropics of Asia and Africa, where it sustains some of the poorest communities. The crop is grown in harsh environments where other crops do not grow well. Improvements in production, accessibility, storage, utilization and consumption of this food crop will significantly contribute to the food security of the inhabitants of these areas (FAO 1995).

In India, more than 70% of the foodgrain production is stored in bulk in different storage structures made from locally available materials like mud, bamboo and plant materials. Sorghum grain is stored on a large scale by government organizations like the Central Warehousing Corporation, Food Corporation of India (FCI) and by traders, most commonly in jute bags in above-ground structures. Some of the storage structures are neither rodent-proof nor secure from fungal and insect attack. Inadequate storage methods lead to grain losses of an unacceptable degree. On an average, 6% of the foodgrain is lost in such storage structures, about half of it due to rodents and half to insects and fungi (Gwinner et al. 1996). The mycoflora associated with sorghum grain pose the risk of contamination by mycotoxins (Gonzalez et al. 1997). Field fungi often invade grain before harvest in the field and affect the quality of grain. The damage caused by them is often neglected until it reaches an advanced stage. In addition to direct losses, some of the fungi, such as *Fusarium* spp and *Aspergillus* spp produce mycotoxins that contaminate food and feed and create health hazards for humans, cattle and poultry (Bhat et al. 2000).

A cost-effective way to cut such losses and risks would be to protect grain from deterioration before harvest by planting a wide variety of tolerance/resistance sources for sorghum grain mold (Bandyopadhyay et al. 1988; Bandyopadhyay et al. 2000; Navi et al. 2003; Singh et al. 1995). Similarly, postharvest losses can be reduced by paying attention to the technical and practical aspects of storage. Cleaning and drying the grain enhances storability, but storage structure design and construction are important too.

## Methodology of Sampling Grain Stored by Farmers

To assess the fungal profile of sorghum seed and grain collected from rural communities, 67 sorghum samples were selected from a collection of 73 taken during surveys conducted in two villages each in Andhra Pradesh and Karnataka states and eight villages in Maharashtra state in 1997. The samples had a representative selection of crops, cultivars (variety/hybrid/landrace), storage types and the farmer population in the respective community (Hodges et al. 1999). The rainy-season harvest of 1996 was represented by 34 samples and the postrainy season harvest of 1996/97 by 33. The samples drawn were from sorghum foodgrains stored by farmers in jute bags (JB), mud-lined baskets (MB), metallic containers, polypropylene bags (PB), open storage in the corner of a room and a combination of MB/PB and JB/PB. Samples of approximately 5 kg grain were collected from each lot using a compartment probe (80 cm long × 2.5 cm diameter) where there was open access to the grain bulk (MB and loose grain piles). Where access was more difficult (stacks of JB and PB), a short probe (27 cm long × 1.5 cm diameter) was used (Hodges et al. 1999).

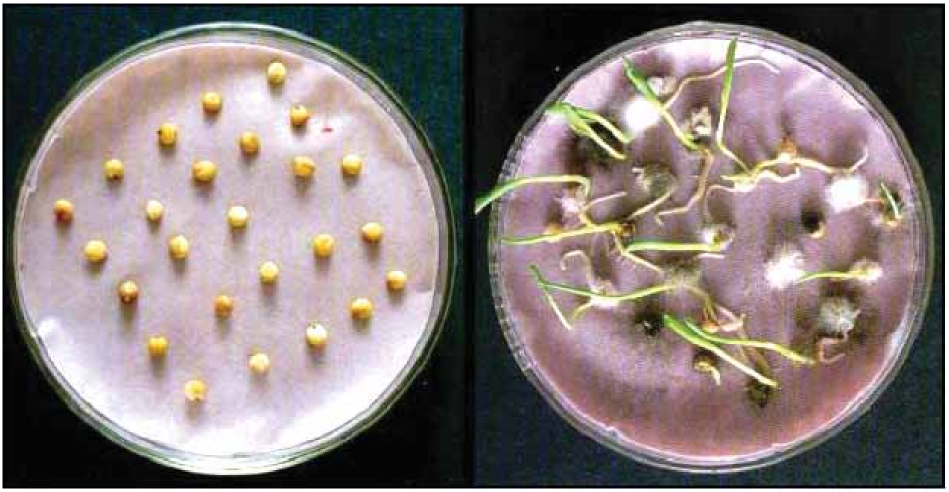

*Figure 12.1. Blotter method used to assess grain mold fungi in laboratory conditions. Source: Navi et al. (1999).*

## Grain /Seed storage structures used in rural areas of Andhra Pradesh, Karnataka and Maharastra states

*1. Jute bags (JB)*
*2. Metalic containers (MC)*
*3. Mud lined bamboo baskets (MB)*
*4. Polypropylene bags (PB)*
*5. open storage in corner of a room may be MB/PB and JB/PB*

## Fungal Profile Measurement

Eight hundred grains were taken from each sample, and subsamples of 200 grain were used for assessing the fungal profile and germination percentage of the grain in four treatments: (1) grain surface-sterilized in 1% sodium hypochlorite (NaOCl) prepared from Clorox® (Clorox, Oakland, CA 94612, USA) containing 5.25% NaOCl, and not treated with fungicide benomyl; (2) grain surface-sterilized and treated with benomyl (0.05%) [Benofit® 50WP (benomyl 50% WP) EID Parry (India)]; (3) grain not surface-sterilized but treated with benomyl; and (4) grain neither surface-sterilized nor treated with benomyl. The main objective of the experiment was to study the association of fungi including *Fusarium* spp in the samples collected. The purpose of treating grains with benomyl was to understand sporulation or elimination of *Fusarium* spp after the fungicide treatment (Navi 2005). The grain from each treatment were separately transferred in steam-sterilized Petridish humid chambers at 25 grain per Petridish (Fig. 12.1) and were incubated at $28 \pm 1^{o}C$ with a 12-hour photoperiod for 5 days. Individual grain in all the treatments was examined under a stereo microscope (Olympus COI®) for grain colonization and a compound microscope (Olympus BH2®) for proper identification of fungi using the scotch-tape method. The identities of the fungi were confirmed from the literature (Standen 1945; Nelson 1959; Barron 1968; Ellis 1971; Ellis 1976; Barnett and Hunter 1972; Raper and Fennel 1973; Sutton 1980; Sivanesan 1987; Champ et al. 1991; Pitt 1991; Hanlin 1990; Hawksworth et al. 1995). The characteristic difference between major and minor fungi was based on the frequency of occurrence of a fungus. If it was >5% occurrence, it was considered as major and <5% as minor by using the general linear means procedure and the least significant difference (LSD) calculated using Tukey's Studentized Range test using the SAS package (Cary, NC, USA) to understand the effect of seasons, storages, cultivars and seed treatment on the frequency of mold fungi.

## Germination Potential of Sorghum Grain/Seed Saved by Farmers

In the rainy-season samples, the mean grain germination percentage was 46% less than in the postrainy-season samples. It may possibly be true that samples from the rainy season tend to possess less viability than postrainy-season samples. Low germination might also depend on colonization by diverse fungi in different storages and cultivars grown during the rainy season. Grains sampled from jute bags had the highest germination percentage followed by MB, and grains piled in the corner of a room had the lowest germination percentage. Similarly, among eight cultivars, grain germination was relatively higher in local yellow, Dagri and Maldandi compared with improved varieties and hybrids. Grain germination varied from 75% to 100% in local cultivars, and from 35% to 62% in hybrids. Again, this measurement is interlinked with the harvesting season. The majority of local cultivars are grown during the postrainy season and the improved varieties and hybrids during the rainy season. Perhaps, observations among the treatments indicated no significant difference (Navi 2005).

## Fungal Profile in Sorghum Grain/Seed Saved by Farmers

Fifty-one fungi and a bacterial contamination were detected in approximately 54000 grains examined across seasons, storages, cultivars and treatments. Of these, *Alternaria alternata* (Fr.) Keissler (Fig. 2a); *Aspergillus flavus* Link (Fig. 2b); *A. niger* Van Tieghem (Fig. 2c); *Bipolaris australiensis* (M.B. Ellis) Tsuda & Ueyama (Fig. 2d); *Curvularia lunata* (Wakker) Boedijn (Fig. 2e); *C. lunata* var *aeria* (Bat., Lima & Vasconcelos) M.B. Ellis (Fig. 2f); *Fusarium verticillioides* (Sacc.) Nierenberg (Synonym *Fusarium moniliforme* Sheldon) Lisea Fujikuroi Sawada (Fig. 2g); *Penicillium citrinum* Thom (Fig. 2h); *Phoma sorghina* (Sacc.) Boerema, Dorenbosch & Van Kesteren (Fig. 2i); and *Rhizopus stolonifer* (Ehrenb:Fr.) Lindner (Fig. 2j) showed a mean frequency of >5%. The frequency levels of the 41 other fungi with less than 5% frequency have been reported (Navi 2005).

## Harvesting Seasons and Fungal Profile in Farmer-Saved Grain/Seeds

The harvesting season showed a significant impact on the frequency of the mycotoxin-producing fungus *F. verticillioides,* formerly *F. moniliforme.* The frequency of this fungus was 5.5% higher in grain sampled from the rainy-season harvest compared with grain sampled from the postrainy-season harvest. While the frequencies for *A. flavus* were 1.6% higher in the rainy season than in the postrainy-season harvest. Likewise, the spectrum of other major fungi varied with the harvesting season. The fungi with >5% frequencies were *A. alternata*, *A. niger*, *C. lunata*, *C. lunata* var *aeria*, *F. verticillioides* and *R. stolonifer.* It is obvious that the rainy-season samples are caught in the rain any time between flowering and post-maturity and tend to have internal infection, which might lead to reduced grain germination percentage. Similarly, it is also possible to have a higher fungal frequency in samples collected from the rainy-season harvest than from the postrainy-season harvest due to the prevailing rain toward the crop maturity stage and high relative humidity in the crop canopy.

## Storage Type and Fungal Profile in Farmer-Saved Grain/Seed

Looking at the frequency of *F. verticillioides*, a mycotoxin-producing *Fusarium* species (Navi et al. 2005a), it is apparent that storage structures influenced its frequency. Grain stored in MB had the least frequency compared with 2–14% for the other storage structures. This was possibly because of less aeration, low relative humidity and low moisture in the container. On the contrary, the frequency of *R. stolonifer* was 50% in grain stored in metallic containers followed by *A. flavus* and *A. niger*, indicating that these may be potential storage fungi occurring in this particular storage structure. Similarly, the frequencies of the other fungi varied with the storage structure (Navi 2005). Navi (2005) reported the frequency of *F. verticillioides* as high as 13.5% in grain sampled from PB/MB, followed by grain sampled from the corner of a room (12.7%), MB (9.7%) and PB (5.1%). The higher frequencies of *F. verticillioides* from grain stored in a corner of a room could be due to infection that had occurred in the field prior to harvest (Navi et al. 2005) or the fungus might have reproduced faster given the exposure of the grain. Also, the higher frequency in MB and PB could be due to high humidity or moisture buildup during storage. Likewise, the frequency of *C. lunata* and *C. lunata* var *aeria* was higher in grain sampled from MB, PB and PB/MB. The major fungi were the same five as reported above.

## Cultivars and Fungal Profile

The germination percentage of grain of hybrid sorghums showed the opposite relationship with major fungal frequencies compared with local cultivars. Hybrid CSH 9 had the highest frequency of *C. lunata* var *aeria*, followed by *C. lunata*, *A. alternata* and *F. verticillioides* (Navi 2005). Interestingly, 7–10% *F. verticillioides* frequency was observed among the hybrids compared to 2–8% in the local cultivars. The low frequency of *F. verticillioides* shown by Maldandi grain is a plus point from the point of view

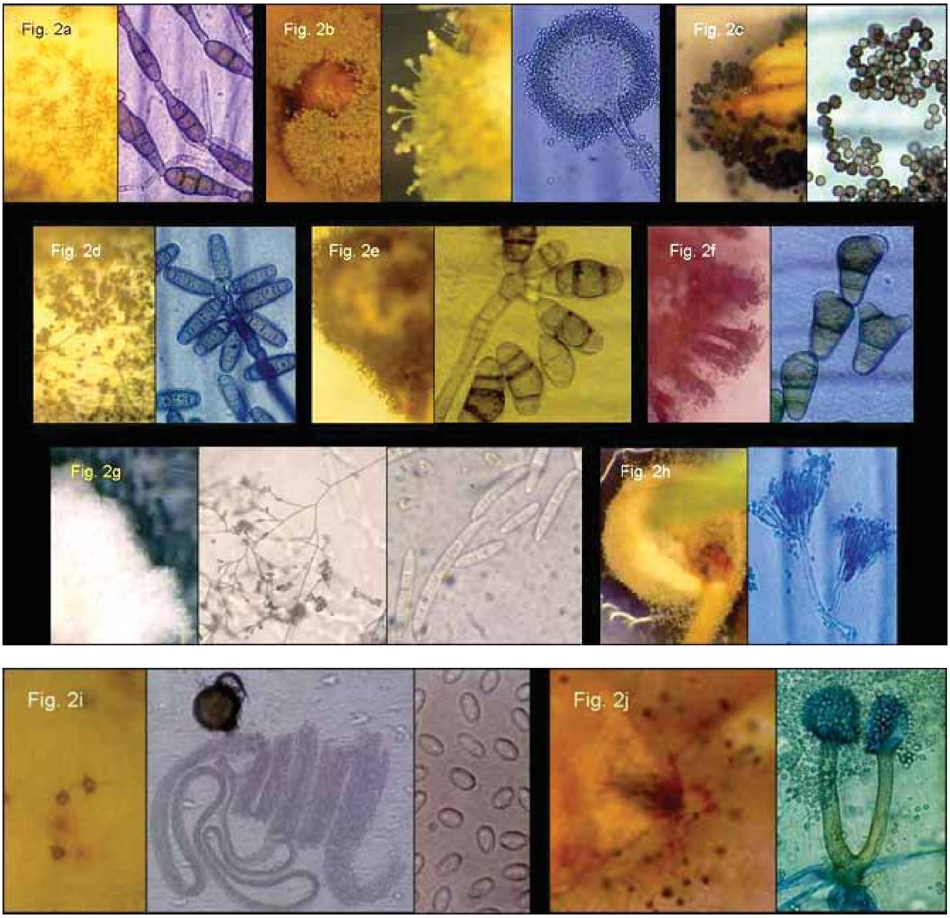


*Figure 12.2. Fungi with >5% frequency across harvesting seasons, storages, cultivars and treatments observed in the blotter test:* Alternaria alternata *(2a);* Aspergillus flavus *(2b);* A. niger *(2c);* Bipolaris australiensis *(2d);* Curvularia lunata *(2e);* C. lunata *var* aeria *(2f);* Fusarium verticillioides *(2g);* Penicillium citrinum *(2h);* Phoma sorghina *(2i); and* Rhizopus stolonifer *(2j). Picture source: Navi* et al. *(1999).*

of consumers who prefer this postrainy-season cultivar over other varieties and hybrids. The frequency of *A. flavus* among hybrids ranged from 0.6% to 2.5%. The frequency of *P. citrinum* went up to 3% in Maldandi/Dagri local, while in the hybrids it was only 0.0–0.2%. Overall, fungal frequency was higher in hybrids compared with local cultivars including Maldandi. It is possible that most of the hybrids are grown during the rainy season as rainfed crops rather than in the postrainy season under assured irrigation. On the contrary, most of the improved varieties and local cultivars are grown during the postrainy season as a rainfed crop than under assured irrigation. It was observed that local cultivars grown during the rainy season are mainly for fodder purposes and rarely for food (Navi et al. 2002).

## Chemical Treatment and Fungal Profile

Surface sterilization normally kills most fungi adhering to the seed. However, in our study, surface sterilization of grain with sodium hypochlorite did not remove many fungi, indicating that most of the major fungi listed in Figure 2 were internally seedborne. Yet, grain treated with benomyl, with or without surface sterilization, considerably reduced the frequency of *A. flavus*, *A. niger, F. verticillioides* and *P. citrinum*. Typically, benomyl (0.05%) greatly reduced the frequency of *F. verticillioides* to <1% compared with 15% in the control. Besides *F. verticillioides*, benomyl was also effective against *A. flavus, A. niger, P. citrinum* and *P. sorghina*, but not against *Alternaria* spp, *Bipolaris* spp and *Curvularia* spp indicating that it may be good to treat sorghum grain to eliminate some of the fungi mentioned above provided the grain are used for sowing and not for consumption.

## Fungal Frequency and Grain/Seed Germination

The frequency of occurrence of *C. lunata* var *aeria* and *A. flavus* was higher in non germinated grains than in germinated. Among the fungi observed on non germinated grains, the frequency of *C. lunata* var *aeria* was highest followed by *R. stolonifer*, *C. lunata* and other fungi. In germinated grains, the frequency of *R. stolonifer* was higher followed by other fungi (Navi 2005).

## Inferences on Farmer-Saved Grain/Seed Quality

Looking at the range of fungi connected with sorghum grain, either colonized in the field prior to harvest or developed in storage, it may be useful to focus on some of the available approaches to minimize grain damage by fungi and the health risk associated with potential mycotoxin contamination. Harvesting of crops is seasonal, but consumption of grain is continual. Fungi can develop in storage if grain have been damaged during harvest, handling, threshing and drying; are stored without sufficient drying; and exposed to increased moisture during storage. It has been observed that *A. flavus* and *P. citrinum* are frequently recorded in very low frequencies in molded panicles during the rainy season and in samples taken from farmers2 storage. However, they have also been recorded in storage (Christensen and Meronuck 1986). In a study conducted on inheritance of grain mold resistance in sorghum grain without a pigmented testa (Rodriguez-Herrera et al. 2000), most prevalent fungi isolated from the field were *F. moniliforme* (46%), *Alternaria* sp (32%), *C. lunata* (8%), *F. semitectum* (7%) and *Drechslera* sp (3%).

Understanding the frequency of potential toxin-producing fungi like *Fusarium* spp and *Aspergillus* spp is essential to guard against nutritional and qualitative losses. Navi et al. (2005a) have reported the prevalence of at least five *Fusarium* spp in the Indian grain mold complex which are potential fumonisins producers and their frequency of occurrence in grain samples collected from five Indian locations (Navi et al. 2005b). It may be possible to use mold inhibitors like propionic acid during the drying process to reduce the risk of mold development in storage (Shetty et al. 1995).

## Options to Improve Quality of Molded Sorghum Grain

In India, sorghum grain is used either for human consumption or for cattle and poultry. Therefore, fungicidal treatment of grain prior to storage may not be acceptable to farmers unless the grain is meant to be used for sowing purposes. Removal of the pericarp is sufficient to remove most of the fungi and reduce mycotoxin contamination, as has been shown in rice (*Oryza sativa* L.) (Vasanthi and Bhat 1998). In the case of sorghum, removal of the pericarp is possible by several means including mechanical dehulling to minimize the moldy appearance of molded grain (ICRISAT 1986). Village-level dehulling of molded grain has been suggested to improve the quality of molded grain (Stenhouse et al. 1998). It may be possible to decorticate the grain using rice polishers (Raghavendra Rao and Desikachar 1964) or the decorticator developed by the International Development Research Center (IDRC), Canada (Reichert et al. 1982), which leaves the germ intact. The commercial value of dehullers and dehulled products has been demonstrated with clean sorghum grain (Geervani and Vimala 1993). Further research is required on several aspects of value addition to superficially molded grain for which linkages with sorghum processors and consumers are necessary. These research areas include identification of suitable cultivars with adequate mold resistance and grain quality characters; optimization of the dehulling procedure and equipment for grain with different levels of moldiness, grain hardness, grain size and mold resistance; limits of grain moldiness under which the technology is operable; economics of value addition and its effect on consumer acceptance; nutritional, storage quality and safety of dehulled grain and other related areas. However, before extensive research can begin, there is a need to determine the consumer acceptability and marketability of the dehulled products and identify the market opportunities in the rural and urban sectors. Therefore, a prefeasibility study is required for dehulling technology which appears to be one of the few short-term solutions to the most important food quality problem of sorghum consumed by the poor.

Recent studies also have suggested polishing or dehulling the molded grain to minimize mold damage (Bandyopadhyay et al. 2000). There is a need to determine the consumer acceptability apart from marketability of the dehulled grain. Similarly, pounding molded grain and treating with crude garlic extract has been reported to reduce major fungal frequency (including *Fusarium* spp) and ergosterol content of molded grain with an emphasis for safer consumption by humans, animals and poultry birds (Navi and Singh 2000; Navi and Singh 2003). Again, this method of treating molded grain needs acceptability by a greater percentage of farmers than at a specific location where the grain were sampled for the study. It may be hard to disregard the acceptance of pounded grain treated with garlic extract because of the easy availability of garlic in most Indian homes, and it is an environmentally friendly treatment. Use of garlic extract for the control of sorghum ergot (*Claviceps* spp), particularly in seed production, was effective and environmentally friendly (Singh and Navi 2000). Similarly, from a limited study by Navi and Singh (2003) on the use of garlic extract (3.17% to 6.25% depending on mold severity) to treat molded grain, it was reported to have had an impact on mold growth and ergosterol content. Hence, this study might aid in framing competitive control approaches to reduce damage due to storage fungi for safer consumption by humans and cattle. Pounding and crude garlic extract treatment of molded grain to reduce the infection of *F. verticillioides*, *F. pallidoroseum* and *C. lunata* and ergosterol content have been reported (Navi and Singh 2000; Navi and Singh 2003). Therefore, based on our limited study, it would be difficult to provide an integrated package for the management of storage fungi of sorghum. However, it is suggested to (a) store grain in jute bags, as many Indian farmers do, than storing in other containers mentioned in the study to minimize the damage from potential fumonisins producing *Fusarium* spp; and (b) grow mold-tolerant/resistant genotypes during the rainy season (Bandyopadhyay et al.1988; Bandyopadhyay et al. 2000; Singh et al. 1995; Rao et al. 1995; Navi et al. 2003).

## About ICRISAT®

The International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) is a nonprofit, non-political organization that does innovative agricultural research and capacity building for sustainable development with a wide array of partners across the globe. ICRISAT's mission is to help empower 600 million poor people to overcome hunger, poverty and a degraded environment in the dry tropics through better agriculture. ICRISAT belongs to the Alliance of Future Harvest Centers of the Consultative Group on International Agricultural Research (CGIAR).

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ISBN 978-92-9066-502-1 Order code BOE 045 16–2007