Guide for Developing PVO/PC Seed Activities

THE ON-FARM SEED PROJECT

by

Tom Osborn
Dakar, Senegal

Winrock International Institute for Agricultural Development
April 1992

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Introduction

It is impossible to discuss agriculture without considering the important role of quality seed. Seeds are catalysts for agricultural development; they contain genetic potential that must be used with appropriate practices and inputs for superior yields. Most previous efforts in seed improvement have focused on the development of improved varieties or national seed programs. These efforts, although important, may not affect the availability of quality seed for small farmers in developing countries. Sometimes improved varieties are inappropriate for a small farmer's needs, and there are often weak linkages between the national systems and farmers. Often overlooked is the fact that the primary source of seed in Africa is the farmer. It is estimated that in the developing world 80% of the seed planted has been produced and saved by the farmer (Delouche, 1982). In Africa, this figure is even higher – farmers often produce and save as much as 100% of their own seed. Seed improvement activities, therefore, should focus on the farmers' needs.

The On-farm Seed Project (OFSP) has been assisting private voluntary organizations (PVOs) and the Peace Corps in Senegal and The Gambia to develop or improve their seed related agricultural activities. The OFSP is different from other seed projects in two ways: first, it focuses on the traditional system by which farmers produce and save their own seed; second, it uses a process-learning approach. Agricultural development activities often use a top-down or blueprint approach to development projects in which the farmer's problems are decided upon before the beginning of the project. By contrast, the first step of the process-learning approach is to investigate the traditional seed production system and identify problem areas of seed and crop production. These problems are examined with the farmers, and modifications that they themselves can implement are developed in order to increase crop yields and farm income. The process-learning approach is complimentary to participatory approaches in that it brings much needed attention to the resource poor farmers. The grass roots activities of many PVOs and the Peace Corps make them particularly well suited to the process-learning methodology.

The purpose of this guide is to provide information about seed technology and about how organizations can determine the feasibility of seed activities in their agricultural programs. Seed activities can be integrated into existing agriculture development programs or established as new or separate programs.

Many types of organizations can benefit from this guide. Thus far, the OFSP has collaborated with nongovernmental organizations (NGOs) to reach indigenous farmer organizations, international NGOs with planned or ongoing seed activities, Peace Corps agricultural programs, and government extension services. The OFSP has operated in West Africa, but the methodology can be used in any developing country.

Part 1 of the guide offers basic information about seed technology, programs, and production with emphasis on concepts that are important for developing farmer seed production activities. Practical examples are given to illustrate how the concepts have

been applied in the context of OFSP activities in West Africa, but it is not a detailed presentation on seed technology and seed programs. The annotated bibliography identifies more in-depth treatments of the subjects discussed.

Part 2 offers a step-by-step process for determining the feasibility of seed activities in any country and for developing and implementing seed related activities. Phase A provides a questionnaire for gathering information about seed in any country. Phase B explains how to develop seed demonstration programs with farmers. Phase C presents the various strategies for farmers' seed activities. While aspects of traditional farming systems, storage, and seed production may be different in other regions of the developing world, the process outlined for developing a seed program should be transferable.

Part 3 includes case studies of collaborative seed activities in Senegal. The practical application of what has been presented in Part 1 and 2 is developed here.

Part One

Background Information

Seed Basics: Terminology and Concepts

Why is seed quality important?

"No matter how hard I work, a good crop is not possible with bad seeds," is one Bolivian farmer's answer (Garay, Pattie, Landivar, and Rosales, 1988).

Good quality seed is crucial to agricultural production: poor seed limits the potential yield and reduces the productivity of the farmer's labor. The farmer needs every possible advantage in crop production; starting with good quality seed is important. There are two basic measures of seed quality: physical/physiological qualities and genetic quality. Physical quality is the physical aspects of seed (i.e., pure seed, seed size, and the absence of inert matter) and the physiological quality refers to the overall health and condition of the seed and includes seed vigor, viability, and freedom from disease. Genetic qualities are the specific genetic characteristics of the seed; ideally, seed should be relatively genetically uniform and adapted to produce optimum yields under local conditions.

Good physical/physiological qualities are characterized by the following:

- **Nearly uniform seed size.** Medium and large size seed will have higher germination and vigor than small and immature seeds. In the conditioning (processing or selection) of seed, small seed is eliminated.

- **Minimal quantities of damaged seed.** Damaged seed may not germinate and is more likely to be attacked by insects or microorganisms.

- **Minimal quantities of weed seed or inert matter.** There is no reason to purchase or to plant weeds, chaff, stones, or dirt with the good seed.

- **Minimal quantities of diseased seed.** Discolored or stained seed can carry microorganisms that already have attacked or will attack the seed when it starts to grow. The plant may live and spread the disease to the other plants.

- **High germination and vigor.** The germination rate is an indicator of the ability of the seed to produce a plant. Seed vigor is the ability of the seed to germinate and survive under potentially stressful field conditions and to grow rapidly under favorable conditions.

Genetic qualities consist of the following:

- **Seed of the same variety.** Seed of different varieties of the same species are often hard to distinguish. A mixture of varieties can be a problem because the varieties may mature at different times, causing difficulties in harvesting and postharvest handling and lower yields.

- **Adaptation to local conditions and high yield potential.** Adaptation is the process by which a population of plants reacts to or fits into new or different environmental conditions by change in form or function. A variety with wide adaptation is one that performs satisfactorily under a wide range of environmental conditions. Plants will grow well and produce an abundance of seed only in a suitable environment. Given that fact, the process of developing and testing varieties to determine their adaptation to local conditions is long and rigorous. Plant breeders breed and select plants for stability of the plant population over many years based on characteristics such as growth cycle, resistance to diseases and insects, drought tolerance and tolerance to local soil conditions. Additionally, plant breeding and selection is based on high-yield potential including physiological factors such as tillering, number of grains per plant, grain size, resistance to lodging, and photosynthetic efficiency. After testing on research stations, varieties are grown in multilocational trials (sometimes on-farm trials) to evaluate the wide adaptability before releasing them to farmers.

- **Proper characteristics for use.** A crop must have the processing, culinary, color, and taste characteristics that are compatible with local preferences. Farmers have rejected many new varieties because of poor taste or cooking factors. Since the plant may be used for various purposes after harvest, such as building material or fodder, other aspects may be important.

When seed has desirable physical, physiological, and genetic qualities, the farmer has a better chance to grow a good crop. Good quality seed is a major factor for getting a good field of rapidly developing plants, even under adverse conditions. Other factors such as rainfall, agronomic practices, soil fertility, and pest control are also crucial to a good crop.

Seed versus food grain

What is the difference between the part of the crop that farmers use for food or for sale and what they use for seed? Food grain can have damaged and broken seed, not be of a uniform size, have low germination, and be a mixture of varieties and still be acceptable for sale or consumption. That same food grain would not be good for planting. Seed for planting should have good quality as previously described so that it will be capable of germinating and producing a good crop. Understanding the distinction that farmers make between the part of the crop used for consumption and the part used for planting seed is important. If farmers are not making this distinction, creating an awareness of the importance of seed, "a seed mentality" so to speak, is an important objective in a seed program.

Traditional varieties and improved varieties

In seed programs, both traditional and improved varieties can potentially improve seed quality at the farmer level.

Traditional varieties are those that have been used in an area for many years. Their source can be selections by farmers from indigenous populations or from a population that has evolved from seed stock originally introduced into the area. In either case, no organized plant-breeding activity was involved for the development of the variety. Although characteristics vary greatly, some generalities of traditional varieties can be noted.

- Historically, they are well adapted to the growing conditions, though sudden changes in these conditions (such as periods of extended drought) may render old varieties unsuitable.

- Their processing, color, culinary, and plant characteristics are culturally acceptable.

- They do not adapt to shorter growing seasons when rainfall is reduced. This is often because the variety is photoperiod sensitive, that is, the plant responds to changes in day length. Historically, photoperiod sensitivity may not be a problem, but with reduced rainfall in some regions, photoperiod-sensitive plants may flower too late for good yield.

- They do not use moderate levels of soil fertility efficiently, resulting in taller plants that falling over (lodge) but do not produce more grain.

- They may not be uniform at maturity, requiring multiple harvests or causing yield losses due to shattering (seed falling on the ground).

- They produce a stable yield from year to year but do not usually have a high yield potential under better growing conditions.

Improved varieties result from plant-breeding programs at a regional, national, or international level. These varieties have been tested in the country to insure adaptability to local conditions. Unfortunately, testing often does not include on-farm trials under low-input conditions (limited or no mineral fertilizer, insecticides, or herbicides). Improved varieties share several general characteristics.

- They mature earlier than traditional varieties in order to cope with reduced rainfall. Early maturing varieties often are photoperiod insensitive, flowering at a predetermined number of days after emergence.[1]

- They respond to moderate soil fertility by producing higher yields rather than larger or taller plants as do traditional varieties. At the same time, some improved varieties require high levels of fertility (application of mineral fertilizer) to produce higher yields than traditional varieties. Use of mineral fertilizer is often financially out of reach for resource-poor farmers.

- In some cases, they resist pests and disease better. Pest resistance has been difficult to achieve in many crops; sometimes broad-based genetic tolerance to pest and diseases is sacrificed for higher yield. There have been successes with disease resistance but also some major failures.

- They are always as culturally acceptable in taste and plant characteristics as traditional varieties.

- They often are shorter in height than traditional varieties, which may make the plant less desirable for fodder or building materials.

For example, in Senegal our experience with improved varieties of rice have been very positive; they have been accepted and preferred by farmers. By contrast some improved millet varieties have not been appropriate or accepted by farmers.

The performance of a traditional variety should be compared to that of an improved variety under farm conditions using methods that are in reach of resource-poor farmers. A farmer's choice of traditional or improved varieties is based on many of the previously mentioned characteristics. The comparison needs to be made by the farmer for specific varieties in specific locations. A major consideration in the Sahel region of Africa is the general reduction in rainfall; there is not enough rainfall for some of the traditional varieties to mature and produce a reasonable crop. Farmers are often interested in trying new varieties that mature earlier. Taste and plant characteristics, such as stalk length, are important factors that have sometimes been overlooked in the development of new varieties.

Pollination and seed production

Pollination is a key step in the reproduction of the plant and in determining the genetics of the progeny. Consequently, the method of pollination (self, cross, or hybrid cross) is a very important factor in the strategy used to produce seed.

Self-pollinated species are characterized by plants that have perfect flowers (male and female organs in the same flower) and the pollen (male) fertilizes the stigma (female)

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[1] Earlier maturing varieties may be vulnerable to increased bird attack at harvest, and because they often mature before the end of the rainy season, may suffer weathering problems. Sometimes these varieties are planted later than the traditional varieties so the maturity of both coincide.

of the same flower. In this way, the seed produced will be genetically similar to the plant from which it came.[2] With self-pollinating species, genetically uniform and stable seed can be easily produced even by small farmers. Self-pollinated crops include rice, wheat, soybeans, peanuts, and cowpeas.

In cross-pollinated (sometimes referred to as open-pollinated) species, the pollen that fertilizes the stigma is not normally from the same plant. Many factors account for this, including the location of the stamen and stigma of the plant, and the timing of the release of the pollen in relation to the receptivity of the stigma. Wind and insects are vectors of pollen transfer that can also affect pollination. The production of genetically pure seed for cross-pollinated species, therefore, is more difficult than for self-pollinated species. Fields for seed production of cross-pollinated species must be isolated (located a prescribed distance) from other fields of the same species so that pollination will be only among the plants of the same variety. Alternatively, fields of seed can be isolated in time when it is possible to plant the field earlier or later than normal, or off-season seed production can be considered using irrigation. In areas where a crop is widely grown, one variety may be pollinated by a different variety from a surrounding field. Cross-pollinated crops include maize (corn) and millet.

Hybrids are the result of a very controlled cross-pollination procedure. They are the first generation after cross-pollination of two pure inbred lines. An inbred line is a variety that has been self-pollinated for several generations to insure a high level of genetic purity. The hybrid that is produced from the two inbred lines has a higher yield potential than the varieties from which it was selected because of the phenomena of hybrid vigor. Seed should not be saved from hybrids because the subsequent generations will be physically and genetically different than the first generation due to genetic segregation. Hybrids are produced under controlled conditions that are very costly to maintain, and the seed is expensive. Thus, they will not be included in our discussion of farmer seed programs.

Seed Systems

National seed programs

National seed programs consist of diverse organizations such as a national agriculture research service or a national seed service, plus public or private organizations for the production and marketing of seed. These organizations must work together if good quality seed is to be produced and utilized by farmers. In most developing countries, national seed programs have a high level of government participation, while in developed countries, the private sector plays the primary role in the seed industry. There is a trend to get the private sector more involved in national seed programs in developing countries. This is outlined in the publication Setting A Seed Industry in

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[2] Even with self-pollinated species, there can be 1% to 5% cross-pollination depending on the species and the presence of pollination insects.

Motion (Garay et al., 1988). The national seed programs of many developing countries have common characteristics.

- They provide new varieties from national or international sources for testing by the national agricultural research service (NARS). The testing of new varieties usually includes on-station and multilocational trials around the country for several years to ensure that the new varieties are suitable for local conditions.

- They have a standard procedure for the initial increase, maintenance, and release of the new varieties. The procedure for releasing a new variety usually involves a seed variety release committee with representatives of the NARS, national seed service, the extension service, and the ministry of agriculture.

- They have a system for seed multiplication to produce sufficient quantities for farmers. Multiplication of small quantities of seed are first carried out by the NARS. Typically, the national seed service then receives small quantities of seed from the NARS and multiplies these early generations with contract growers. Later generations are multiplied by parastatal organizations or private contractors.

- A system of quality control ensures seed quality through the successive steps of multiplication until it is sold to farmers. The critical role of quality control is the responsibility of the national seed service. Standards for the physical and genetic quality have been worked out in developed countries and can be used as a model. These standards include procedures for field inspection to ensure genetic purity during production, and testing of samples after harvest to ensure the germination rate, genetic purity, and physical quality. There is often legislation that outlines the legal framework for seed production and quality control in the country.

- They distribute seed to farmers through the extension service, private dealers, and others.

- An extension system demonstrates and promotes the use of improved varieties and the associated agronomic practices. The national seed service can play an important role, not as "policeman" for quality control, but for extension and education of farmers and producers to help them produce high quality seed.

To summarize, national seed programs deal with successive seed generations that should result in quality seed for small farmers. These successive seed generations are described as follows: (The terminology used is the American system with the European terminology in parenthesis.)

First generation. Breeder seed (Pre-Basic) produced in small quantities by the NARS; its progeny will be foundation seed.

Second generation. Foundation seed (Basic Seed) produced in limited quantities by the national seed program; its progeny will be registered seed.

Third generation. Registered seed (Certified 1) produced in large quantities by the national seed program or seed enterprises; its progeny will be certified seed.

Fourth generation. Certified seed (Certified 2) produced in large quantities by contract seed growers for sale to farmers for general crop production.

The goals of national seed programs vary greatly (and sometimes are not realistic). Some examples follow:

- To have a strategic reserve of seed for the country in case of crop failure.

  This can be difficult to achieve since most seed cannot be stored for more than one or two years. Since yearly replacement of the strategic reserve is necessary, it is subject to the same risk of crop failure. Often the greatest demand for seed from the national system occurs when there has been a poor production year and supplies are limited.

- To produce sufficient seed to plant the entire national hectarage of that crop.

  This is an unrealistic goal because it does not account for farmer-saved seed and problems in distribution and marketing.

- To base seed production goals on crop replacement rate.

  For cross-pollinated species, this is every 1 to 2 years and for self-pollinated crops every 3 to 4 years. This strategy means that sufficient seed is necessary to plant only 10% to 20% of the national hectarage of each crop. Although this planning is more realistic, it still must take into account the factors involved in farmers buying seed, which will be discussed in the following section.

- To facilitate the development of a viable private seed industry in the country.

  This is an ideal goal for a national seed program because it ultimately reduces the government's role. This happened in the United States and many other developed countries and is being pursued in developing countries like Bolivia.

National seed programs require coordinated effort among many organizations to produce quality seed. Because the multiplication of successive seed generations is an integral part of the program, long-range planning is essential to produce the desired quantities. The idea is to create a stream in which quality seed of new varieties are introduced into the system each year in sufficient quantities to fulfill demand. Any weakness in the system causes the whole system to break down. The effectiveness of the national seed systems varies greatly between countries and even among species in a country. For example, when improved varieties have been developed on the national level, there has not been an effective distribution and marketing system to

get these varieties to the farmer. Centralized national public systems also often have problems with quality production, production targets, and predicting demand.

This would be desirable for national seed programs at an early stage of development to have the goal of producing and making available small quantities of high quality seed of the basic food and cash crops to farmers for multiplication, use, and sale at the village level. In this way there could be an integration of national seed programs and the farmer's traditional systems. The problems and cost of a centralized national seed program could be avoided. In fact, many countries are moving towards a national seed system that is responsible for seed quality control, while production and marketing is in the hands of the private sector.

For example, in Senegal export crops like peanuts have a highly developed system of seed production and distribution. Food crops like millet and sorghum have a limited seed production and distribution system.

Factors for farmers buying seed

In developing countries, the majority of seed (80% to 90%) used by farmers is not purchased but produced and saved by them. This situation continues despite the existence of national seed programs and millions of dollars in funding devoted to national seed programs. Several questions must be asked to understand this behavior.

- Is the national seed program producing certified seed of varieties that are new to the farmers, or are the varieties similar to ones the farmers already use?

  Farmers are most inclined to purchase a new variety that they have seen their neighbors grow. National seed programs are sometimes important for the production of disease-free seed or resistance to new races of endemic diseases.

- Is extension available to demonstrate the new variety and to help farmers properly utilize the new variety if it is purchased?

- Is certified seed available to farmers on a timely basis at a regional or local level?

  When certified seed is produced at a national level, it may remain in a few selected locations and not be generally available. This is one of the problems of centralized government-sponsored seed production as opposed to decentralized private seed enterprises.

- If certified seed is available, what are its physical and physiological/genetic qualities?

  Seed producers must produce consistently high quality seed for farmers to develop enough confidence to purchase it. Seed quality is difficult to judge. Although physical seed quality characteristics such as cleanliness, number damaged, and uniformity of size can be determined by farmers, other important quality characteristics such as germination rate, genetic purity, and varietal characteristics cannot be easily judged by casual

visual inspection. Often seed is sold without labels or sufficient information about its quality. Farmers are not inclined to buy poor quality seed at premium prices. Once the farmer is sold poor quality seed, he or she will lose confidence in the seed producer. Conversely, if the seed quality is good, the farmer will be encouraged to purchase more in the future.

If the quality control system breaks down or even if quality seed is kept until the next season, the quality will be uneven or deteriorated greatly.

- Does the farmer have the money or credit available at the time of purchase?

  Because planting time is normally a period of limited cash flow for farmers, they may lack funds to purchase seed. Additionally, seed costs more than food grain, and the farmer must feel confident that buying it is a wise financial investment.

- The demand to purchase seed is always greatest after a drought year when the farmers may not have any seed. In such cases, will seed be available from the national seed system?

  Drought years also have a negative effect on the seed production of the national seed program unless seed can be produced during the off season.

How Seed is Produced

The concepts used in seed production are basically the same for farmers producing their own seed and for contract growers producing seed for commercial seed enterprises. The application of the concepts vary. What follows is a brief description of the seed production system for farmer-saved seed and for seed specifically produced for supply to farmers, including small producers, large producers, and contract growers for commercial seed production.

The basic distinction between farmer seed-saving practices and production of seed for supply to farmers is that farmer-saved seed is selected from fields that are used for seed and food grain. For dedicated seed growers, the entire field is used exclusively for seed. A slightly different strategy is thus required for each system.

Farmer-saved seed. To improve the way farmers produce their own seed, one must understand the way farmers produce it and explore how this traditional system can be improved by modifying practices or using improved varieties. Farmer-saved seed is usually selected from food grain. The seed is then used by the farmer or traded or loaned to friends or family, but seldom sold.

Seed produced for supply to farmers. Selected farmers produce improved seed varieties as a cash crop based on a contract with a commercial seed enterprise or a national seed program. The farmer is required to observe certain production procedures and submit to field inspection by the seed enterprise or a branch of the

national seed program so that the quality can be verified. In return, the farmers receive a premium price for their crop. In this case the entire field is used for seed.

Seed production can been divided into four interrelated components.

- *Production*: planting and growing the crop
- *Harvesting*: timing and plant selection practices
- *Postharvest handling*: drying and conditioning
- *Storage*: protection and precautions

Each component has activities critical for the production of high quality seed. Conversely, when certain operations are neglected, quality can be adversely affected. The seed quality factors of most interest are ability to germinate and produce a vigorous seedling, and varietal purity. Under each component, the critical factors for farmers producing their own seed and for seed growers will be discussed with concrete examples from our experience.

Production

Many of the practices necessary for quality seed production are the same for food grain production, and many improved practices recommended apply to both. This is a dual benefit of seed programs for farmers.

Pre-planting operation for farmer-saved seed

Several issues should be considered near the time of planting that relate to seed quality. Farmers must start by knowing the quality of their seed. Though there are laboratory tests that can be conducted to determine seed quality, some tests can be done on the farm. A simple germination test is an excellent indicator of seed quality (see "Seed Germination Test for Farmers and Extension Agents" in appendix 2). This test can be performed by farmers before planting and will allow them to adjust the planting rate based on the actual seed germination rate. If farmers are purchasing seed, a germination test can indicate the quality of the seed before it is purchased. Seed with a low rate of germination needs to be planted at a higher density than high germination seed in order to achieve the same plant population. Farmers cannot make this decision without a germination test. The importance of germination testing cannot be over emphasized, particularly with purchased seed of species susceptible to high deterioration rates during storage such as legumes.

Farmers can improve seed quality through conditioning by removing small, immature, or damaged seed, trash, or other foreign material in several different ways. Locally available screens, used in screening grain for cooking, can be used in separating the small and immature seed of species such as millet from larger, more vigorous seed. Different screen sizes will allow the small seed of different species to

pass through while retaining the larger seed. Water separation based on density is possible with maize and rice. The immature seed will float, and the good dense seed will sink. With maize, the tip of the ear is often removed since those seeds are smaller and the kernels from the middle section of the ear are used for seed. With large seed, like peanuts and cowpeas, hand selection is possible to remove those that are shriveled, small, and damaged. Alternatively, if the germination rate is below 50% after selection, the farmer may want to consider obtaining seed of higher germination for planting.

Pre-planting operation for seed produced to supply farmers

Seed growers must be progressive, competent farmers with the necessary land, labor, and equipment to produce seed. Observing farmers and their fields over several seasons is very helpful in selecting potentially good seed growers since quality seed production requires the correct performance of both normal production practices and additional quality control measures.

Field selection for seed production should consider several factors. If possible, the same species should not have been grown on the field the year before because seed from the previous season could sprout and affect the purity of the seed produced. Soil fertility should be adequate for good seed yields. The field should be located so that it can be easily supervised and used for demonstration purposes. If a cross-pollinated seed crop is being grown, attention must be given to having an adequate isolation distance from other fields of the same species. For example, the isolation distance for certified seed production of millet and corn is 200 meters; this can be difficult to achieve when fields are small and these crops are widely grown.

The farmer must establish an agreement for the sale of the seed to the contracting organization. Often the organization provides the seed, deducting an equivalent amount from the harvest. A premium price is usually paid to the farmer, 10% to 25% over market price, to compensate for the extra care that must be taken in seed production.

The seed used by the producers is of known origin, high quality, and genetically pure since it is registered seed from the national program (assuming that the national seed program is producing quality seed). The seed needs to be delivered to the farmers well in advance to avoid delays in planting.

Planting for farmer-saved seed and seed produced to supply farmers

There are many seed-related issues around the time of planting, for example, the condition of the seed bed, how the seed is planted, pest or disease attack after the seed is in the ground, and environmental factors such as drought or crusting of the soil surface. There also are different planting methods: broadcast, transplanted, dibble stick, and mechanical seeders drawn by animals or tractors. All determine the establishment of a good crop.

For example, the age and condition of mechanical seeders is a source of concern. Damage to the seed by old seeders is more likely with legumes, such as peanuts, because of the fragility of seed once it is removed from the shell. The peanut is a dicot with a thin seed coat, which means that the seed can be easily split by physical pressure along the embryonic axis. Damaged seed may not germinate or may produce weak plants that later die. The speed of the seeder also is a factor in potential damage to the seed and the quality of the planting. If the seeder is drawn too fast, seed can be damaged in the planter box. Similarly, seeders need to be pulled at constant speed with stopping only at the end of the row so that there will be a consistent and smooth flow.

If the furrow is not opened well or not completely closed the soil around the seed can dry out and the seed will have insufficient moisture to germinate.

Chemical seed treatment can be important for improved stand establishment especially if there is stress during germination and emergence (as is often the case in the Sahel). In commercial seed production, the treatment is applied during the seed conditioning. With farmer-saved seed, the treatment is mixed with the seed just before planting. The seed treatment (fungicide and insecticide) is like an insurance; it is most useful when there is stress and not so useful when conditions are good during germination. Seed treatment can help protect the seed from insect and bird attacks.

Whatever the planting method, a key factor at planting is to achieve a seeding density that will provide an optimum number of plants per unit area. Optimum plant density varies depending on the particular species. Key factors in plant density are the germination rate, the planting rate, and environmental and other conditions at planting time. Appropriate plant densities will be a factor in high yield.

Soil fertility for farmer-saved seed and contract seed growers

Soil fertility is as important for high yields in seed production as it is for crop production. With seed production, however, it is not only a question of adequate fertility to produce high yields but also adequate fertility to help the seed achieve its maximum size and high quality. Medium- and large-size seed are more vigorous and

have more food reserves than smaller seeds, which can be important during emergence, particularly in stressful conditions.

Maintaining or improving soil fertility is a difficult and critical issue for resource-poor farmers. Mineral fertilizers are expensive, and farmers will often not use them if there is a high risk of crop failure. Additionally, mineral fertilizers are sometimes applied at the wrong time or with the wrong method so that little benefit is derived. Our approach has been to concentrate on correct agronomic practices before promoting mineral fertilizer so that the farmer can reap the full benefit of the fertilizer when it is used.

For example, in Senegal we have found that using manure or a small quantity of mineral fertilizer on the nursery bed for transplanted rice is crucial for getting healthy seedlings that have a high survival rate and overcome transplant shock sooner.

There are various ways to contribute to soil fertility without using mineral fertilizers. Crop rotation and incorporation of organic matter such as manure, crop residues, and composting are all strategies that can be used to improve soil fertility. Addition of organic matter also helps the soil structure and moisture-holding capacity. Even if an entire field cannot receive organic or mineral fertilizer, it is suggested that the section of the field that will be used for seed should be fertilized.

Weed control for farmer-saved seed and seed produced to supply farmers

Weed control is important because weeds compete with the crop for light, water, and nutrients. Weeds are a major limiting factor in seed and crop production. Keys to weed control are elimination from the seed bed before planting and from the field early in the crop's growth cycle when competition is most damaging. Ultimately, the farmers may find that a small area with improved management such as weeding will produce more than a larger area that has been managed less intensively. Weed control is especially important when seed is produced for supply to other farmers because it keeps weed seed out of the crop seed.

For example, with direct seeded rice in rows rather than broadcast planted rice the farmer is able to start weeding earlier between the rows. With broadcast rice the farmers have to wait until the weeds can be distinguished from the rice. At that point it is often too late to keep the weeds from causing a drastic yield reduction.

Pest and disease control for farmer-saved seed and seed produced to supply farmers

Insect populations that are in a natural balance and do not cause significant levels of damage are always present in crops. If the pest populations reach a level that causes substantial damage, pest control may become economically advantageous. Sucking insects that attack the seed when it is maturing create a double problem. They eat the seed so it will not germinate or will be weak, or they allow diseases to enter the seed. Either way, insect attack late in the season is detrimental to seed production and quality.

Disease control is a critical factor in seed production that requires vigilance on the part of the farmer and extensionist. Many plant diseases can cause yield loss by attacking and killing the plant at early stages of growth. Others do not kill the plant but colonize it so that the disease is in the newly produced seed. When diseases are carried by the seed, they can attack the plant next season and can spread to other plants by insects, water, or wind causng even greater losses than the previous year. Early detection and removal of diseased plants is a very important factor in producing quality seed.

Crop rotation can be an important element in the strategy to control plant pests and diseases. Alternating crops in a field can help break the life cycle of the pest or disease since pests and diseases are often crop-specific.

Quality control for farmer-saved seed

The methods of quality control for farmer-saved seed depends on whether the crop is self- or cross-pollinated. With cross-pollinated species, plants to be used for seed are selected at harvest.

With self-pollinated crops such as rice, it is advisable to harvest or remove the offtypes (plants of a different variety of the same species) before the seed is harvested so that the seed will not become mixed. Another quality control practice is the removal of diseased plants so that the disease will not spread and contaminate the seed.

Quality control for seed produced to supply farmers

Roguing is the removal of undesired plants from a seed field that includes offtypes, plants of different species that have seed similar to the variety being grown, and weed that may be harvested with the seed. If the planting stock is not pure, roguing may need to be performed several times during the production phase to insure that all the undesired plants are removed. With cross-pollinated crops, the roguing must be done before flowering to prevent pollination with undesired species. With the self-pollinated crops, the roguing must be done before harvest.

Field inspection is performed by a qualified inspector for the national seed service to determine if the field meets the standards for certified seed production, that is, isolation distances, freedom from disease, and within the tolerances for offtypes and noxious weeds. If the field does not meet the standards, the inspector will advise the farmer on what needs to be done. If by the last inspection the field does not meet the standards, the crop will be rejected for use as certified seed.

Harvesting

Selection at harvest of farmer-saved seed. Often farmers select the best plants from a food grain field for seed. This form of selection, called mass selection, has been

practiced by farmers for thousands of years and should still be encouraged. It is important to know farmers' practices related to plant selection criteria and timing of seed harvesting since this has a major impact on seed quality and characteristics of the next generation.

With cross-pollinated species, plant selection at harvest is essential because these species are so genetically heterogeneous. The need for plant selection at harvest is apparent when a field of a cross-pollinated species, such as millet or maize, is examined just before harvest. There will be differences, for example, in height, color, presence or absence of disease, size of head, and number of tillers. The plant with the desired characteristics should be harvested for seed. As this annual plant selection continues over the years, the general population will gradually exhibit more of the desired characteristics, though still remaining genetically heterogeneous. In general, plants for seed are selected based on characteristics such as size, maturity, color, yield, and freedom from disease. More specific characteristics for plant selection depend on the particular species. When selecting plants for the desired characteristics, it is advisable to select from the central portion of the field. In this way there is a higher probability that the plant was fertilized by another plant from the same field. The outside rows filter out pollen from nearby fields.

For example, in Senegal farmers have been encouraged to have a 20 m x 20 m seed plot in the middle of their millet field where they thin the millet to one plant per hill and select seed plant based on desired characteristics.

With self-pollinated species such as rice or peanuts, there will be less variation among plants in the field compared to cross-pollinated species unless a mixture of varieties was planted. Plants should be selected from the portion of the field that appears the healthiest, that is, those that are disease-free, dark green in color, and uniform in height and maturity. Avoid plant selection for seed from the edge of the field where there is a higher probability of cross-pollination or mixture of varieties.

Selection at harvest of seed produced to supply farmers

Plant selection at harvest is not performed in fields of seed growers because the seed planted is of a known origin and the field has been isolated, rogued, and inspected so that the entire field can be used as seed.

Timing of harvest for farmer-saved seed and seed produced to supply farmers

The timing of harvesting has a critical effect on seed quality. When seed is harvested too early, it will be immature and incapable of producing plants that grow vigorously. Seed harvested too late is vulnerable to many factors that reduce quality. The sun weathers the seed by over drying and exposure to high temperatures. Additionally, the seed is exposed to attack by pests and disease. Wetting and drying from rain or heavy dew can induce disease problems. The seed should be harvested when it is mature, and not at a later date when seed quality has started to decline. If the growth

cycle of the variety and the planting date is known, the approximate harvest date easily can be determined. Ultimately, the moisture content of the seed on the plant should be examined to determine if it is dry enough to harvest. Traditional moisture determination techniques such as cutting, biting, or crushing the seed can provide an accurate gauge of the moisture for the experienced farmer. Each species has specific plant and seed indicators that alert the farmer to begin the harvest.

The harvest period is a crucial time for seed quality, and reenforceing the farmer's awareness is important. Farmer-saved seed should be given priority at harvest over the food grain. The seed will be a relatively small part of the yield of the field; therefore it can receive special treatment to insure that it is protected from the causes of deterioration just described.

Postharvest handling of farmer-saved seed and seed produced to supply farmers

After harvesting, several practices are necessary to insure seed quality. Farmer-saved seed should have priority treatment in these operations over food grain.

- Avoid mixing different varieties (or what has been selected as seed with the remainder of the harvest) in order to maintain varietal purity.

- Dry seeds rapidly with adequate air circulation to prevent mold formation and discoloration. Mold is detrimental to quality because it can attack the seed when it is planted. Quality often is affected during drying when the seed is high in moisture content and air circulation is inadequate. The seed has to be frequently turned so that it can dry evenly and quickly, but turning of the heaps is labor intensive during a season when there is a labor shortage. Overexposure to the sun can cause heat damage.

Seed conditioning for farmer-saved seed

Conditioning is the process by which undesired material is removed from the harvested seed. The undesired material is broken, immature, and small seed, weed seed, miscellaneous plant parts, other crop seed, soil, stones, and dead insects. Seed conditioning is a key step to improving overall quality.

Farmer practices for conditioning vary with the crop and how it is stored. Many crops traditionally are stored unthreshed and not conditioned in any way before storage, for example, peanuts in the shell, bunches of panicles of rice, bundles of millet heads, and ears of corn. In these cases, conditioning of the seed takes place just prior to planting.

When the seed is conditioned, it is first threshed to remove it from the panicle, head, or ear. It then must be winnowed to remove the hulls and small seed, usually with the help of the wind. Hand selection (with large seed) or screens (with small seed) can be used at this time to remove immature seed and inert material.

Seed conditioning for seed produced to supply farmers

Depending on the crop and the terms of the contract, the responsibilities for threshing and conditioning the seed can vary. The commercial enterprise normally has seed-cleaning equipment for conditioning, treating, and bagging. The principal equipment for seed conditioning is the air screen cleaner that uses a combination of air and series of changeable screens to effectively remove most undesirable material and small-size seed. Other specialized equipment complement the air screen cleaner. Chemical seed treatment is applied before the seed is bagged to deter seed-borne diseases. It is often prior to conditioning and storage that the seed enterprise takes possession of the seed.

Seed quality is verified after the harvest and conditioning. Either the farmer or the inspector collects the seed for testing. The seed laboratory tests for seed moisture content, variety purity, level of inert matter, noxious weeds, and germination. The results of these tests can be a basis for acceptance or rejection of the seed for use as certified seed.

Storage

The condition of seed can never be improved during storage; on the contrary, it deteriorates. Deterioration means loss of germination and vigor, characteristics essential for seed but not for food grains. Therefore, seed should receive priority in storage over food grain in order to minimize deterioration.

Factors affecting seed deterioration

The rate of deterioration varies between species and among varieties of the same species. For example, legumes high in oil, such as peanuts and soybeans, deteriorate more rapidly in storage than cowpeas. Corn and millet deteriorate at a slower rate than cowpeas; rice and wheat have very slow rates of deterioration in storage. The cereals generally have a slow rate of deterioration while legumes have a rapid rate of deterioration when temperature, humidity, and moisture content of the seed are equal.

Seed moisture content is the most critical factor affecting the rate of deterioration; the desired level is below 10%. The lower the seed moisture, the slower the rate of seed respiration and thus of deterioration. Therefore, proper drying before storage is critical for minimizing deterioration during storage.

Seed moisture content is reduced initially to the desired level by drying, usually in the sun. Seed is hygroscopic, meaning it absorbs moisture from the air. After the initial drying and during storage, the seed will absorb moisture from the air until it comes into equilibrium with the air's relative humidity. Hence, the term *seed equilibrium moisture content*. If the relative humidity is high during storage, then the seed moisture content will be high. For example, in climates such as that of the Sahel where the relative humidity is low during the storage period, the seed will remain at a

low moisture content. In tropical climates where the relative humidity is high during the storage period, problems can develop. Higher seed moisture content also promotes insect infestation and growth of microorganisms, requiring the exercise of special precautions. Table 1 illustrates the relationship between relative humidity and the seed equilibrium moisture content.

Table 1. Seed Equilibrium Moisture Content at Various Levels of Relative Humidity (RH)

Kind of seed	RH 15%	RH 45%	RH 60%	RH 75%	RH 90%
Maize	6.5%	10.5%	13.0%	14.8%	19.0%
Peanuts	2.6%	5.6%	7.2%	9.8%	13.0%
Rice	6.8%	10.7%	12.6%	14.4%	18.1%
Sorghum	6.4%	10.5%	12.0%	15.2%	18.8%
Soybean	4.3%	7.4%	12.0%	13.1%	18.8%
Sunflower		6.5%	8.0%	10.0%	15.0%

Temperature is an important factor in storage since higher temperatures mean higher rates of seed respiration and deterioration. It is not as significant as moisture content, however, because sufficiently dry seed can withstand relatively high temperatures without significant deterioration.

Protection of seed from insects, rodents, and birds is essential to prevent quantity and quality losses during storage. This protection includes cleanliness in the storage area and seed treatment with chemical or other means.

Hermetically sealed storage of well-dried seed in containers such as metal drums, cans, or plastic bags does not allow the entry of air. After several months, the respiration of the seed and any insects will cause all the oxygen to be used and produce a higher level of carbon dioxide. Thus, any insects that emerge after 2 months will die from lack of oxygen. A problem with this concept is achieving and maintaining a hermetically sealed storage environment. Also, it is essential that the seed is very dry or mold can develop as the seed reaches the equilibrium moisture content with the limited air in the container.

Recommended storage practices for farmer-saved seed

Successful storage begins with how the seed has been handled before storage. The key points in proper handling before storage are:

- Minimize insect infestation in the field and optimize seed quality by timely harvesting and removal from the field.

- Eliminate insect-infested seed before storage to remove sources of future infestation.

- Dry the seed sufficiently to prevent microorganism growth, insect growth, and reduce the respiration rate.

- Treat the seed with a suitable traditional or chemical insecticide to control insect infestation.

After these initial steps, the storage method and environment can have a major effect on the rate of seed deterioration.

Insects. In most countries, insects are a major threat to seed storage. There are two classes of storage insects: primary feeders that can attack the whole seed, and secondary feeders that can attack only damaged seed. Most storage insects are small and require close observation for detection. There are four essential factors in control of storage insects.

- Prompt removal is crucial to minimize initial infestation since several insects attack the seed while it is drying in the field.

- Proper drying of seed to a low moisture content has a negative effect on many insects.

- Sanitation of storage containers, such as bags or barrels, and of the storage structure is important.

- Treating seed with nonchemical or chemical means depends on the local situation, availability, and effectiveness. Traditional nonchemical means can be effective under the right circumstances.

Rodents. A storage area that is well organized and clean is the best deterrent to rodents. Rodent-proof storage denies rodents a place to live and hide and denies them access to the seed.

Microorganisms. Numerous microorganisms, particularly fungi, can attack if the seed moisture content is high due to poor drying or high relative humidity. Sufficiently dry seed is less affected by fungi.

Seed storage inspection. Inspection on a regular basis is essential for successful seed storage. These guidelines for storage inspection were developed for use with small village seed stores. Inspection at least once a month is important and should include the following points:

- Inspect the outside of the building for drainage and erosion problems, signs of rodent paths and holes, and the presence of trash or weeds that might foster rodent and insect activity.

- Inspect the inside of the building for moisture such as leaks in the roof, dampness on the floor, or water stains on the walls. Note signs of rodent activity: places of entry, feces, damage, and places to hide. Observe insect activity in the floor, walls, bags, or air, and cracks where insects can hide. Note any musty odors that suggest a mold problem.

- Keep seed bags off the floor because moisture migration from the floor into the bag can affect seed moisture content, seed deterioration rates, and seed germination. Bags should be placed on pallets or tree branches in a lattice on the floor.

- Inspect the seed inside the bags or storage container for insects and moisture.

- If you detect problems, take immediate action to avoid loss.

Storage structures for farmer-saved seed

A wide variety of storage structures are used in the village. The traditional storage structures that are of a crib design or clay-walled are used in many areas. Storage rooms and small buildings are also common. Storage in 200-liter drums is popular with peanut seeds. Remember, the quantity of seed that needs to be stored is small relative to the farmer's entire production. Seed is stored until the next season and not periodically used like food grain. This relatively long storage period requires extra attention to pest control. Therefore, storage procedures can be used for seed that may not be possible for food grain; for example, storing peanut seed in 200-liter metal drums or mixing cowpeas with ash to protect them from insect attack. What is important is that storage structures are evaluated using criteria that provide insight into their relative performance and bearing in mind that a relatively small quantity of seed needs to be stored. Some criteria are:

Air flow. Air flow is important when the seed is not sufficiently dry when put into storage. This is more often the case with seed such as heads of millet, maize on the cob, or bundles of rice panicles that is stored unthreshed. Many of the traditional storage methods are cribs that allow air circulation. In tropical areas, seed and food grain are stored above the cooking fire. This creates hot air and smoke flow through the seed, keeps the seed sufficiently dry, and deters insects. If the seed moisture is below 10%, air flow is less important and the seed may be stored in a sealed environment.

Protection from pests. Protection from insects and rodents is difficult to achieve under traditional conditions such as cribs. The specific strategy needed depends on what pests are a problem. Ease of cleaning, sanitation, and organization are important.

Protection from moisture. In tropical areas, roofs leaking onto stored seed grain can be disastrous. In dry climates, leaking roofs are less of a problem since seed storage

takes place during the dry season when rain is unlikely. Seed bags should not be placed directly on dirt or cement floors. Pallets or plastic can prevent moisture migration from the ground under the storage structure to the seed.

Cost (labor and materials) and capacity. The materials needed to build the structure or container should be locally available. If not, the costs should be within the reach of the farmer. The labor investment must be considered, and the capacity sufficient to store the seed necessary for next season's planting.

Durability and maintenance. The structure or container should be durable enough to last many years. A high level of maintenance to remain operational is undesirable.

We have concentrated on providing basic technical information on seed, seed programs, and seed production, with examples from our experiences in West Africa. Our aim is to expose readers without a technical background to the essential aspects of seed. If basic concepts discussed here are incorporated in traditional seed production systems, the farmer should have quality seed. This quality seed will then have the potential to produce a good crop, and the seed system starts again. Part 2 examines how to apply these concepts.

Part Two

Guide for Developing Seed Activities

The seed industry (formal and informal) in a developing country involves diverse participants and organizations: the farmer's traditional seed system by which he or she selects, produces, and saves seed; the national agricultural research system (NARS) and international agricultural research centers (IARCs), which develop and test improved varieties; and the national seed programs for multiplication and distribution of improved varieties. Farmer-produced seed is often viewed as low in quality and undesirable. Because of this, the traditional seed production systems in which farmers produce and save their own seed often are overlooked when strategies are developed to improve the quantity and quality of seed available to farmers. It must be remembered, however, that the farmer is the major source of seed in Africa.

A major area of agricultural research of NARS and IARCs has been the development of improved varieties. These improved varieties often do not benefit resource-poor farmers, however, who lack access to fertilizers, insecticides, and herbicides. This guide proposes an approach that encourages the national seed program to work *with* the traditional seed systems. Together the two systems can produce high-quality seed that is both accessible and acceptable to the farmers.

Appropriate and effective modifications can be made in farmers' seed production systems using a process-learning approach, which starts with gaining knowledge and understanding of the existing system, including the farmer, the national seed system, and related organizations. In the process-learning approach, information is shared and mutual understanding develops between farmers and the organizations involved. A reliance on consultation with the beneficiaries of the program is a cornerstone of the process-learning approach.

Phase A. Information Gathering

The first phase in this process is information gathering as an ongoing activity. It is important to develop an understanding of the production practices and the seed-related problems of the farmers. Seed-related information should be gathered at both the farmer and national levels. The country seed survey that follows is part of this activity. New problems may be identified, and adjustments in the program may be necessary based on farmer feedback.

Step 1. Review existing information

An essential element of determining the feasibility of developing a seed activity depends on having in-country information on various topics. Three important topics are

- The status of the national seed system
- Organizations engaged in seed activities
- Your organization's current activities in agriculture, not specifically in seed

The questions are designed to stimulate thinking about the elements of developing a seed activity and to be a discussion guide even if you are not able to answer them fully. Obviously, the more information you have, the better you can determine the feasibility of a seed activity for your program. As with any information-gathering exercise, care must be taken in the way questions are asked and in avoiding the overly optimistic or pessimistic responses that may be given. When possible, work through people you know and verify the responses to important questions from several sources.

Status of the national seed system

In all countries, some system (or parts of a system) exists for the development, testing, and distribution of seed of major crops. Often the government controls at least part of this system. The basic components are research, production, quality control, distribution, and marketing. The following questions can serve as a guide to find out what exists.

1. What is the national research system doing to develop and test seed of improved varieties of various crops?

   In Africa, improved varieties that have been developed at international research centers, regional centers, or in other countries are often tested in variety trials and the best ones selected for future distribution to farmers. In other circumstances, crop breeding as well as testing of new varieties is carried out in the country. Discuss this topic with contacts in the national agricultural research system.

   - Which crops are receiving the most attention?
   - Are new crop varieties tested only under high-input conditions, or are variety trials conducted on-farm under traditional practices?

   This is an important issue because some improved varieties perform better than the traditional varieties only under high levels of management and fertilizers. (This has been the case with millet in Senegal.) Other improved varieties can perform better than the traditional varieties under low-input conditions. (This is the case with rice in Senegal.)

- Do researchers believe that farmers are adopting the new varieties? If so, why? If not, why not?

2. Once improved varieties are tested, how are they selected for release to farmers?

A variety release committee often makes the decision on new varieties, but in other cases, there may be no formal system for releasing varieties for general use..

- Is there a variety release committee, or something like it?
- Is this committee functioning?
- How often are new varieties released?
- What is the adoption rate – what percentage of the newly released varieties are used by farmers?

3. Once an improved variety is selected for release, how is the seed multiplied?

Only a small quantity of seed is produced during the research phase. Find out who is responsible for the multiplication of the seed in sufficient quantities for distribution to farmers. Often this activity is carried out on government seed farms or with private farmers who produce the seed on a contract basis with the government.

4. How is the genetic purity of the seed maintained at the research station and during the multiplication phase?

The production of high quality seed of uniform size, free of inert material and weed seed, of high germination, and most importantly, not a mixture of different varieties is essential for a viable seed system. It is important, therefore, to obtain a sample of seed produced by the national seed system so that the quality of the seed can be tested.

- Talk to various sources about the general quality of seed produced by the national seed system in your country.

5. How is the seed distributed and marketed?

6. Once the seed is produced, how does it get to the farmer?

It is often a problem to get the seed to rural areas because of centralized production and weak infrastructure. In some cases, farmers are not interested in purchasing from the national seed system because the quality is so low or because it offers a variety that they already have.

Organizations engaged in seed activities

NGOs, government agencies, or donor agencies may support projects involved in seed. These organizations will be important sources of information for many of the questions in the survey.

1. What are they doing and where are they working?

2. What is their source of technical assistance?

3. With what crops are they working?

4. What is their strategy? Are they working with traditional varieties or improved varieties?

5. What have been their successes and problems?

Your organization's current activities in agriculture

The same type of analysis must be made of the experience, objectives, and opportunities of your organization.

1. In what areas of the country do you have agricultural activities?

2. What is the climate and rainfall in your areas of activity?

   Estimate temperature, rainfall, and humidity during the period between harvest and planting since this information is important in examining the storage of seed in your country.

3. What are the major crops in the areas of your organization's activities?

4. What is the focus and strategy of your activities at this time?

   Include numbers of field staff, history of activities, success and problem issues, and training methods.

5. Are your activities in anyway involved with seed or food grain storage?

Step 2. Farmer interviews and observations

There are many ways to gain an understanding of farmers' seed practices in your area. The problem in many "information-gathering activities" is obtaining accurate information. Rapid Rural Appraisal (RRA) is a credible methodology for gaining an understanding of many topics at the village level and should be considered for use with seed practices. Understanding RRA's key concepts is important (RRA

publications for review are listed in the bibliography). What follows are simple guidelines for gathering information.

- Obviously, farmers themselves are the most important source of information, but how can they be successfully approached to get useful information on seed practices? Initially, it may be more culturally appropriate to conduct group interviews. If possible, groups should be divided by sex and age since mixed groups often are not conducive for general participation. After gaining the confidence of the farmers and conducting group interviews, individual interviews should be conducted to verify information obtained from the groups. Additionally, experienced field staff may start the interview process by conducting interviews with farmers they know.

- Secondary sources of information such as your field staff, researchers, and extension agents can be important. Seek out documents and studies that may have been conducted on the agriculture of the area.

- Particular attention needs to be given to women because of their primary role in production, harvesting, and storage. In some farming systems, food crops are cultivated by women only. It is important to identify their roles in the seed system.

- Triangulation, i.e., to verify information in three ways, is a key concept from RRA. This can be accomplished by having a team that represents different backgrounds and perspectives; by using different methods to explore topics; and by exploring the questions and topics with different informants.

- Topics should be explored in such a way that there is a respect for indigenous knowledge, i.e., the farmers' perspective and understanding of practices, problems, and constraints. This is particularly true with seed since the techniques used are often very traditional.

- If time permits, interviews should be followed by observation to verify the practices. This implies going with farmers to their fields and assisting them with the work, even if just as a gesture. In this way, greater trust will be developed with the farmers and a better understanding of the farming system and seed system will be obtained.

Use the following questions as a guide in conducting an informal survey for at least three of the major crops of the area. Alternatively, you could look at crops that, from your previous information gathering, seem to have the greatest potential for a seed activity. The information you gather should be representative for the farmers in the area and not be taken from only the best and worst farmers.

Seed Source

1. What is the source of the planted seed? Was it saved, traded, or purchased?

   - If the seed was traded or purchased, where, from whom, at what cost, and how far from the farm was it obtained?
   - Is the farmer using a traditional or improved variety?
   - Has the farmer tried improved varieties? What were the farmer's impressions?
   - Where does the farmer get backup seed in case of poor germination or early crop loss?

Planting

2. Before planting, is the seed selected, cleaned, or sorted in any way?

   With some crops, such as peanuts, damaged or shriveled seeds are removed before planting. If possible, obtain a sample of the farmer's seed of each crop at planting time. In this way, the quality of the seed can be examined through visual examination and germination testing.

3. Does the farmer use a germination test to verify seed quality, particularly on purchased seed?

4. Is the seed treated with any chemical product at the time of planting? If so, what?

   The use of seed treatment that contains fungicide or insecticide is practiced in some areas.

5. Are seeds planted by hand or with a planter?

   - What are the approximate planting rates or the distances between plants or hills?

Production

6. Are separate fields planted for the production of seed only? This is not a common practice; if it exists, it is noteworthy.

7. Are crops planted as mono-crops or mixed crops? If mixed, in what associations?

8. Are organic fertilizer, crop residues, or mineral fertilizers used to maintain soil fertility?

9. When and how often is weeding performed?

10. Are there particular pest or disease problems?

Harvesting

11. What are weather conditions at harvest?

    Rainy weather at harvest can be very detrimental to seed quality.

12. During harvesting, are individual plants selected in the field to keep for seed?

    - If so, when and what do farmers look for?

13. Is seed harvested at the same time as the rest of the crop?

14. After harvest, is the seed treated differently from the rest of the crop (for example, dried separately, or removed early from the field)?

15. How and where is the seed dried?

Storage

16. When does the seed (or food grain) go into storage?

    - How long is it between harvest and storage?
    - What is the length of the storage period?

17. Is the seed (or food grain) threshed before storage?

18. Is it stored in a crib, silo, room, small building, or hung in a tree?

    - What is the condition of the building or structure used for storage?

19. Is the seed put in bags, bundles, piles, or barrels?

20. Is there evidence of or damage from rodents or insects in the stored seed and grain?

21. Is the seed treated with chemical or traditional treatments at the time of storage? If so, with what?

22. Is the seed inspected during storage to make sure it stays in good condition? How often?

23. Is the seed separated from food grain and stored differently?

Problems

24. What are the problems or needs of the farmers concerning seed that secondary sources have identified?

25. What problems have you observed?

26. What problems have the farmers expressed?

    What would farmers change about the varieties they use if they could –e.g., earlier maturing, taller, shorter, greater disease resistance, or higher yield.

Step 3. Conclusions of information gathering

Initial information gathering will provide basic ideas on the farmer seed production system. Compare farmer seed practices to the critical steps in seed production outlined in the seed basics section of this guide to identify weaknesses in the way farmers are producing seed.

1. From exploring the national agriculture research system and the national seed program, can one identify improved varieties and potential resource people for a seed activity?

   In order to develop an activity that is technically sound, you will need a source of technical assistance and training. If improved varieties are involved, you also will need at least an initial supply of seed.

2. What lessons can one draw for the activities from other organizations in seed? Do other seed activities have relevance to what you want to develop?

3. Is there an opportunity for linking a seed activity to your current agriculture program? Does your staff and field staff have time to undertake a new activity?

4. Were you able to identify seed problems at the farmer level that warrant further investigation as a starting point for a seed activity?

5. Are there changes that can be made that will fit with what farmers are doing now? Can some simple demonstrations be developed with the farmer to compare the present method to your potential solutions to the seed problems?

Phase B. Development and Implementation of Initial Demonstrations

Step 1. Objectives

Information gathering should provide insight into the seed-related problems of the farmers and generate potential strategies to ameliorate the problems. In this section (Phase B), potential solutions will be developed into simple demonstrations to be carried out with farmers.

The purpose of demonstrations is to compare your proposed solution to farmer seed problems with current practices in the farmers' fields. Performing demonstrations with farmers is still one of the most effective agricultural extension tools. Farmers need to see what you are proposing in order to judge if is worthwhile for them to try. A demonstration also provides an opportunity to receive direct feedback from the farmers on the proposed change. Such feedback is essential in participatory activities, and it will assist in planning future activities.

Are the changes that have been chosen appropriate and sustainable for use by resource-poor farmers? Is there a minimum of risk for farmers who want to try the changes? The most successful experience of the OFSP with its collaborators has been to introduce incremental changes through the demonstrations. As each change is understood and practiced, new changes can be developed based on observation and farmer feedback for later introduction and future demonstration. Farmers use practices that they understand and that benefit them. When farmers are partners in the change process, they determine the direction and pace of change. For example, initial attention in some of our activities has focused on an improved variety and a few modified practices that will help the improved variety produce more than the traditional variety.

A *step-by-step, long-term approach* is critical for sustainable improvements in yield and farmer productivity. By contrast, dramatic and immediate increases in yields and farmer productivity can be obtained by using high-input farming, i.e., improved varieties, fertilizer, herbicides, etc., but these kinds of changes are not appropriate, sustainable, or economically viable for resource-poor farmers.

Thoughts on farmer participatory activities

A high level of farmer participation is essential to determine the viability and appropriateness of the seed intervention in the process approach to seed activities. Farmer participatory activities require that the outsider enters the world of the farmers and works at their pace. This can be frustrating for extension workers and researchers because the farmer determines the pace and scope of the activity, not the outsider. What does this approach mean for an outsider?

- It is necessary to develop a personal relationship with farmers. In Africa, each person needs to be known and respected on a personal basis before meaningful discussions of other topics can be undertaken.

- Listening to farmers on their terms in their villages, fields, and homes is the basis of any activity with farmers. Important information and feedback often come in subtle ways. Cultural norms must be observed in this process in which there may be numerous meetings that have little technical merit but great cultural meaning. Detailed knowledge of the culture and local language is essential for effective communication.

- Clarity is essential. Explain what the activity is and is not, and be consistent. Even with clear explanations, there will be misunderstandings that must be solved over time. Don't make any promises that you cannot keep. Because farmers have been the victims of many broken promises by projects, extension workers, and the government, they are skeptical and wary of outsiders. Explain that you want to work with the farmer to test some ideas that may or may not work.

- Solid technical knowledge and experience will help build credibility with farmers. Farmers have intimate knowledge of what they do. If you do not appreciate their indigenous technical knowledge (ITK) and desire to discuss it with them, then a real dialogue and exchange of information is impossible.

- Remember that a demonstration with farmers participating is not a highly controlled research trial. Expect large variations in practices, and expect farmers to modify your recommendations to suit their needs. What is important is to record what farmers do and the results so that you have feedback and information for making decisions for your seed activities.

Step 2. Demonstration guidelines

Kinds of seed demonstrations

The technical content of the initial demonstration will depend on the problems you have identified and their potential solutions. What follows are suggestions for the possible direction of the demonstrations based on our field experiences.

Seed technology changes with traditional varieties. There is often much that can be done to improve the seed of existing varieties. Germination testing to verify seed quality is important. Improving seed selection and plant selection at harvest with cross-pollinated varieties can help improve plant stands and contribute to yield increases. The problem is that often other factors limit yield besides the seed, such as fertility, drought, and pests.

Improved varieties. Introducing improved varieties that will be grown with traditional practices often is not sufficient to improve yields. The improved variety

must be grown with modified production practices. For example, we have found that with modified nursery bed preparation and transplanting of young seedlings, an improved rice variety contributed 50% to 100% yield increases. When the same rice variety was grown without the modified production practices, marginal yield increases were obtained. In these cases, fertility and pests were not the limiting factors. In addition, when improved varieties are introduced, appropriate seed technology must be used to maintain seed quality of the variety.

Production practices. Modified production practices of early weeding and fertility management are often the key to seed quality improvement and yield increases. When working with resource-poor farmers, attention must be given to introducing modified practices that are *within the reach* of the farmers. Mineral fertilizer can increase yields, but organic fertilizer may be a more appropriate strategy. Similarly, timely field operations such as weeding are often more important first steps in yield increases than the use of fertilizer. One input that isn't costly but is very useful is seed treatment at planting. If this input is available, its use should be encouraged for protection of the germinating seed.

Storage technology. Seed and food grain storage losses of cereals are often in the range of 5% to 15%. Reducing this loss is possible but may not be considered significant by the farmer. With legumes, losses can be much higher; therefore storage is a major problem for seed availability at planting. We have seen losses with peanuts and cowpeas of nearly 100%. When this level of loss can be reduced to 10%, the farmer will see the significant difference and be receptive to the new practices. *We have found that traditional low-cost methods of pest control are as effective as chemical treatment.*

The technology package that is developed with farmers needs to be an integrated package that may focus on seed improvement with traditional and improved varieties and production practices as well as storage. There needs to be a step by step approach that concentrates on a few problems where potential gains can be made. From there, other problems can be approached. The case studies describe some of the activities undertaken in Senegal and The Gambia.

Implementing an effective demonstration

Farmer and land selection. The farmer should be a productive farmer, respected in the community, responsible, and willing to carry out the demonstration. If the demonstration involves production rather than storage, land should be selected that is representative of the area and easily accessible from the village for supervision and observation by the villagers. The demonstration should be next to a plot representing the traditional methods for easy comparison.

Inputs. If the demonstration involves an improved variety, loan the small quantity of seed to the farmer at planting and get it back at harvest. With self-pollinated varieties like rice, the harvest from the demonstration plot can be used for seed the next year by the farmer or traded with other farmers.

Plot size. Keep the area of the demonstration small. In small rice fields of 400-1000 m^2, demonstrations of 100-200 m^2 are used. In larger fields of millet seed, plots of 400 m^2 are used. It is quality, not quantity, that is important. If the area is too large, getting operations done on a timely basis may be difficult. A small plot is easier to manage and a lower risk in case the demonstration is a failure.

Monitoring. It is the responsibility of the extension agents to get the inputs to the farmer and make visits on a regular basis to provide encouragement and feedback to the farmer. The extension agent will also gather basic data on the farmer's activity, such as the time of planting, weeding problems, the date of harvest, yield, as well as his or her comments.

Discussion of results of the demonstrations. The farmers of the area should have an opportunity to view and discuss the results of the demonstrations with the extension agent and the farmer that carried out the demonstration. Field days are one way to facilitate discussion with farmers that will provide valuable feedback on the direction of your activities. If the farmer's fields are small, demonstration in the field should be well placed so farmers will see the activity without a field day (as we found with rice demonstration plots). There will still be the need to hold meetings and individual discussions with farmers for feedback.

Demonstration follow-up. Based on the results of the demonstration and the feedback from the farmers and extension agents, the demonstrations need to be evaluated and the nature of future demonstrations determined.

- Did demonstrations have better results than the traditional practices? What was the reaction of the farmers? Do they want to use the procedure or change again the next season? Of the farmers that viewed the demonstration, do they want to be a part of a demonstration next year?

- Did the initial demonstrations provide insight into additional changes or modifications that should be made in the technical aspects of your seed activity?

- Was the system for monitoring the activity effective in encouraging the farmers and gathering sufficient information on the demonstrations?

- Is there agreement that the demonstration should be extended to more farmers and villages? If you have been successful, the activity should be extended beyond the initial area. We have found that good innovations spread by themselves among farmers.

Phase C. Determination of Long-term Strategies

After developing and implementing the initial seed-related demonstrations with farmers, what is the next step in a seed activity? There are two basic strategies for seed activities once seed problems and possible interventions have been identified, tested, and deemed worthwhile: improving the quality of farmer-saved seed, and the development of seed enterprises. The strategy will depend on local conditions and the goals of your agriculture program.

Improving the quality of farmer-saved seed

Since nearly all the seed that farmers plant is seed that she or he has saved, improving the quality of farmer-saved seed can fulfill an important basic need. Our activities with rice and peanuts are based on the approach of improving farmer-saved seed. This strategy could be called a *seed extension approach* in which the initial demonstration would be continued while gradually increasing the numbers of farmers and villages. In this way the seed and the technologies will spread from farmer to farmer. The advantage of this strategy is that seed technology spreads in a traditional and appropriate manner. The major role for the PVO/PC is getting the activity started. The limitation of this strategy is that if certain seed is in high demand, it may be difficult to meet the demand. There also needs to be a reliable supply of quality seed for initial distribution to farmers.

An initial focus on farmer-saved seed can create the demand for quality seed and a "seed awareness," the knowledge of the value of good seed with appropriate technologies. This first step in building demand can be a key factor for future development of small seed enterprises.

Fostering individual, group or contract seed enterprises

When there is a need for rapid multiplication of seed, the seed enterprise approach using contract growers can be useful. The advantage of this approach is that it can increase the local availability of quality seed in sufficient quantity to meet demand. The disadvantage is that it requires more involvement by the PVO/PC in the planning and supervision of the seed production, storage, and marketing than is necessary for farmer-saved seed.

When certified seed of an improved variety is produced for sale, it may involve the national seed service (depending on the seed legislation in the country). In such a situation the national seed service is normally involved in the quality control procedures of the seed, such as field inspection, and seed sampling and testing. With the move towards privatization in the seed sectors of many countries, fostering approaches to village-level seed production by seed enterprises may be needed. There are two roles for the PVO/PC in fostering seed enterprises.

PVO/PC as seed enterprises

After initial demonstrations, the PVO/PC may decide to take the lead in local seed activities to get things started. Your organization may serve as an intermediary between the national seed program and the contract growers. It includes a role in marketing of the seed. Steps in the process include the following:

- **Establish contact with the national seed program:** A source of seed needs to be established as well as a mechanism for seed testing and field inspection.

- **Provide seed extension training to your field staff:** The exact extent of the training depends on the division of responsibilities between your organization and the national seed program in the production and certification of the seed.

For example, in The Gambia PVOs often do all the seed extension and field inspection, with the national seed service providing the seed testing. By contrast, in Senegal the national seed service provided the field inspection and seed testing.

Training and supervising contract growers. It will be necessary to select, train, and supervise the farmers that will be contract growers. The PVO/PC takes responsibility for timely delivery of seed and other inputs as necessary to the farmer. In some cases, village groups have been selected to produce seed, but this does not always prove to be satisfactory because of the special attention that is required to produce quality seed. It has been found that individuals often perform better as contract growers.

Marketing the seed. There are different kinds of marketing arrangements for seed produced by contract growers. Sometimes the contract grower is allowed to keep up to 50% of the seed for sale in his or her village. In some cases, the PVO/PC purchases all the seed for distribution to other villages. Where village groups have produced seed, the seed is marketed in the village or to surrounding villages.

A close supervision of farmers is necessary for the production of certified seed. It requires a commitment of time by the PVO/PC field staff that, given their many activities, is often difficult to provide. Contract seed production has proven more satisfactory with individuals than farmer groups because farmers put a higher priority on their own fields than on communal fields. This special attention is necessary for seed production.

Various NGOs in The Gambia are using contract grower strategy in cooperation with the Seed Technology Unit of the Ministry of Agriculture. The NGOs work with individuals and groups of farmers in the production of certified seed under the field supervision of the NGO field staff.

PVO/PC as facilitator of seed enterprises

The PVO/PC as facilitator of seed enterprises must be considered a stage in the process of turning over the seed enterprise from the PVO/PC to the farmers. Therefore the previously discussed issues of linkage with the national seed service, training, and marketing are all relevant to the development of farmer seed enterprises. Other issues that determine the feasibility of village-level seed enterprises follow.

Organizational. What is the organizational structure of the seed enterprise going to be? The range spans individual farmers who decide to focus on seed production to cooperatives, associations, or input dealers that recognize the commercial potential of seed. The important factor in the organizational structure is that it can produce and market quality seed at a reasonable price.

Seed quality. The importance of seed quality cannot be over emphasized. The seed enterprise must produce consistently high quality seed of appropriate varieties in order to have a product that the farmers will purchase. High quality seed depends on the many factors we have discussed, including production, quality control, conditioning, and storage.

Marketing. Will farmers continue to purchase seed once they have tried the seed rather than save their own? Is there sufficient demand for seed to make an enterprise feasible? Will your organization be able to assist in marketing seed in a wider area? All these questions must be considered for the feasibility of a seed enterprise.

What has been provided here has been a brief overview of the development of seed enterprises. These topics are treated in much greater detail in *Setting A Seed Industry in Motion* (Garay et al., 1988).

Part 2 has explained the process of determining the feasibility of seed activities based on the technical information of Part 1. The process includes information gathering, developing and implementing demonstrations, and the determination of long-term strategies for your organization. Examples from OFSP field activities have been included. Part 3 provides case studies of seed activities that have successfully used this process.

Part Three

Case Studies

Case Study 1. The OFSP and Peace Corps Rice Project

Sustainable rice yield increases in West Africa have proven to be an elusive goal for agricultural development activities. The literature on West African rice development (Winslow et al., 1989; Spencer, 1989) has identified as problem areas: the lack of appropriate rice varieties, poor water control, fertilizer and input shortages, weeds, traditional production practices, shortage of labor, low rainfall, and ethnic factors. Appropriate interventions in the field, however, have been difficult to implement.

Improvements in rice yields have been difficult to achieve because of the diversity of the ecologies in which it is grown as well as varieties, planting methods, and production systems. The numerous ecologies in which rice is grown includes upland, phreatic (sometimes submerged), paddy (always submerged), mangrove, and riverain (deep flooded). Planting methods include broadcasting, planting in rows, and transplanting. The number of identified varieties in the Casamance of Senegal alone is more than 200, each with different production requirements. The timing of production practices varies greatly according to labor constraints, rainfall, ecology, and cultural factors. The "package approach" of an improved variety, fertilizer, and fixed production practices promoted hitherto have not been adopted in a sustained fashion by West African rice farmers.

The On-Farm Seed Project (OFSP) and the Peace Corps Africa Food Systems Initiative (AFSI) program in Senegal started by collaborating with Alphonse Faye, a Senegalese rice agronomist and plant breeder from the Institut Senegalais De Recherches Agricoles (ISRA), to develop a pilot rice extension program in the Casamance. The objective of this program is to improve rice yields on a sustainable basis by using a process approach to gain knowledge and understanding of farmer's seed-related problems rooted in quality, variety, or production characteristics.

The technical expertise of Mr. Faye, the on-site monitoring by 4 Peace Corps volunteers (PCV) in the villages, and the coordination by the OFSP and Peace Corps staff constituted a multi-institutional, comprehensive, and technically sound team. This small-scale pilot program was initiated to test the methodology and technology of a multi-institutional rice seed extension approach for technology development with farmers. Based on the results of the first year, the program may be diffused to more villages and organizations in the region.

Phase A. Information gathering

Step 1. Review existing information

The research system in Senegal. Agricultural research has a long history in Senegal. Senegal was the headquarters for agricultural research in French West Africa for almost 50 years, starting in 1921. Today, Senegal, with seven agronomy research stations, has one of the most extensive agricultural research systems in Francophone Sahel. From 1921 to 1974, research was in the hands of specialized French institutions. "This left a tradition of researchers accountable primarily to a disciplinary scientific group within a bureaucratically organized research institute" (Bingen and Faye, 1985). In 1974, the Institut Senegalais de Recherches Agricole (ISRA) was created. This brought all the French institutions together in one structure for agricultural research in Senegal.

From 1968 to 1980, the system of Unites Experimentales was one of the first examples of farming systems research in West Africa. This system had problems in its top-down approach, and it made little progress towards establishing a research-extension relationship (Bingen and Faye 1985).

In 1982, a Production Systems Research Department was established with the assistance of the World Bank and USAID. Michigan State University had a contract to implement the work with ISRA interdisciplinary teams at Djbilor, Kaolack, and St. Louis. This approach led to better understanding of the traditional farming systems and the potentials and constraints of farmers in adopting the technology developed by ISRA. ISRA itself does not have a mandate to do extension, but it worked with extension.

Substantial financial support is provided by donors, so that research programs can be influenced by fluctuations in the availability of funding. ISRA has been particularly affected by the World Bank/IMF Economic Recovery Program (ERP) for Senegal. Well-trained and scientifically motivated researchers find themselves constrained not only by financial circumstances, but by a rigid demarcation between research and extension, so that it is difficult for them to follow the technologies they develop through to the farmer.

The extension system in Senegal. The primary organization for agricultural extension in Senegal is Societe Regionale de Developmente Rural (SRDR). The society's regional development agencies are responsible for a range of development activities within a geographic area. It was with selected SRDRs that the Production Systems Department of ISRA established a relationship. A major issue with the SRDRs is that they are funded by the government and donors so that the staff numbers, activities, and support vary greatly with available funding. The SRDRs are not oriented towards working with the resource-poor farmers, but instead promote high-input agriculture with credit.

The SRDRs have established links with the Production Systems Department of ISRA to facilitate technology transfer to the farmer. In reality, something quite different has happened – the institutional and funding issues involved in this form of collaboration between government agencies stimulated the SRDR to conduct its own research, often independently of ISRA. For example, SRDR conducted trials with SOMIVAC (in the Casamance) with herbicides, fungicides, insecticides, and rice varieties from the West African Rice Development Association (WARDA) rather than the rice varieties tested and developed by ISRA. In another example, SODEVA (in the peanut basin) conducted trials on fertilizer application and varieties on-station and with progressive farmers. This duplicated previous work of ISRA. Results of these activities were then extended to the farmer as packages of inputs in new varieties, fertilizer, herbicides, and insecticides with credit available to purchase the inputs, usually from SRDR. In the final analysis, this top-down, high-input approach was irrelevant to resource-poor farmers.

The recent economic recovery programs and the new agricultural policy to reduce the government's role in supplying agricultural inputs and to promote privatization have substantially reduced the scale of operations of the SRDRs. A gap has consequently opened up in extension services in the rural areas.

Nongovernmental organizations (NGOs). International and indigenous non-governmental organizations have emerged as an increasingly important force in African development. Several factors have contributed to the emergence of NGOs. International attention following the drought of the 1970s provided funding for drought relief activities through NGOs. Second, economic crises in African countries and the resulting ERPs have scaled down public services in all sectors, thus reducing their ability to provide services and to carry out development activities. Third, the donor community (bilateral and multilateral) now view NGOs, international and indigenous, as a sensitive means of implementing development activities in rural areas. NGOs are involved in a range of activities, including literacy, health, water, natural resource management, and agriculture.

In Senegal, the gap in agriculture extension that has developed through reduction of the public and donor support in this area is being filled by NGOs. The NGOs have the financial and staff support necessary to serve the needs of the rural communities but often small geographic areas. There are more than 100 international and indigenous NGOs registered with the government in Senegal, 64 of which are members of the Conseil des Organisations Non Gouvernmentales D'Appui au Developpment (CONGAD). Of the 64 CONGAD members, 20 are international NGOs and 39 are indigenous or African NGOs. Those working in agriculture generally have strong grassroots structures.

The NGOs' agricultural emphasis has been on water development and gardening during the dry season, though interest is increasing in traditional rainy season crops. NGOs now are more concerned with technically sound and sustainable activities. Participatory approaches with farmers are entirely compatible with the NGO philosophy. Some questions that have bearing on our discussion below are: What are

the sources of innovation by NGOs? Do they have the time and resources to develop their technical capabilities and links with sources of innovation? NGOs are taking steps to increase the technical skills of their staff, but are they moving fast enough?

The national seed system in Senegal. The national seed system in Senegal consists of several related components:

- A source of new varieties from national or international entities that ISRA tests and selects for use.
- A system of seed multiplication. Early stages of multiplication are carried out by ISRA and the Direction de la Production et du Controle des Semences (DPCS), with contract growers used for later stages of multiplication.
- A system of quality control throughout the multiplication process. This is the responsibility of the DPCS.
- A system for distribution of the seed to the farmers through SRDR, SONACOS, and private dealers.

The focus of seed production in Senegal has been on the main cash crop, peanuts. Other crops have received limited attention and funding. As a consequence of the Economic Recovery Program, a new agricultural policy was developed with the result that the government is taking a reduced role in the seed system. It is intended that the DPCS will withdraw from seed production and restrict their role to quality control. Though privatization of marketing of agricultural inputs (including seed) is being encouraged, it remains to be seen if the private sector can replace the government in agriculture input supply. In the interim, farmers will have an increased responsibility for their own seed supply. Nevertheless, the majority (80% to 90%) of seed used by farmers is not purchased but is the farmers' own.

One major weakness in the seed system for food crops lies in the high cost of distributing and marketing seed at the local level. A second is the limited testing conducted with these varieties under farmers' conditions to assess compatibility with their production systems and to identify appropriate husbandry practices.

Successful identification and production of appropriate seed clearly requires research and extension inputs. However, farmers themselves can multiply many varieties of seed once they have the basic material. In fact, seed production can be a small-scale rural enterprise.

Rice production systems in the Casamance. Rice production in the Casamance (the southernmost region in Senegal) originated at least 1000 years ago. The Casamance is the center of origin of *Oryza glaberrima*, a lesser known species of rice. In the 15th and 16th centuries, the Asian species *Oryza sativa*, was introduced by the Portuguese. Rice production and consumption are central features of the Diola and the Mandink ethnic groups of this area. Rice is usually grown only for consumption, not for sale.

The ecologies for rice production include the upland, phreatic, paddy, and mangrove. In the last 20 years, rainfall levels have dropped from 1500 mm to 1100 mm (rainfall data from Djiblor, Casamance); this has had two effects. First, the reduced flow in the Casamance River has resulted in salt water moving farther up the slow-moving river and affecting the mangrove and paddy rice ecologies next to the river. Second, the traditional varieties do not mature while there is still sufficient moisture during the grain fill stage of growth. The result is reduced yield.

Many of the traditional varieties are photoperiod sensitive; a certain length of day is required for flowering. This day length does not occur until October when moisture is limited. Therefore, although the traditional varieties were well adapted to pre-drought conditions, they are not adapted to the 27% reduction in rainfall that has been experienced in the last 20 years.

There are two basic systems of rice production in the Casamance used by both of the main ethnic groups.

Step 2. Farmer interviews and observations

Initial information was gathered directly from farmers and secondary sources. For information from farmers, the PCVs identified small groups of villagers (mostly women) in five villages, who were interested in participating in a discussion of their rice practices. Group interviews with the farmers, led by Alphonse Faye, were conducted in January 1989 to discuss the production practices, timing of field operations, varieties used, and problems encountered in the villages of Dioloulou, Karong, Mangoulene, Tendouk, and Tiobon. These initial meetings were slightly formal as village leaders were included. A month later, the rice fields were visited to gather more information on soil types, salinity problems, and water levels. Individual interviews were conducted with the women by the PCVs and staff during and after the growing season. Discussion and feedback, primarily from the women, was an essential component of the program. Secondary material was drawn extensively from work of the rice team and farming systems section of ISRA in the Casamance (Sall, 1988).

The following is a summary of information on rice production systems obtained through discussion with more than 60 farmers in 11 villages from January 1989 to April 1990.

1. **Diola Rice Production System.** The Diola system is used in 45% of the total rice production area in the Casamance (Sall, 1988). In our initial program, this included the villages of Diouloulou, Tendouk, and Tiobon.

    a. *Labor*: Men and woman participate in rice production. Men do the plowing. Women prepare the nursery beds and plant, weed, and harvest. During the interviews, the women provided information about the transplanting and harvest dates and brought samples of seed rice for examination and

identification. The men demonstrated more knowledge of the timing of field preparation.

b. *Ecology*: The plots are in either phreatic or paddy ecologies near the mangrove area of the river. In these areas with salinity, iron toxicity, and acid soil, the farmer depends on the plots being well-flushed with rain before planting. Farmers taste the water to determine if the salinity has been reduced sufficiently; transplanting can usually begin by August 7-15, after 500-600 mm of total rainfall. At the end of the rainy season (end of October), the salt concentration begins to increase again.

c. *Land preparation*: Men do most of the plowing using the traditional long-handled shovel, the kagando, to make ridges in the soil. In extremely saline areas, initial ridging is done in February or March to inhibit the capillary action that brings the salt to the surface. The plowing also is performed after the initial rains when the weeds have emerged. Manure often is added just before plowing. This ridging system of plowing buries the weeds and manure, composts them, creates drainage that retains more water in the plots, and keeps salt away from the plants. Several farmers used animal traction for plowing.

d. *Plots and water control*: Plots are small, 200 m^2 or less, because of fragmentation of land holdings. Water comes from rainfall rather than irrigation and is drained only if excessively deep during transplanting.

e. *Seeding method*: Rice seedlings are transplanted from large nursery beds at 30 to 60 days after seeding once there is sufficient water in the plots and the salt content has been reduced. Spacing between seedlings after transplanting is dense (10 x 10 cm).

f. *Fertility management*: Cattle graze the rice stubble during the dry season leaving valuable manure. Ash, leaves, household waste, and manure are added to the plots before plowing. Chemical fertilizer seldom is used. The following quotes from farmers provide insight into their system of fertility management.

"I put the nursery bed for the seedlings where the cattle have been kept so there is plenty of manure to make the seedlings strong."

"I tried to use chemical fertilizer, but it is expensive, and it does not stay in the soil. I prefer our traditional system of using manure."

"I used the chemical fertilizer, but it just made the weeds grow."

"The soil is stronger and retains moisture longer when the manure is used compared to the chemical fertilizer."

g. *Weeding*: Minimal weeding is required since the plowing method buries initial weeds. Keeping plots submerged for transplanting also inhibits weed growth.

h. *Varieties*: Farmers use two to five varieties to fit the various water conditions. Traditional photosensitive varieties are used by all farmers interviewed. Traditional varieties flower in October, and yield is reduced because recent low rainfall limits water when the plant is in the grain fill stage.

In our survey, all farmers saved their own seed, and the varietal purity of the rice appeared to be high.

i. *Harvest and drying*: Rice is dried before it is stored. Groups of women harvest only the panicles, tying these into small bundles which are stacked together for storage. Average rice yields range from 800-1000 kg/ha.

j. *Storage*: Rice seed, stored on the panicle in small bundles, is kept in a storage room or the attic in the family compound separate from the rice for consumption. Although this storage system allows the rice to dry properly, it is susceptible to attack by insects and rodents.

2. **Mandink Rice Production System.** The Mandink system is used in 41.7% of the rice production area of the Casamance (Sall, 1988). In the trials, the village of Mangoulene represented the Mandink system. A modified Mandink system was used in Karong.

a. *Labor*: Only women work with rice; men work with the upland crops of peanuts, corn, and millet. Even though women do the work, in initial interviews the men insisted on answering most of the questions.

b. *Ecology*: The plots are in inland valley swamps that have no problems of salinity.

c. *Land preparation*: The women use a small hoe to loosen the soil and remove weeds after the first rains.

d. *Water control*: Plots are larger than in the Diola system, averaging 2,000 m^2. Water control is minimal.

e. *Seeding method*: Seed is broadcast after there is sufficient moisture in the plots.

f. *Fertility management*: Women work manure, the main source of fertilizer, into the soil while plowing.

g. *Weeding*: Weeding is done 30 to 60 days after planting. Earlier weeding is not possible because when the rice is broadcast, weeds cannot be distinguished from rice at early growth stages and so become a major factor in yield reduction.

h. *Varieties*: Traditional varieties are used exclusively.

i. *Harvesting, drying, and storage*: These practices are the same as the Diola system. Average yields range from 800-1,000 kg/ha.

3. **Comparison of the two systems.** The Diola and Mandink systems may be categorized respectively as intensive and extensive rice production systems. Labor is a major constraint in the Mandink system, since only women are involved in rice production. Large plots and the scope for mechanization means that rice projects have favored the Mandink areas.

   The Diola hand-plowing technique, using the kajando, allows the rice to be cultivated in conditions of salinity, acidity, and iron toxicity and is essential for fertility maintenance, weed control, and water control. It represents an appropriate and sustainable indigenous technology. Rice development projects have found it impossible to improve on this indigenous kajando technology.

Step 3. Conclusions from information gathered

1. The two rice production systems will require different approaches to seed and production problems.

2. The traditional seed production system is basically sound in both systems.

   a. As rice is highly self-pollinated, maintaining varietal purity is not a problem.

   b. Rice seed is stored separately from food rice, and women are knowledgeable about the characteristics of the varieties they grow.

   c. Harvesting and storage of the rice in bundles of panicles results in some mold on the stems in the center of the bundles, but otherwise the rice seed quality is reasonable.

   d. Rice seed has excellent storing properties, especially in the low humidity conditions of Senegal during the storage season. Loss of rice quality and quantity during storage is not a major problem. Simple seed germination tests before planting indicate 80% to 95% germination.

3. All farmers mentioned that problems of salinity as encountered in the Diola system area and reduced rainfall in both areas resulted in production problems. OFSP interventions should therefore seek to address them. Initial discussions

with Alphonse Faye indicate several improved varieties are available that would meet the identified needs of farmers.

Phase B. Development and implementation of trials

Step 1. Objectives

Many rice projects have operated in the Casamance with new varieties, fertilizer, herbicides, insecticides, credit, and even tractors. After the projects terminated the farmers returned to their old varieties and production practices.

The OFSP approach, by contrast, is to understand the traditional production system and suggest modifications compatible with it. This strategy is a *step-by-step, long-term approach* of working with farmers rather than looking for dramatic and immediate increases in yield. As each change is understood and practiced, new changes are initiated based on feedback from farmers. Farmers thus determine the direction and pace of change. Initial attention is focused on an improved variety and a few modified practices that will help the improved variety produce more than the traditional variety.

Plan of action. Farmers were selected to participate in a rice demonstration plot of 200 m^2 on their own land, using 2 kg of seed purchased from OFSP, giving attention to a few modified practices.

1. OFSP gave no credit or free inputs. Farmers paid $0.50 for a small quantity of seed rice when they received it.

2. The work started with two improved adapted varieties that would perform better than the traditional variety under low-input conditions as long as a few production practices were modified.

3. Four women's groups and 15 families each grew approximately 200 m^2 of the new variety with the PCV monitoring the activity. The rice produced was used by the farmer the next year as seed thereby introducing it into the traditional seed production system.

Varieties used in the demonstrations. ISRA (with Alphonse Faye) has developed several improved varieties that have been tested under farmers' low-input conditions and have produced more than the traditional varieties. These improved varieties have several characteristics important to farmers:

1. They are photoperiod insensitive and mature earlier than traditional varieties – 105 to 120 days compared to 150 days for traditional varieties.

2. They use available levels of fertility for grain production rather than for a larger or taller plant as with the traditional varieties. Traditional varieties are also prone to lodging.

3. Their tillering capacity is higher than traditional varieties, which translates into higher yield potential.

4. Grain size, milling characteristics, and taste are compatible with local preferences.

5. They are resistant to rice blast, a major rice disease in West Africa.

Step 2. Demonstration guidelines

Modified production practices used in demonstrations. For these new varieties to produce better than the traditional varieties, several production practices must be modified.

1. For DJ12-519 and DJ684 D when transplanted in the Diola rice production system:

   a. *Nursery bed preparation*: Sufficient manure (15 kg/10 m^2) is incorporated into the nursery bed to improve texture and fertility of the soil, and seeds are treated with an insecticide and fungicide to improve seedling emergence and to deter bird and insect attack.

   b. *Age of seedling at transplanting*: Seedlings are 20 days old at the time of transplanting, whereas the traditional age of seedlings is anywhere from 30 to 60 days. After they are 35 days old, they have no time to produce tillers before entering the reproductive stage. This modified practice is a dramatic change from traditional practices, but only in the timing, not in the amount of labor.

2. For DJ12-519 and DJ684D when directly seeded in the Mandink rice production system:

   a. *Planting in rows*: This is essential for earlier weeding; in the traditional broadcast-planting method, it is not possible to distinguish rice from weeds at early stages of growth. An optimal 20 cm spacing between rows gives a high plant population, and good shading to suppress weeds without crowding the plants themselves. Evenly spaced rows can be made with a locally constructed rake with spikes each 20 cm to make the furrow. Seeding is by hand. Planting in rows requires more labor than the broadcast method but is compensated by increased production.

   b. *Weeding*: With the rice in rows, two weedings are done (at 20 and 40 days) in less time than the one weeding under the broadcast system.

Monitoring. In February, the sites of the trials were examined by Alphonse Faye with the farmers to determine which variety to use. Thereafter, monthly monitoring visits

were made by PCVs who were able to encourage farmers to follow the new practices on time and record both the timing of operations and other basic data. Tables 2 and 3 show how several Diola farmers, listed by villages, managed their trials and what yields they received. Table 4 covers the Mandink trials.

Table 2. Diola Rice Production System: Variety - DJ12-519

Village name	Transplanting date	Age of seedling[1]	Yield[2] kg/ha
Diouloulou			
Mariama Gassama	Aug 3	31	1759
Fatou Sagna	Sept 1	40	554
Gathie Diassy	Aug 24	39	1261
Tiobon			
Malafi Dieme	Aug 17	27	3618
Karong			
Landing Mane	Aug 16	19	1264

[1]Recommended age of seedlings at transplanting: 21 days
[2]Days to maturity: 105

- *Transplanting date*: Actual transplanting dates, which depended on the rainfall and on other farming and personal obligations, varied from August 1 to September 1. The later dates, August 24 and September 1, are the time of traditional transplanting.

- *Age of seedlings*: The average seedling age was 32 days, against the recommended 21 days. When the data on seedlings were divided, seedlings of 20-30 days old yielded an average of 1328 kg/ha against 907.5 kg/ha for seedlings of more than 31 days.

- *Yield*: Differences in farmers' practices and fertility varied greatly. The combined effect of late transplanting and old seedlings had a detrimental effect on yield, with variations between 554 and 3618 kg/ha.

Table 3. Diola Rice Production System: Variety - DJ 684 D

Village name	Transplant date	Age of seedlings[1]	Yield[2] kg/ha
Diouloulou			
Mamadou Diallo	Aug 2	22	2912
Groupe Morobia	Aug 16	19	1699
Karong			
Amadou Ba	Aug 16	21	1987
Tendouk			
Ambroise Dieme	Aug 23	32	1471
Anna Dieme	Aug 16	29	1890
Mme Diatta	Aug 23	32	1801

[1]Recommended age of seedlings at transplanting: 21 days
[2]Days to maturity: 120

- *Transplanting Date*: Dates here were acceptable since transplanting normally must be after August 15 because of salinity in these areas.

- *Age of Seedlings*: The average age of the seedlings was 26 days. The older seedlings in Tendouk (and reduced yield) were caused by a lack of labor and a lack of coordination between the planting of the nursery bed and the time of transplanting.

- *Yield*: The average yield of DJ 684D, 1960 kg/ha, is higher than the DJ12-519, illustrating the higher yield potential of a longer duration variety (120 days vs 105 days) when there is sufficient rainfall. Again, variations in farmers' practices made a major difference in the yield that is not explained by the age of the seedlings alone.

Table 4. Mandink Rice Production System: Variety - DJ 12-519

Village name	Planting date[1]	Weeding days after planting[2]	Yield kg/ha
Tiobon			
Malafi Dieme	July 24		3511
Mangoulene			
Diarra Sane	July 11	39	1329
Abasse Sane	Aug 4	45	670
Alimatou Sane	July 26	40	1675
Yousa Sane	July 31	75	235

[1]Recommended planting date: July 10
[2]Recommended weeding date: 20 and 40 days

- *Planting date*: The planting dates were an average of 12 days later than recommended. There was 500 mm of rain before the rice was planted, 400 cm more than is necessary. Consequently, weeds became established, and planting nutrients were leached, resulting in poor development of the seedlings.

- *Weeding*: Because of late planting, superficial plowing, and good early rains, weeds were established before planting. Furthermore, the average weeding date of 49 days after planting substantially retarded rice growth. The plots at Mangoulene had an average yield of 977 kg/ha. In contrast, Malifa Dieme at Tiobon controlled weeds before planting with the Diola method of plowing and used organic fertilizer, resulting in an outstanding yield of 3511 kg/ha.

Conclusions

As can be expected with farmer trials, the results varied greatly because of the difference in individual farming practices, i.e., water control, fertility management, and the degree to which the modified practices were adopted. This was also the first year of an activity whose methods and technology must be tested, and farmers have no "on-the-ground" example to follow.

Results of the program with the Mandink system were disappointing, but local leadership at Mangoulene was weak and previous rice project activity in the area created false expectations for this program. Most of the work was performed by groups rather than by individuals, and group activity usually had low priority. Dramatic results were not expected, but were achieved by two farmers whose average yields were 3345 kg/ha. Previous ISRA data show that the average yield is 800-1000 kg/ha in the Diola and Mandink systems. Yields from years with similar rainfall (1300 mm) were 1040 kg/ha. In OFSP trials with the Diola system, the DJ684D averaged 1960 kg/ha (an 88% increase) and the DJ12-519 averaged 1491 kg/ha (a 43%

increase). These comparisons show why the farmers were delighted with the results compared to their other fields.

Discussion of the results with farmers. The monthly visits to each of the trial sites by Mr. Faye, PC staff, and OFSP staff for discussion with the farmer and the PCV was an important monitoring and extension activity. The small size of the plots and the high concentration of the plots in small areas made the trial plots highly visible. PCVs estimated that the demonstrations were observed by most women (200 to 300 women) who grow rice in each village. There were no formal field days at harvest time, but because the plots normally are harvested by groups of women, the news of their potential spread spontaneously.

Farmers' reactions. The program had a direct involvement of 80 women and 20 men. Interviews revealed the following:

Farmers in Dioloulou, Tendouk, and Tiobon who participated in the trials were pleased with the activity for several reasons.

1. They appreciated the participatory approach of working with farmers in a simple step-by-step manner without the complications of contracts, loans, or other obligations.

   "This first year we did not know what to think about what you wanted to do with us because we have seen a lot of rice projects before with all the promises, loans, and problems. We like the way you listen to us and now that we understand the program, we will work even harder."

2. They liked the characteristics of the new rice varieties: vigorous seedlings, good growth, high tillering, earlier maturing, high yielding, and palatable.

   "I noticed that the new variety tillers more than my variety. Next year I will decrease the planting density to give the rice more room to grow."

   "The panicles were so big and heavy compared to my own variety. I am very happy."

   "This variety did not fall down before harvest like most of the other varieties in the field."

   "The first thing we did after harvest was to eat some of the new rice, and we really like the taste."

   "When I pounded (milled) the rice, it smelled so good; when I tasted it, it was delicious."

3. These farmers and their neighbors are enthusiastic about working with the project next year, and others who have seen the plots are already approaching them to obtain some of the "magic seed."

> "So many women have come by the house and want to trade some of their rice for the new rice."
>
> "Look at all these bundles of rice that my neighbors want to trade for the new rice variety."
>
> "I have seven new families that are going to work with me next year. I am going to give them the seed and show them what to do so we can all produce more rice to eat." (This quote is from Malafi Dieme, the most outstanding farmer.)
>
> "I saw Amma Deime's field that was still standing straight and tall while my rice had all fallen over. I want to try some of that rice next year."
>
> "When we harvested the trial field, I saw how big the rice panicles were compared to my rice. I want to try that rice next year."
>
> "We will be able to plant most of our plot to the new variety next season and be able to give some seed to our neighbors."

4. Farmers expressed interest in other varieties that are taller for easier harvesting, of slightly longer duration, and tolerant of saline or acid conditions. As a result of this feedback, several more varieties will be tested next year.

> "I really liked the new variety, but do you have a variety that is a little taller so we do not have to bend over when we harvest it?"
>
> "This year there was still water in the plot at harvest time. Do you have a variety that will mature later?"

In some cases, the modified practices were not followed and the results reflect this. In the villages of Karong and Mangoulene where trials were not as well-received, previous projects have operated with fertilizer and credit. The practices suggested for these trials were not followed, and there were constant requests for fertilizer like they have received from other sources.

> "Now we understand that you are really trying to help us not bring fertilizer or make loans. Next year we are going to try harder."

Phase C. Determination of long-term strategies

The program will continue working with the same farmers and villages. The approach being developed will involve using the farmer that had the best plot in each village as the demonstration farmer and bring the farmers together before each critical practice for instruction and discussion. The critical production practices will include the following:

In the Diola system. The nursery bed will be planted so that harvest of the new variety will coincide with traditional varieties. The seed will be treated with an insecticide and fungicide, and the nursery bed will be planted in stages so that seedlings will not be too old before they are transplanted. Tillers will be counted with farmers so that the higher tiller number of new varieties can be verified. Date of harvest compared to other plots and water availability will be recorded.

In the Mandink system. An effort will be made to recruit individuals rather than groups to do the demonstration plots so that there is more incentive for manure application and timely plowing. Planting in rows after 100 mm of rainfall will be suggested using the locally constructed rake row marker. Weeding will be encouraged with a hoe 20 and 40 days after planting.

Diffusion. More farmers will be included in project activities in the coming year. Farmers in the initial villages who already have received seed from farmers who participated last year will be included. Farmers in six other villages near the initial villages will also be included. In most cases, a participating farmer from last year will help the PCV initiate the program in the new villages. Essential data such as timing of production practices and yields of trial and traditional plots of the farmers who participate will be gathered. The spread of the new rice will be monitored, i.e., numbers of farmers who are growing it, timing of production practices, area, and degree of satisfaction. Results will be diffused to other extension efforts in the area.

Training activities will be conducted in the region to introduce the approach and technology to:

- The Government Extension Service
- NGOs with extension activities in the area
- Farmer groups involved in rice production
- Other interested groups

What has been initiated in the field is the result of the efforts of the whole team – the farmers, PCVs, PC staff, OFSP staff, and ISRA researchers. A key to success has been the process approach for identifying problems with farmers. This approach initiated much feedback and information-sharing on problems the farmers have identified and the project has worked with them to solve. It is hoped that the trust and confidence established between AFSI/OFSP and the farmers will result in continued feedback. This feedback will be important to the selection of additional activities to ameliorate the farmers' seed problems. From a technical perspective, the project was fortunate to

have access to an improved variety suited to the production practices and palatability preference of the farmers. Now they have several new varieties that they can multiply and use and distribute to their neighbors.

Case Study 2. Improving Peanut Seed Storage with Farmers in Senegal

The On-farm Seed Project and the African Food Systems Initiative of the Peace Corps in Senegal collaborated on this project for peanuts, an important cash, fodder, and food crop. Recent changes in Senegal's agricultural policy have disengaged the government from supplying agricultural inputs, so farmers are now responsible for storing their own peanut seed. The peanut bruchid (*Caryedon serratus*) is a recognized problem in Senegal, and peanut seeds are vulnerable to high levels of loss during the 6-month storage period unless proper preventive action is taken. These initial facts indicated that seed storage might be a problem worth further examination.

Peanut seed normally is stored in the shell, and this provides partial protection against physical damage, moisture, and some insects, although not the peanut bruchid. Burlap or jute bags of peanut seed are often stored at the family compound, or the seed is sometimes stored in 200-liter oil drums. In this case, the peanuts normally are shelled before storage so as to maximize the storage capacity of the barrel. The peanuts are shelled by hand, a time-consuming process that some rural families start after harvest and continue throughout the dry season. Peanuts that have been stored in the shell are shelled just prior to planting (during April and May). Once shelled, they are susceptible to both physical damage and damage from various insects.

Phase A. Information gathering

Ten African Food Systems Initiative (AFSI) Peace Corps Volunteers (PCV) finished training and went to villages just prior to planting in June 1988. They noticed a large quantity of damaged peanuts during the final stages of shelling of peanut seed in the villages. Farmers complained that even when they use chemicals on the peanuts before storage, losses can be high. Cases were documented of 100% loss of 1,000 kg of stored peanut seed. Ongoing informal information gathering revealed that peanut seed storage losses were generally a problem.

The following findings are PCV Joe Pope's observations from a survey conducted with 79 farmers in the villages of Ngayene, Loyene, Sungop, and Keur Bakary, arrondissement of Medina Seback, department of Nioro de Rip, region of Kaolack.

- **Quantity.** The average quantity of peanut seed stored was 1.8 sacks, each sack weighing 70 kg.

- **Storage container.** 94% of the farmers used burlap, cloth, or woven plastic sacks; 6% of the farmers used 200-liter oil drums.

- **Location.** All farmers stored the sacks in their house or storage hut, often directly on the dirt floor, allowing moisture migration from the floor into the bag.

- **Treatment.** 59% of the farmers used methyl parathion, a highly toxic insecticide banned in most countries. The distribution of other treatments among the remaining farmers was: chemicals, 24%; no chemicals, 27%; neem leaves, 13%; ash, 4%.

The fact that the most common storage treatment was a highly toxic insecticide was rather disturbing. It provides excellent protection against the peanut bruchid, but the potential health risk is high.

- **Insect damage.** Chemicals provided adequate protection, whereas no treatment resulted in high levels of damage.

- **Rodent damage.** This source of loss was correlated directly to the organization and cleanliness of the storage area. Rodents prefer conditions where they can live in the storage area. A clean and well-organized storage provides limited places for rodents to hide and live.

Phase B. Development and implementation of trials and demonstrations

Peanut seed storage trials were conducted at nine locations. PCVs conducted the trials with local farmers in the Nioro department (southern Peanut Basin of Senegal) and the Bignona department in the Casamance of Senegal. The peanuts used in the trials were purchased from the farmers to avoid any risk to the farmers. The purpose of the field trials was to test the effectiveness of various treatments against damage by the peanut bruchid (*Caryedon serratus*) for a 6-month storage period. Germination tests were conducted on peanuts stored under the various treatments by the seed testing laboratory of the Direction de la Production et du Contrôle des Semences in Dakar. The trials were conducted in 100-micron thick, unsealed plastic bags with 20 kilos of peanuts per treatment. The clear plastic bags made it possible to observe the peanuts during storage.

Treatments used in the trials

Chemicals. Farmers had complained that they often suffer high losses during storage even when they use storage insecticides. We wanted to determine, therefore, if there would be adequate protection when a chemical was properly applied before storage. There are many issues concerning the use of storage insecticides.

- *Cost*: For Actellic, the cost is 125 cfa (US $0.50) per 100 kg of peanuts.

- *Availability*: Is it available in local markets?

- *Quality*: What is the quality of the insecticides available? How old is it? Has it been adulterated? It is often sold in open plastic bags without labels.

- *Safety*: Are adequate precautions taken in handling toxic chemicals during the application or later in the shelling process?

- *Application*: Is the insecticide being properly applied? Chemicals often are sprinkled on the surface rather than thoroughly mixed with the seed.

In these trials, Actellic (2% primiphos methyl), a low-toxicity class III storage insecticide, was used. This insecticide is recommended and widely used by farmers. As with all storage insecticides, there must be uniform distribution of the chemical throughout the stored seed for the product to be effective.

Sand. A traditional storage treatment, which creates a physical barrier around the seed to prevent the movement of insects. Fifty percent of the storage volume is air. When the space is filled with sand, the movement of insects and the oxygen supply are limited. Dry sand has a lower moisture content that the seed so it draws moisture away from the peanut seed. This is beneficial because moisture may result in seed deterioration. A disadvantage of using sand is that it makes the storage container extremely heavy; the container can not be moved once sand is applied. To be completely effective, the sand must fill all the spaces between the seeds, and the bag or container must not allow the sand to leak. Though storage of peanuts in sand pits is an old tradition, it is not currently practiced. Sand, widely available at no cost, is an attractive storage treatment to test.

Wood ash. Wood ash can be an effective storage treatment because the sharp ash particles scratch the cuticles of the insects. Once the cuticle is scratched, the hygroscopic property of the ash draws moisture from the insects and desiccates them. The ash should be evenly distributed in the stored seed, coating all the seed but not necessarily filling all the spaces between the seed. The eggs of the peanut bruchid are laid on the peanut shell and the ash has a detrimental effect on egg development. Ash has the advantage of being much lighter than sand. It is also widely available from cooking fires, although the quantity necessary (one part ash to four parts peanuts) makes it rather inconvenient to gather and store. Ash is also dusty and difficult to apply. The survey indicated that farmers occasionally use ash.

Neem. The leaves and seeds of the neem tree (*Azadirachta indica*), which is widely grown in Senegal, have insecticidal properties. The neem seed has the highest concentration of the active ingredients, but the preparation of neem seed is rather difficult and time consuming for use in storage. The high oil content makes it difficult to produce a powder from the neem seed and to distribute it evenly throughout the stored peanut seed. Neem leaves are traditionally used with stored seed and grain in Senegal. Often, whole leaves are mixed or spread on the top of the seed. In the trials,

the leaves were dried, crushed, and mixed thoroughly with the seed in the ratio of one part neem leaves to four parts peanuts.

Early removal. The peanut bruchid attacks peanuts while they are drying in the field. Early removal of the peanuts from the field was undertaken to determine if this would minimize initial infestation. The peanuts were removed from the field 2 to 4 weeks after harvest when the peanuts reached a moisture content of 10%. Normally, the peanuts are stacked in the field for 2 to 4 months, which exposes them to pests and excessive drying and deterioration in germination. Peanuts are a delicate seed that need special care to maintain high germination. The early removal samples had a control that received no treatment and one that was treated with Actellic.

Brick box. The traditional brick box is of interest because it is a local technology, is low cost, and provides protection against insects, rodents, and theft. The box was observed in The Gambia where it provided satisfactory storage. It is normally kept inside a house in the corner of a room where it is protected from excessive temperature caused by direct exposure to the sun. The box is sealed on top with clay after it is filled with 100 to 200 kg of peanuts. In this trial, the peanuts were put in the box after being treated with Actellic.

Diffusion of results

Results demonstrated that the storage insecticidal dust Actellic (contains 2% pirimiphos-methyl), sand, and ash were all effective in minimizing loss to the peanut bruchid. It is encouraging that locally available nonchemical, no-cost treatments are as effective as chemicals. The use of crushed neem leaves was not effective. The early removal treatment with Actellic was not significantly different in results than the traditional removal. The early removal with no Actellic was significantly better than the traditional removal with no Actellic. Table 5 provides the compiled results from the 10 sites. The control treatment was highly damaged; only 28% whole seed remained at the end of the storage period.

Table 5. Comparison of storage treatments of peanuts.

Removal/treatment	Final germination %	Whole seed %	Bruchid %	Mold %
Early/Actellic	84	92	3	2
Trad/Ash	84	84	11	5
Trad/Actellic	82	94	1	5
Trad/Sand	81	93	3	4
Trad/Neem leaf	68	50	46	3
Early/None	64	66	31	2
Trad/Actellic/box	62	81	14	5
Trad/None	58	28	69	2

Results of the trials demonstrate that the use of sand and ash was as effective as chemical insecticides for protection of peanut seed during storage. The farmer can treat seed with sand or ash at little cost and obtain good results without the danger, cost, or uncertainty of using chemicals. From a practical point of view, sand offers an important advantage over ash because sand is easy to obtain whereas collecting a large quantity of ash takes considerable time and effort. The neem leaves were largely a failure, but the use of neem seed deserves further attention.

Similarly, the clay brick box merits further trials to see if problems with it can be solved. The effectiveness of the brick box was inconclusive (data not presented). The percentage of whole seed after storage ranged from 29% to 99%; five out of the eight locations had 92% or higher whole seed percentage. The percentage of seed germination ranged from 29% to 81%. *Though there was a high percentage of undamaged seed, the germination percentage of this seed was highly variable.* Also, the results using the box were mixed since in the Bignona area termite attack was a problem, and box construction and locations varied greatly. In the one trial in Karong where ash was used with the box instead of Actellic, the germination was extremely low.

A possible explanation for the problems may be moisture migration from the floor as there was no moisture barrier in the box. Where ash was used with the box, the ash may absorb so much moisture that seed deterioration could be accelerated resulting in low germination.

Though plastic bags were suitable containers for the trials, their higher cost, and limited availability and durability suggests that they should not be promoted in Senegal. In the future, treatments could be used with other storage containers, such as cloth or jute bags, clay pots, or brick boxes.

Summary of Storage Treatment Application Methods

1. Sand

   - The proportion of peanuts to sand should be 2:1.
   - Put one-half of the peanuts in the container and add sifted dry sand. The sand will filter down through-out the peanuts. Shake or tilt the container to make sure that all air spaces are filled.
   - Add the remaining one-half of the peanuts and fill with sand until there is a layer of sand on top.
   - Remember that the high proportion of sand will make the container extremely heavy and hard to move once it is filled.

2. Ash

   - The proportion of peanuts to ash should be 4:1.
   - Use a layering method to apply the ash to assure uniform coverage of the peanuts where layers of peanuts 3 to 5 cm thick are followed by application of ash that will not fill all the space between the peanuts but will cover the peanuts with a coating of ash.
   - Apply a generous final layer of ash on the last layer of peanuts.
   - Ash, though lighter than sand, is dusty, so apply in an open area or in a way to minimize inhalation of the dust.

3. Insecticidal dust Actellic

   - The application rate for storage dusts, for example, 50 grams/100 kg, is a small quantity of insecticide to apply to a large quantity of peanuts. Therefore, calculate the recommended quantity and put it into a matchbox for easy application. A small matchbox in Senegal holds 20 grams of insecticidal dust.
   - A layering method is used with insecticides, put a layer of peanuts in the container and sparingly sprinkle the dust from the barely open matchbox. A plastic bag can be used over your hand to minimize exposure to the dust. Shake the container or stir the peanuts with a stick to help get the dust evenly distributed in the peanuts.
   - Wash your hands with soap and water after the mixing is completed.

Field days

At the conclusion of the storage trial, field days were conducted at each site to present the results of the trials. A total of more than 200 farmers attended the field days at the nine locations. The field days were organized by the PCVs but presented by a local farmer or extension agent. Each treatment was discussed, with a sample passed around on large trays for farmers to examine. There were shelled samples of each treatment that were separated in small plastic bags of damaged and undamaged peanuts so that the effectiveness of each treatment could be easily observed.

Information gathered from farmers at field days. In the department of Nioro, information was recorded from 90 farmers who attended the field days. The information varied from our previous survey because it covered a wider area.

- Storage containers: 89% of seed was stored in bags, 6% in barrels, and 5% in piles or pits.

- Early removal: 13% of the farmers removed the seed from the field early for storage to reduce infestation by insects.

  This means they recognize when the seed is likely to be infested and will treat their seed peanuts differently than the peanuts they will sell. This fact was not revealed in the previous survey.

- Shelled or unshelled: 40% of the farmers shelled the peanuts before storage; 11% of these farmers were going to store the shelled seed in barrels.

  That 40% of the farmers are shelling the peanuts before storage is a concern because peanuts deteriorate at a faster rate and are more susceptible to insect attack once shelled.

- Treatment: Treatments used by farmers were as follows: methyl parathion, 33%; other chemicals, 33%; no treatment, 16%; neem leaves, 8%; sand, 7%; and other traditional treatments, 4%.

  Neem leaves are being used despite tests that found them to be ineffective. Farmers using neem leaves or no treatment at all must be suffering high levels of loss and should be encouraged to use sand or ash.

  About 10% of the farmers use more than one treatment, often to compare different treatments.

- Follow-up requests: 60% of the farmers requested information or assistance in the ash seed storage treatments, 20% in sand, 13% in chemical, and 3% in the box.

  Many farmers who requested follow-up were using chemicals effectively, but new treatments that are lower in cost appealed to them.

The field days were well received by the farmers and provided the project much needed exposure and feedback. Additionally, the request for follow-up provided an important link with farmers. These contacts will facilitate looking at not only peanut seed storage but also other seed practices and problems.

Phase C. Determination of long-term strategy

Building on the results of last year's storage trials with additional trials and extension is necessary to carry the results into a more practical phase. The second year of the peanut seed storage trials will include the following:

- Emphasize the traditional treatments that worked best (sand and ash) in more traditional and readily available storage containers (rice and jute bags) rather than the plastic bags.

- Assess the effectiveness of the mud brick box in Nioro as it generally performed well in that region.

- Assess the effectiveness of barrel storage since this storage is widely used in the Bignona and to a limited extent in the Nioro area.

- Conduct follow-up with farmers who attended our field days last year and who wish to try one of the storage treatments (or a variation thereof) on his or her own peanuts.

- Carry out general peanut seed storage extension. Our current extension package consists of the following recommendations:

  Early removal from the field
  Thorough cleaning and drying before storage
  Storage in a clean bag off the floor
  Treatment with sand or ash and insecticide if its efficacy can be guaranteed
  A clean and organized storage area
  Regular inspection of the seed to detect storage problems.

Conclusion

A three-phase process was initiated and carried out during this first year. The process will start again as additional testing, extension, and feedback from the farmers is obtained. What has been initiated in the field is the result of the efforts of the whole team involved in the activity, i.e., the farmers, the PCVs, PC staff, and OFSP staff. The research methods permitted feedback and information sharing. Important communication has been initiated with farmers based on problems that they have identified and that we have worked with them to solve. If the trust and confidence established between AFSI/OFSP and the farmers continues, this will further activities to ameliorate farmers' seed problems.

Appendix

Insect Pests of Stored Seed

Storage insects are a major threat to seed storage in The Gambia. As they are very small, they require careful inspection to be detected. The greatest losses are caused by the ones that infest the crop during harvest and then continue to feed and multiply in the storage facility.

The main seed insect pests include *Caryedon serratus* (groundnut bruchid), *Callosobruchus maculatus* (cowpea weevil), *Sitotroga cerealella* (angoumois grain moth, which attacks millet, maize and rice), *Sitophilus oryzae* (rice weevil), and *Sitophilus zea maize* (maize weevil, which also attacks sorghum). The following includes insect descriptions, life cycles, feeding habits, and control.

A. ***Caryedon serratus* (peanut weevil)**

Description: Adult 4-7 mm; reddish brown with dark marks; strong flier. It is the only insect that can penetrate the peanut shell.

Life cycle: Lives in legume trees and storage structures. Attacks groundnuts in the field from the moment they are lifted from the ground. Female lays 50 eggs attached to the outside of the groundnut shell. Larva hatches and penetrates the shell, feeds on the kernel, and emerges from the groundnut to pupate in ovoid cocoons. It has a 50-60 day life cycle. Adult does not feed.

Control: Remove the groundnuts from the field as soon as they are in a fit state to do so. Treat with a suitable pesticide while bagging or placing in containers.

B. ***Callosobruchus maculatus* (cowpea weevil)**

Description: Adult 2-3 mm; tan with dark spots.

Life Cycle: Lives in legume trees and stored cowpeas. Attacks cowpeas as they mature. Female attaches 60-90 eggs to cowpea pods. Larva hatches and penetrates the pod, feeds on the cowpeas and emerges from the cowpea to pupate in a cocoon. It has a 25-35 day life cycle. Adult lives 10 days.

Control: Harvest cowpeas as they mature, shell before storage; use neem, peanut oil, pesticides.

C. *Sitotroga cerealella* **(angoumois grain moth)**

Description: Adult 5-8 mm; wing span, 13-19 mm; fringed wings.

Life Cycle: Lives in stored grain. Attacks the seed as it matures. Female lays around 150 eggs on the outside of the seed. Larva penetrates the seed, feeds on it, and pupates in it. Adult emerges and starts laying eggs 2-3 days later. It has a 20-25 day life cycle.

Control: Harvest promptly; sanitize around storage areas; thresh the seed; use neem and pesticide control.

D. *Sitophilus oryzae* **(rice weevil)**

Description: Adult 2-3 mm; four reddish spots on wing covers; good flier.

Life cycle: Female bores hole in kernel; deposits egg and seals the egg inside; lays up to 300. Larva feeds on seed, pupates within seed. Adult eats its way out. It has a 20-25 day life cycle.

Control: Harvest promptly; sanitize storage area; use neem and chemicals.

E. *Sitophilus zea maize* **(maize weevil)**

Description: Adult 3-5 mm; four distinct red spots on brown wing covers; weak flier.

Life Cycle: Same as rice weevil.

The primary defense against these insects is to prevent them from infesting the seed crop by timely harvesting and prompt removal from the field. If there is a problem, early detection and prompt treatment is necessary.

The second group of storage insects are those that infest the seed once it is stored. The source of the infestation is old stored seed, poor storage sanitation, or nearby storage structures. Most of these insects attack only previously damaged seed.

A. *Tribolium confusum* **(confused flour beetle)**

Description: Adult 3-4 mm long; brown color; does not fly. Larva has forked appendage on last segment. Larva and adult feed on the germ. Adult secretes a compound with a sharp, acrid odor.

Life Cycle: Female lays 300-500 eggs outside of kernels. Larva feeds on broken kernels and grain dust. Pupation occurs outside the kernel with no cocoon formed. From egg to adult takes 30-35 days.

Control: Prevent infestation through storage sanitation.

B. *Rhyzopertha dominics* (lesser grain borer)

Description: Adult 3 mm long; cylindrical body; brown color. Larva has thoracic legs. Larva and adult consume germ and endosperm. Larva and adult produce quantities of dust which has a sweetish musty odor.

Life Cycle: Female lays 400-500 eggs outside the kernels. Larva chews into kernel and develops into adults. Life cycle of 30 days.

Control: Prevent infestation through storage sanitation.

C. *Ephestia cautella* (almond moth)

Description: Adult 16 mm long; brown and gray wings. Larva is pinkish with small dark spots. Larva consumes germ; adult does not feed. Webbing is evidence of infestation. Moths active at night.

Life Cycle: Female lays about 200 eggs within 3-4 days of emergence. Larva leaves threads of silk as it moves about and mature larva leaves food supply to pupate in silken cocoons. Life cycle is about 30 days.

Control: Storage sanitation, cleaning and sunning of storage bags.

D. *Corcyra cephalonica* (rice moth)

Description: Adult wingspan 15-25 mm, brown or gray in color; larva 13 mm, dirty white with legs; pupa 8-9 mm long, pale yellow, in a silken cocoon commonly covered with food particles.

Life Cycle: Female lays 150 eggs. Eggs hatch in 3-10 days. Life cycle is 4-6 weeks. Webbing in the grain produced by larva denotes its presence.

Control: Storage sanitation.

Seed Germination Test for Farmers and Extension Agents

A farmer plants a field and only a few plants come up. If the problem is the seed, a simple germination test would show it. It is important to know the germination percentage of seed to determine their suitability for planting and to determine the planting rate. For example, if 85% or more seed germinates, fewer seeds need to be planted than if 65% to 70% germinates. Seed that germinates below 50% should not

be used for planting without increasing the seeding rate or reselecting the seed to remove the low germination seed (damaged, immature, or discolored seed).

A seed testing laboratory is not necessary to conduct a fairly accurate germination test. This can be performed using materials available in the village and thus provide a valuable service by verifying the seed germination before planting.

Obtaining a representative seed sample for testing. The number of seed tested should be at least 100 but not more than 200. These seeds should be selected randomly from the seed to be planted. If more than one container (bag) of seed is to be used for planting one field, take some seed from each bag. Push your hand into the open bag of seed, and take two or three small handfuls from different parts of the bag. If more than one bag is to be sampled, take one or two small handfuls of seed from each bag. Mix the small samples thoroughly in a small container, then count out the number of seed to be tested.

If seed are threshed or shelled just prior to planting take a few seed from several different heads of sorghum or millet or shell enough groundnuts to get enough seed to test. It is important to get seed from several different heads or from several different places in the storage unit because seed may not germinate the same in all parts of the stack, bundle, or bag.

When to perform the test. Seed is often tested after harvest to verify quality before it is purchased as seed. For our purposes, testing is most useful 2 to 3 weeks before planting in the field. Seed, even quality seed, can deteriorate dramatically during improper storage.

Where to perform the test. The test can be performed in a container or in a garden or field. A container of sand is recommended since conditions of moisture and pests are difficult to control in the field. A calabash, wooden tray, or large bowl can be used as the container. The container can be kept inside the house or outside but not in the sun. Make sure that there are holes in the bottom of the container to allow for drainage to keep the seed from getting too wet. The container should allow for a depth of 10 to 12 cm of clean sand. The container should be large enough to allow seed of maize and groundnut to be planted 2 to 3 cm apart and small seed such as millet, sorghum, rice, or sesame to be planted about 1 cm apart. After the test, the container should be dumped and allowed to dry.

Performing the test. After the clean moist sand is placed loosely in the container and smoothed out, the seeds should be planted in uniform rows using a small stick to make the hole for each seed. Large seed such as maize, peanuts, or cowpeas should be planted 2 to 3 cm deep; small seed such as millet, sorghum, rice, and sesame should be planted 1 to 1-1/2 cm deep. After planting, water the seed and check daily to be sure that the sand does not become too dry for seed to germinate. Keep the sand damp but not extremely wet. You may want to cover the container to keep the sand from drying out. Seedlings should begin to emerge in 3 to 5 days after planting.

Determining the germination (%). Count the number of seedlings as they emerge. The speed at which the seedlings emerge is an indication of the vigor of the seed. If some seedlings emerge rapidly and others much later, the vigor of the seed is mixed. Some seedlings may die within a few days after emergence. These seedlings would probably have died had the seed been planted in the field.

Testing Germination

Variety	First count	Last count
Rice	5 days	14 days
Millet	3 days	7 days
Cowpeas	5 days	8 days
Groundnuts	5 days	10 days

If you planted 100 seeds and 76 emerged, then the germination is 76%. If 200 seeds are planted and 180 emerge, the germination is 90%. Seedlings that emerge after 2 weeks represent lower quality seed.

Glossary

Breeder seed. It is a small quantity of seed of very high genetic purity produced by the plant breeder. It also is the first generation of a variety that has been selected by a seed program for multiplication to produce foundation seed.

Certified seed. Seed produced to maintain the genetic identity of crop varieties under an officially designated system that includes provision for seed multiplication and distribution.

Cross-pollinated species. A heterogeneous species that was allowed to inter-pollinate freely during seed production. Also referred to as open pollinated.

Dormancy. A physical or physiological condition of a viable seed that prevents germination even in the presence of otherwise favorable conditions.

Equilibrium moisture content. The condition when the moisture content of the air and the seed remains constant with no movement of moisture either into or out of the seed.

Field emergence. Emergence of seedlings from seeds planted in the field; usually refers to the percentage of seed planted in the field that germinate and produce seedlings strong enough to emerge through the soil.

Foundation seed. The progeny of breeder seed, used as planting stock for registered and certified seed.

Genetic purity. Trueness to type or variety, usually referring to seed.

Germination. The resumption of active growth by the embryo culminating in the development of a young plant from a seed.

High-input agriculture. Agricultural systems that are capital intensive and depend on high levels of fertilizer, pesticides, and herbicides.

Hybrid. The first-generation seed of a cross produced by controlling the pollination of two or more inbred lines. The second generation or subsequent generations from such crosses are not regarded as hybrids.

Hybrid vigor. The increase in vigor of hybrids over their parental inbred types, also known as heterosis.

Improved varieties. A population of plants with similar uniform and stabile characteristics that are the result of plant breeding programs at an international, regional, or national level. These varieties are developed for such factors as higher yield, disease resistance, and earlier maturity.

Inert material. One of the components of a purity test, it includes all nonseed material such as chaff, dirt, stones, and other seed material as classified by seed testing rules.

Isolation requirement. The minimum distance between a seed multiplication field and other crop varieties or weeds necessary to prevent contamination, especially between cross-pollinated species.

Lodging. Refers to the condition when plants fall over before harvesting as a result of being too tall with weak stems, or from high wind. Lodging is common with traditional varieties.

Low-input agriculture. Agricultural systems used by resource-poor farmers that depend on minimal inputs such as fertilizer, pesticides, and herbicides.

Mass selection. The process of improving a population by harvesting seed from superior plants in each generation and bulking them together for sowing to produce the next generation.

Moisture content. The weight of water in a seed or sample expressed as a percentage of the total weight of the seed at the time of determination.

Noxious weed. Weeds that are particularly difficult to eradicate and that are liable to be introduced in a field of crop seed.

Offtype. A plant in a seed crop that deviates from the norm for the cultivar but does not obviously belong to another cultivar or species.

Perfect flower. Flowers that have both male and female organs.

Photoperiod insensitive. Refers to plants that flower at a predetermined number of days after emergence regardless of day length.

Photoperiod sensitive. Refers to plants that require a certain day length for flowering. These varieties may require a long growing or may flower very early in the growth cycle.

Pollination. The transfer of pollen grains from an anther to a stigma followed by fertilization of the ovule.

Progeny. Offspring.

Replacement rate. The frequency with which the seed of a variety should be replaced in order to retain seed quality, particularly genetic purity and yield.

Rogue. An offtype plant or the act of removing offtype plants and other undesired plants from a seed field.

Sampling. The taking of small quantities of seed from a large quantity for the purposes of quality assessment.

Sealed storage. Refers to storage in a sealed container. In hermetic storage, no gas or moisture can enter or escape.

Seed. Mature ovule consisting of an embryonic plant together with stored food, all surrounded by a seed coat.

Seedling. A young plant grown from a seed.

Species. Group of closely related organisms. *Oriza sativa*, for example, is the botanical name for rice: *Oriza* is the genus and *sativa* is the species. Another species belonging to the genus *Oriza* is *Oriza glaberrima*, African rice from West Africa.

Stand establishment. Refers to the plants that are still growing 10 to 15 days after emergence, a critical phase in seed and crop production of getting uniform, vigorous growth with an appropriate plant density.

Variety. A population of plants with similar characteristics that display uniformity and stability.

Viability. Indicates that a seed contains structures and substances, including enzyme systems, that give it the capacity to germinate under favorable conditions in the absence of dormancy.

Vigor. The vitality or strength of germination, especially under unfavorable conditions.

Weed. Any plant in a place where it is considered to be a nuisance.

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