Abstract

Seed drying, processing and storage are essential operational components of a seed program/industry. Adequate provisions for establishment of the necessary capability in these areas must be included in seed program development plans from the very beginning.

Traditional practices of seed drying, cleaning and storage are not adequate for the needs in a developing seed program of any substantial scope. At least an intermediate level of mechanization and technology is required.

Drying of seed is a most critical operation in any location, but especially so in the humid tropics and subtropics. In these areas, seed must be harvested early at high moisture contents in order to minimize field deterioration and infestations with insects. High moisture content seed in a warm environment will rapidly deteriorate unless they are dried promptly and properly. Since drying is technically more difficult in a warm, humid climate, expert advice and assistance should be enlisted for design and operational check of drying systems.

Drying is one seed operation that cannot be delayed. It must commence within a few hours after harvest and continue without interruption until it is completed. Accordingly, drying capacity should be sufficient for maximum anticipated daily loads.
Processing operations which follow drying are not so urgent as drying. Thus, it is neither necessary nor desirable for processing capacity to be equal to drying capacity. Since processing rate is usually slower than drying rate, provisions must be made for temporary bulk storage of dried seed until they are processed.

Some kinds of seed are dried before final threshing: maize, beans, peanuts, etc. In these cases shelling and threshing must be completed before cleaning and other processing operations. Shelling and threshing are always possible sources of mechanical injury to seed, thus, care must be exercised in these operations to minimize injury.

After shelling and threshing as necessary, seed are cleaned, size graded (when required), treated and packaged. In its basic form, a seed processing system consists of a seed cleaner, a treater, and a bagging-weighing device with necessary elevators and conveyors to move seed into and away from the various machines. Depending on the characteristics of the contaminants that have to be separated and the need for size-grading, other cleaning and grading machines are added to the basic processing system. These include length, width and thickness separators, aspirators, and gravity separators.

Adequate provisions for storage of seed are a common feature of successful seed production-marketing program regardless of their geographical location. A successful seed storage program is the product of careful, informed planning and implementation. The principal factors affecting seed storage are temperature and relative humidity, or seed moisture content. For storage
periods greater than about 8-10 months some conditioning of both temperature and humidity to lower levels is needed in most of the less developed countries. When climatic conditions are very unfavorable, conditioned storage is often necessary for any period longer than 2-3 months. Expert advice and assistance ought to be enlisted in developing storage plans and in the design of storage facilities.

Several "guidelines" for progress derived from experiences in seed program development over the past 15 years are recommended to the Symposium.
SEED PROCESSING AND STORAGE

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New and improved crop cultivars become an important agricultural input only when good quality seed of such cultivars are available to cultivators in adequate quantities at the right time and place. Seed processing and storage are integral components of the technology involved in transforming the genetic engineering of the plant breeder into a supply of improved seed. In its broadest sense seed processing encompasses all the steps involved in conditioning and preparation of harvested seed for terminal storage and/or distribution and marketing: drying, shelling, handling, bulk and interim storage, preconditioning, cleaning, sizing, upgrading, treating and packaging. Seed drying as well as many critical interim periods of storage are, therefore, operationally within the scope of processing. Only the terminal phase of storage during which period cleaned, packaged seed are in the warehouse or distribution channel has an identity separate from processing. For clarity and convenience, however, drying, and storage are considered somewhat separately from other aspects of processing in this paper.

Now that the broad boundaries of our subject have been generally defined, it is necessary to digress briefly into the broader arena of seed program/industry

1/ Journal Paper No., Mississippi Agricultural and Forestry Experiment Station. This paper is based on experiences of the author and his colleagues in technical assistance activities in the less developed countries under several contractual arrangements between the U.S. Agency for International Development, Washington, D.C. and Mississippi State University from 1958 to the present.
development because our subject has relevance only within this larger perspective.

In traditional agriculture as practiced for many generations and still prevalent in many areas of the world, the cultivator sets aside a portion of each season's harvest to plant the succeeding crop. Practical, successful methods and procedures for selecting, drying, cleaning and storing seed were developed and passed on generation-to-generation. As long as the local crop "cultivars" were also passed on from generation to generation with little or no improvement in their qualities, there was—and is—little to be gained through the introduction of any degree of the "advanced technology" of seed production and supply. Efforts in the 1950's and early 1960's to establish seed programs in traditional agricultural systems most often turned out to be a step backward rather than forward because the seed "produced", "tested", "processed" and "distributed" were seldom better and usually worse than that saved by cultivators in the traditional manner. This development was surprising and most unsettling although it should not have been so considering the many problems that beset beginning seed programs and the enormous advantage to the cultivator in having to save and care for only a small quantity of seed—enough for his own planting.

Several important lessons emerged out of the disappointing and often wasteful seed program development activities in the 1950's and early 1960's which must not be forgotten. The first lesson is: a seed program/industry can become established only within the frame of a progressive agriculture based on substantial and continuous improvements in cultivars of major crops, fertilizer
supply and usage, crop protection, water management and all the other ingredients of the agricultural improvement "package". Unfortunately, it does not follow that a seed program/industry will become established or will be easy to establish whenever and wherever this suitable frame exists. Indeed, the organization of this International Seed Symposium is a testimonial to the great difficulties that presently stifle seed program/industry development activities, even at a time when conditions for such development are seemingly favorable and becoming more so in so many countries. In an important sense, conditions in many countries are not just favorable for a seed production and supply system, they demand it! Inadequate supplies of seed of dramatically improved and adapted cultivars frustrate and impede agricultural progress in far too many countries.

Traditional cultivator-seed-saving practices are not adequate to the needs of accelerated agricultural development, although they can be adapted to play an important role in it. Accelerated agricultural development - the common theme in many country plans - requires the development and implementation of an orderly system for the efficient and effective multiplication and dissemination of improvements in crop cultivars to adapted crop lands as these improvements are effected: in other words, a seed program/industry is needed.

The second important lesson that emerged out of experiences in the 1950s and early 1960s is that a seed industry does not arise full formed out of some isolated act or activity regardless of how well-intentioned such act or activity is, or how lavishly it is supported. A processing plant does not a seed industry
make, neither does a drying facility nor a well conditioned store room. They are only links in a chain with little utility unless anchored to seed multiplication-production on one end and seed distribution-marketing on the other. In retrospect, it appears that those of us who were engaged as advisors on "seed" in the less developed countries in the 1950's and early 1960's were afflicted with the acute myopia of the specialist. We "saw" seed program development in terms of our specialities in seed testing, certification, processing, storage, etc. And, there were no suitable models or precedents in our experience to correct our vision. Even now, I do not believe we "see" seed program/industry development as clearly as we should. Nevertheless, I am convinced that our vision is sufficiently improved to move along a progressive path.

The third and final lesson we should have learned from earlier times is one weaved into the fabric of the whole development experience. Hopefully, we have learned the value of the old virtues: patience and persistence. A seed industry evolves in response to needs and opportunities. It can be imposed only under certain conditions.

In the remainder of this discussion we will first examine the role and importance of seed drying, processing and storage against the background projected above. Then a few selected examples of implemented activities will be discussed and recommendations offered.
Need for Seed Drying, Processing and Storage Technology

Seed drying, processing and storage are essential components of a seed program/industry. Thus, seed program development plans must provide for establishment of a capability in these areas in concert with other components of the seed program such as seed multiplication and production, seed control, seed marketing, etc. Serious questions do arise, however, regarding the degree or level of drying, processing and storage technology that should be introduced and implemented. Some persons feel that only a very limited level of technology is needed, while others contend that conditions demand the most modern technology. As in most cases, the appropriate path probably lies between these two extremes.

There are at least four compelling reasons for the introduction of at least an intermediate level of technology into seed drying, processing and storage operations at the very beginning stages of seed program/industry development.

(1) Some degree of concentration of seed production is necessary and inevitable in a seed program/industry. Concentration is necessary because the close management and rigorous quality control essential for production of quality seed is just not possible when production units are small, numerous and widely dispersed. While concentration of seed production in larger units facilitates management of production, it overwhelms traditional drying, processing and storage arrangements and facilities. A few kilograms of seed can be hand threshed, dried on a small drying floor, cleaned by winnowing and sieving with a wicker tray, further hand sorted as desirable and stored in an earthenware vessel in a dry part of the house. Handling 10 metric tons (mt) of seed in a similar manner, however, is exceeding difficult, 100 mt becomes unmanageable, and 1000 mt is unthinkable. Consequently, mechanization of at least some of the more critical operations in drying, processing, and storage is necessary whenever seed production goals exceed a few tons.
(2) Conditions within the relatively large masses of seed that issue from concentrated seed production can rapidly become very unfavorable for maintenance of seed viability. Biological heating within the seed mass, which is very detrimental to viability, will occur when seed moisture is above 15-16% unless the seed are dried promptly and properly. The microenvironment in a mass of high moisture seed is also very favorable for development of storage molds and insects. Because of these situations, the efficiency and effectiveness of seed operations, especially those involved in drying and storage, become more critical as the quantity of seed handled becomes larger. The gains in efficiency and effectiveness required can be achieved only through mechanization.

(3) Most of the less developed countries are situated in the subtropics or tropics. Climatic conditions in these zones are much less favorable for seed production, drying and storage than they are in temperate or arid regions. Under adverse conditions every operation in the seed program/industry from production through distribution must be accomplished efficiently and effectively to minimize deterioration and loss of germinability. There is little margin for laxity or error. Seed drying and storage are also technically more difficult in warm-humid climates than in temperate climates. For these reasons, mechanization and associated technology must not only be introduced into seed drying, processing and storage operations, they must also be adapted and modified to perform satisfactorily under adverse climatic conditions.

(4) Appearance is not often accorded a high place among the quality attributes of seed. Yet, it is an important consideration in the psychology of promotion and marketing of improved seed. The cultivator examining improved seed does not see short stiff straw, disease resistance, fertilizer responsiveness, or high yields. He sees seed - seed that are basically the same size and shape as the seed he has been planting. When the improved seed are weathered and discolored, trashy, shriveled, insect damaged and so on, the cultivator's suspicions are aroused. Regardless of the inherent superiority of the seed, they simply do not look improved. If the cultivator does buy the seed, plants them and gets a poor stand of plants or no stand because of low germination, whatever confidence he has been able to muster in the development program will be destroyed. There are numerous examples of severe setbacks in development programs arising out of poor germination of seed supplied to farmers. It is most important, therefore, that the seed of improved cultivars supplied to farmers be varietally pure, clean, of overall good appearance, and high enough in germination to produce a good stand of plants. Attainment of
these goals requires timely harvesting and threshing, prompt drying, thorough cleaning and good storage conditions, all of which can only be achieved through the introduction of some degree of mechanization and associated technology.

Seed Drying

Drying of seed is a most critical operation in any location, but especially so in the humid tropics and sub-tropics. The importance of drying and its critical nature are closely related to the timing of harvest and to events that precede harvest.

The physiological quality of seed, i.e., viability and vigor, is highest at the time they reach maturity. Seed maturity, which is usually more precisely termed "physiological maturity" or "functional maturity", corresponds to the point of maximum dry matter accumulation. Since physiological maturity is attained in most species of crops at seed moisture contents too high for efficient harvest by either mechanical or hand methods, seed are - in effect - stored in the field during the period between maturation and harvest. Since conditions in the field are seldom favorable for seed storage, except possibly in arid-irrigated regions, some deterioration is inevitable. The degree of deterioration or reduction in germination and vigor of seed prior to harvest is determined by the interval between maturation and harvest, i.e., how long harvest is delayed after maturation, and climatic conditions during the period.

In the developed countries, the problem of field deterioration of seed has been substantially moderated by mechanization of harvest, which permits earlier
more rapid harvest, artificial drying, and shifts in production of seed of certain
crop species to arid-irrigated regions. Few of the less developed countries,
however, have taken or can presently take advantage of all these practices
because of limited foreign exchange for purchase of essential equipment, lack of
maintenance facilities, small production units, inadequate land resources,
expensive fuel and so on. Nevertheless, earlier harvest and artificial drying
must become established practices in the less developed countries. There is
simply no other way to efficiently produce and successfully store the quantities
of improved seed needed for accelerated agricultural development.

Harvesting seed early to minimize field deterioration means that moisture
content of harvested seed will generally be above 16-18%. Unless the seed are
promptly and properly dried to a moisture content of 13% or less, germination
will be drastically reduced offsetting and more, the advantages of early harvest.

Seed drying is a highly specialized, technical operation. The drying system
must be designed to perform satisfactorily under the prevailing climatic
conditions, which are likely to be much more rigorous than those in the
temperate climates of North America and Western Europe where grain and
seed drying technology was developed and most types of drying units are
manufactured. It is important, therefore, that the services of a knowledgeable,
experienced drying specialist be obtained and utilized in the facility establishment
phase of seed program/industry development.
Many different types of systems are used for drying agricultural products. The forced air drying system, however, is the type most suitable for seed. Unheated (natural) or heated air is used depending on climatic conditions and the amount of moisture that has to be removed from the seed. Generally, unheated air is satisfactory for reducing seed moisture content 2-4% except when high temperature and humidity reduce the drying capacity of the unheated air to the extent that drying is dangerously prolonged. In most subtropical and tropical climates the drying air should be heated.

A forced air drying system essentially consists of five components:

1. **Fan or blower** - the fan or blower forces air through the seed and must be capable of delivering the required volume of air against the resistance of the seed. The fan is powered by electricity or a gasoline motor. The air forced through the seed transfers heat to the seed for evaporation of moisture and transports evaporated moisture out of the seed mass.

2. **Heater** - the heater provides the heat energy needed for drying and increases the drying capacity of the air. Heat can be generated by combustion of natural gas, L.P. gas, fuel oil, and, less satisfactorily, wood, coal, straw, hulls, etc.

3. **Drying bed unit** - the drying bed unit consists of a plenum or air chamber separated from the seed holding bin by various types of ducts or, preferably, a perforated floor. Heated air enters the plenum and is forced through the layer of seed in the holding bin by static pressure. There are many variations of shape, size, and construction of drying bins and accessory ducting.

4. **Controls** - controls are of two types. The heater or degree of heating is controlled by a thermostat or combination of thermostat and humistat to ensure that drying air temperature does not exceed 43-45°C. Other controls activate various safety devices to minimize the fire hazard.
(5) Loading and unloading — seed have to be loaded into the dryer bin and then unloaded when drying is completed. While these operations can be performed by manual labor, efficient use of the drying system requires at least partial mechanization of loading and unloading.

Generally, the drying system is located within a facility complex that includes the processing plant and store rooms. This location is satisfactory provided the harvested, threshed seed can be delivered to the dryer within a few hours.

If this is not possible, then the drying system should be situated close enough to production centers to permit commencement of drying within a short time after harvest. Drying is one operation that cannot be delayed, and once it is begun it must be carried to completion. This will mean continuous drying day and night, holidays and weekends, until the harvest is completed and all the seed are dried to moisture contents safe for bulk storage.

The drying system should also be designed with a capacity based on peak or maximum drying load rather than average drying load. This can, however, easily result in an unnecessarily large, complex and expensive drying installation unless production is scheduled so as to spread harvest over a reasonable period.

Competent management is, probably, more important for drying than for any other seed operation. When drying is not done properly and on time all the good work in seed multiplication, production and harvesting can be lost in a few hours.
Although the critical need for drying has been emphasized, it should be recognized that there are some situations in which drying is not necessary even in the less developed countries. Cropping patterns across North Africa are such that crops mature during a hot dry period. Since field deterioration of seed is minimal, harvest can be delayed until the seed have dried sufficiently on the plant unless shattering causes excessive loss of seed. Even in subtropical or tropical zones some crops mature during the dry period and require only minimal drying if any. In both cases cited, however, aeration of the seed while they are in bulk storage is beneficial in preventing stratification of both temperature and moisture in the seed mass. Aeration systems are similar to forced air drying systems except that no heat is used and air volumes are very low.

Seed Processing

Processing operations which follow drying are not as urgent as drying. Thus, it is neither necessary nor desirable for processing capacity to be equal to drying capacity. Processing can be accomplished over a much longer period of time. Since processing rate is slower than drying rate, some type of temporary bulk storage is needed to hold the dried seed until they can be processed and packaged. Drying bins or aeration bins are very satisfactory in bulk storage of seed. The drying unit or aeration fan can be turned on periodically to redry the seed if high ambient humidity causes seed moisture to increase or to prevent
the migration and concentration of moisture within the seed mass brought about by wide fluctuations in temperature.

After drying, several processing operations may be necessary to prepare the seed for terminal storage, distribution, and marketing: shelling, threshing, and preconditioning as necessary, and cleaning, sizing, treating, and packaging.

**Shelling, Threshing, and Preconditioning**

Some kinds of seed are dried before final threshing. Maize is dried in the ear, sorghum is often dried in the panicle, peanuts and beans are dried in the pod. In these cases, shelling and threshing must be completed before cleaning, sizing, treating, and other processing operations. Maize is normally shelled immediately after drying to reduce the volume of material entering bulk storage. Similarly, sorghum dried in the panicle and beans dried in the pod are threshed soon after drying. Peanuts, however, should not be shelled until just before planting because shelled seeds do not store nearly so well as those in the pod, especially when mechanical shellers are used. Very often it is preferable to do whatever cleaning and sorting can be done with peanuts in the pod and to market them in an unshelled condition. Shelling and treating can then be done by the cultivator just before planting.

Shelling and threshing are always sources of possible injury to seed, whether they are done mechanically or manually. Thus, care must be taken to minimize the mechanical injury associated with these operations.
Often it is desirable—sometimes necessary—to remove appendages from seed to facilitate cleaning, treating, and planting; for example, the awns of *Avena* and *Hordeum*. Machines are available that will remove appendages of this sort and, thus, precondition the seed for cleaning. These machines are variously called "debearders" or "scourers."

**Cleaning**

Basic seed cleaning is usually accomplished with an air and screen (sieve) cleaner. Cleaners of this type are available in many variations of size and capacity, but essentially consist of integrated sieving (screening) and air separation systems. Seed are fed from a hopper at a controlled rate into a stream of air (optional) which removes dust and small lightweight contaminants, then pass over a series of vibrating, inclined sieves (screens) with openings of various sizes, and finally, through a final blast of air to remove remaining rotten, broken, and immature seed. Undesirable material is removed from the seed stream by the top air, each screen, and the bottom air. The clean seed are discharged at the bottom of the machine, where they can be bagged directly or elevated into a holding bin above the treater or weighing-packaging machine.

In its simplest form, a seed cleaning system consists of an elevator to lift seed into the hopper of the air and screen machine, the air-screen cleaner itself, a second elevator to lift the clean seed to a holding bin, a treater, and a bagging-weighing device. Depending on the characteristics of the different
contaminants that have to be removed, other cleaning machines are added to this basic cleaning system to form a cleaning or processing line. These might include length separators, width and thickness separators, aspirators, gravity separators, and so on. Each machine is linked to the ones before and after it in the processing line by conveyors, which may be gravity flow spouting in multi-level plants, so that the seed flow continuously through the entire line. Thus, the various cleaning machines have to be reasonably well matched for capacity or cleaning rate.

The importance of conveyors and elevators for efficient movement of seed into, through, and away from the main cleaning line should be recognized. We have seen far too many processing plants equipped with excellent cleaning machinery, but which were miserably inefficient since all seed conveying was done manually because hand labor was plentiful and inexpensive. Regardless of how plentiful and inexpensive hand labor might be, it is simply too inefficient to substitute for mechanization within the processing line.

In many situations and for certain kinds of seed, the basic, simple cleaning system mentioned above is all that is needed to clean seed and enhance their appearance so that they will "look improved". Additional cleaning should be done only when it can be justified on the basis of results.

When additional cleaning is justified, the processing line should be designed so that there is substantial flexibility in operations and procedures. Those kinds and lots of seed that require only basic cleaning should not have to pass through
all the subsequent machines in the line simply because they are between the air­
screen cleaner and the treater or weigher-bagger. Rather, it should be possible
to bypass these additional machines when they are not needed.

Specialized cleaning machines that are especially useful include length,
width, and thickness separators to remove contaminants that are larger or
smaller than the good seed in these dimensions, and aspirators or gravity
separators to remove rotten, insect damaged, and immature seed. Gravity
separators are especially effective in improving germination and vigor of seed
lots by separation of rotten, badly diseased, low density seed, but they require
considerable operational skill.

Sizing

During or after cleaning it may be desirable to size grade certain kinds of
seed to improve plantability and/or quality. Size grading becomes more impor-
tant as planting is mechanized. Some size grading is usually done on maize
seed and peanut seed. Small, immature, and shriveled seed are, of course,
removed from all kinds of seed during basic cleaning.

Sizing is accomplished with width, thickness, and length separators of the
type mentioned above in connection with cleaning. The basic air-screen cleaner
can also be used to size grade certain kinds of seed.
Treating

Treatment of seed with various chemicals to protect them from storage and soil insects (insecticides), to disinfect the seed of certain diseases, and to protect the seed from soil-borne micro-organisms (fungicides) is a recommended practice for many kinds of seed: maize, wheat, peanuts, sorghum, rice, etc. Since the dosage and uniformity of coverage of the chemicals are important, treatment is best accomplished with a seed treating machine that applies the chemicals at the desired rate and distributes them uniformly over the seed.

Seed treating is usually done during processing before packaging. It should be recognized, however, that seed treatment chemicals are usually poisonous and treated seed not used for planting cannot be used for food, feed, or industrial purposes. Because of this situation it is often desirable to treat only a portion of the seed during processing (the highest quality seed with assured market) and to delay treatment of the remainder until a later time when it is known that the seed will be needed and are still of good enough quality for planting. In some cases, treatment material can be supplied to the cultivator along with the seed so that he can treat them before planting.

Strict precautions must always be taken to safeguard the health of the workers and to prevent the diversion of treated seed to food, feed, and industrial markets. In this connection, the slurry type treatments are preferable to dust formulations, as they do not pollute the air in processing plants as much as the dusts.
Packaging

Packaging is the final step in processing. Weighed quantities of clean seed are packaged in cloth, paper, or plastic bags. The bags are closed by sewing, gluing, or heat sealing, and seed labels or tags are attached. Bags are an expendable supply item and should not be reused for seed. They may, of course, be used for other purposes if the seed were not treated.

In most seed operations, a bagger-weigher machine should be used. These range from relatively simple and inexpensive devices which consist of an adjustable dump hopper, platform scale, and portable bag closer, to systems with integrated weighing-dumping systems, bag closer, and bag conveyor. The new valve-type multi-wall paper bags do not require closure but must be packed with a special valve-pack machine. Bagger-weigher machines even of the semi-automatic type will generally permit bagging of seed at the rate the clean seed are discharged from the cleaning line, while a completely hand bagging, weighing, and sewing operation will not "keep up" with rate of cleaning and becomes an impediment to efficiency.

Seed Storage

Adequate provisions for storage of seed are a common feature of successful seed production-marketing programs regardless of their geographical location. Seed in storage represent not only a program or company's potential return on substantial investments in research and development, production, processing,
facilities and promotion, but also an input vital for continued agriculture improve-
ment.

A successful seed storage program does not just happen. It is the product of careful planning just as is successful seed production or an effective seed promotion campaign. To be effective planning for seed storage must be thorough and based on a clear concept of the objective of storage, an understanding of the determinants of seed quality and the process of deterioration, knowledge of pertinent principles of environmental engineering, data on local climatic conditions, and a careful analysis of specific seed storage needs.

The objective of seed storage is to maintain viability and vigor of the seed from harvest to planting. Maintenance of viability and vigor should be emphasized because even the best of storage conditions cannot improve these qualities. Accepting this objective of storage, it is obvious that a complete storage plan or program must encompass more than just a physical facility and attention during the period that packaged seed are in the storehouse. Other periods of storage often overlooked and/or neglected can have more influence on seed quality than the packaged seed storage period.

Factors Affecting Storage of Seed

Storage problems are among the most common and serious ones that plague seed programs in the less developed countries. A major cause of these problems is the relatively adverse climates—high temperature and humidity—that prevail in
most of the countries, but it is not the only cause. Almost equally important is the generally low quality of seed produced. Field deteriorated, improperly dried seed do not store well even under good conditions. Put another way, good packaged seed storage facilities do not compensate for delayed harvest, and improper, poorly managed drying, bulk storage, handling and processing. The first principle of successful packaged seed storage is to store clean, high quality seed.

The contribution of subtropical and tropical climates to seed storage problems should not be minimized. High temperature and humidity affect seed directly and indirectly. Seed are hygroscopic so that their moisture content is in equilibrium with ambient relative humidity. When relative humidity is high, seed moisture content is also high; when it is low, seed moisture content is low. A high seed moisture content combined with warm temperature greatly accelerates the natural processes of degeneration of biological systems (the seed) so that under such conditions seed rapidly lose vigor, and somewhat later, their capacity to germinate.

Storage molds and insects are also more prevalent and active in warm, moist environments and can quickly exact their toll of seed quality. The converse, of course, is also true: storage molds and insects are less active under dry, cold conditions.

Inherent longevity or storage potential varies among species and even among cultivars within a species. For example, rice seed are inherently long-lived and
this characteristic probably accounts for the fact that rice is the only major seed propagated crop in many humid tropical areas. Soybean seed, on the other hand, are inherently short-lived and just barely survive from harvest to planting (7-9 months) even in mild climates. Inherent differences in storability among seed kinds must be considered in planting for storage.

Requirements for Seed Storage

The general prescription for seed storage is to store them in dry, cool conditions. Just how "cool" and how "dry" is determined by the kind of seed, period of storage, initial quality of the seed, and the reduction in quality that is acceptable.

Storage like drying is a complex component of the seed program which must be planned for within the context of local environmental conditions. In most seed programs several "qualities" of storage are needed ranging from open or ambient to highly conditioned. Expert advice should be sought early in program/industry development to assist in formulation of short and long range plans for seed storage.

Types of Seed Storage

Types of seed storage in terms of construction, size, etc., are endlessly variable. From the standpoint of utility and quality of the storage environment, however, three basic types are recognized: bulk storage, packaged seed open storage, and packaged seed conditioned storage.
Bulk storage refers to storage of seed en masse as contrasted to storage in bags or other packages. The temporary or holding storage needed after drying, or after harvest but before processing in cases where drying is not necessary, fall into the bulk storage category. Bulk storage is usually in bins which may be constructed of wood, concrete, brick or metal. It is not conditioned except under the most unusual conditions, but is often equipped with an aeration system.

Packaged open storage differs from bulk storage only in that the seed are usually cleaned and in bags, and the storage structure is a building or warehouse rather than a bin. Except in very adverse climates the major portion of commercial seed of basic crops is stored in an open or unconditioned storage warehouse. The quantities of seed involved are usually too large for complete conditioned storage of all the seed except when absolutely necessary.

In conditioned storage, temperature and/or relative humidity are moderated in the storeroom by air cooling, dehumidification, moisture vapor proof packaging or combination of these.

Effective conditioning of a storage environment requires, first of all, a well constructed room with some insulation and moisture vapor proofing. Air cooling can be accomplished by a self-contained room type air conditioner when only a moderate temperature drop is needed, or by industrial type refrigeration units when very low temperatures are desired. Room type air conditioners of the proper type also dehumidify, usually enough to eliminate any need for special
dehumidification. A well designed refrigeration system will also dehumidify the air down to a relative humidity of 40%. Unfortunately, the expertise needed to design a system of this type is usually not available, and humidity rises to very high levels in cold rooms. For this reason, use of desiccant dehumidifiers in combination with a refrigeration system is recommended to achieve the cold, dry conditions needed for long term storage of valuable seed stocks.

Another method of "conditioning" the storage environment is through the use of moisture vapor proof packages. Seed are dried to about 10% (8% or less for oil and vegetable seeds) and packaged in plastic bags or metal containers. Since seed moisture content will determine the relative humidity in the package, relative humidity will be below 50%.

In most seed program/industries three levels of storage conditions will be needed. These are:

(1) **Short term storage** - Conditions that will maintain seed quality from harvest to the next planting season (1-9 months) are needed. A moderate degree of conditioning might be necessary in areas where climatic conditions are especially adverse. In such cases, room type air conditioners are very satisfactory.

(2) **Intermediate term storage** - Conditions are needed to "carry over" some seed from harvest to the second planting season, which may be a period up to 18 months. Conditioning will be needed in most subtropical and tropical
successful implementation of these activities within the context of an on-going, productive seed program/industry. Poor development of other essential components of the program such as production and distribution-marketing have limited both the degree of implementation and success of seed drying, processing and storage operations in many countries.

Our laboratory has advised on and designed seed drying-processing-storage facilities in many countries in most geographical areas. Some of these facilities were constructed and equipped and are operational. Others are under construction, while still others were dropped in the planning stage in favor of different priorities.

The three facilities described below were not necessarily selected on the basis of their success. Rather, they were selected to illustrate the general types of facilities needed in a developing seed program industry.

Peru - La Molina Facilities

In the late 1960's our laboratory assisted with the design and development of seed drying, processing, and storage facilities for the Programa Cooperativa Investigaciones en Maiz, Universidad Agraria, La Molina, Peru. La Molina, which is located just outside Lima, has a very favorable climate for seed production, drying, processing and storage. It seldom rains.

The facilities were designed specifically for maize seed although there is no reason why they can not be used for sorghum, rice, or other kinds of seed. The facilities designed consist of an ear maize dryer with loading and unloading systems, a maize seed cleaning, size grading, treating and packaging plant,
and an open storage unit (Figures 1 and 2).

Since rain is not a problem in La Molina, the processing plant is of the "open air" type with only a roof above for shade. After drying the seed are shelled and cleaned with an air-screen cleaner that also removes the very large and very small seed. The clean seed are then size graded into several sizes with cylindrical, rotating screens, treated with a dust formulation, and packaged in multi-wall paper bags. The packaged seed are stored on an elevated floor, covered with only a roof, which is satisfactory for one season's storage. Carryover of seed, however, would require some conditioning of the storage environment as humidity is relatively high and temperature is warm.

The processing plant and storage shed were constructed first. The dryer was added later. The total facility effectively serves the needs of La Molina's aggressive and successful maize breeding, seed certification, processing, marketing and production program.

The La Molina facility is illustrative of a basic specialized (maize seed) operation in a relatively favorable climate.

Honduran Facilities

During the late 1960's we also assisted with design and development of two seed drying, processing and storage complexes for DESURRAL, MOA, Honduras, located at San Pedro Sula and Tegucigalpa. The San Pedro Sula complex was designed primarily for maize and rice seed, while the Tegucigalpa facility was designed for bean and sorghum seed. Both plants were constructed in 1968-69.

The San Pedro Sula complex contains an ear maize dryer, a sack-type rice
seed dryer, processing plant, conditioned storage rooms, a cold room for storage of genetic materials, and laboratory and offices (Figures 3 and 4). The facility was remodeled in 1970 to provide for limited size grading of maize.

Climatic conditions at San Pedro Sula are very adverse for seed storage. Thus, the large, moderately conditioned store houses are of special interest. Ten store rooms each with a capacity of about 100 mt bagged seed were constructed - five rooms in each of two buildings. The two buildings were constructed with an elevated concrete floor, concrete block walls, insulated ceiling and tight fitting doors. Each of the 10 rooms was equipped with a room type self-contained air conditioner and a refrigerated coil condensation type dehumidifier. Cooling and dehumidification capacity was calculated to maintain a temperature of about 22°C and a relative humidity of 50-55% in each room. Subsequent performance data indicated that design conditions were achieved, and that maize and rice seed can be stored successfully for periods up to about 18 months. Major problems have been maintenance for air conditioners and dehumidifiers.

The Tegucigalpa facility is very similar to the one at San Pedro Sula except that the bean seed dryer is of the sack-type. Since temperature is lower at Tegucigalpa than at San Pedro Sula, the storerooms were equipped only with dehumidifiers with provisions for addition of air conditioners as needed.

Both Honduran facilities have been operating successfully for several years. They have much more capacity than is presently being used.

Philippines - BPI Maligaya Facility

A model seed drying, processing and storage facility was constructed at
the BPI Maligaya Station in 1970-72. Development of this facility represented a rather unique cooperative effort including the Bureau of Plant Industry, UNDP-FAO, USAID/Philippines and our University under contract to AID/Washington. We designed the facilities, the FAO specialist advised on construction, program development, and on-site training, USAID and UNDP assisted with financing, and the staff of the facility was trained in our laboratory. The total facility, which also includes a seed testing laboratory, was established as an operational unit and training center. In these capacities, it should admirably serve the needs of the developing seed program/industry in the Philippines in the years ahead.

Guidelines for Progress

The technical, organizational and managerial problems that have attended development and implementation of seed drying, processing and storage operations in the less developed countries could be dwelled on at great length. And, a host of specific recommendations and alternatives could be advanced toward solution of the various problems. The result I'm afraid, would be a tedious litany of mistakes and obvious suggestions that would soon become rather boring.

In lieu of a long discourse on specific problems and solutions, I have gathered together several of the basic lessons we have learned from experiences during 15 years of consultation and technical assistance in the less developed countries. They are cast in the form of "guidelines for progress". Several of these guidelines or lessons were presented in the introductory section but are repeated here for emphasis. The remainder have appeared in other publications.
They are equally applicable to both seed program/industry development as a whole and to specific components of the program.

(1) A seed program/industry can become established only within the frame of a progressive agriculture based on substantial and continuous improvements in cultivars of major crops. Other elements of the improvement package, of course, are also essential.

(2) A seed program/industry is constructed of a number of essential components, each of which is vital to the over-all success of the program. The program is never stronger than the weakest or poorest developed component.

(3) Planning, review and evaluation are continuous. One plan, a half-hearted review and evaluation are not sufficient to build a program. They can at best only start a program. The "plan" must be revised, expanded, contracted, and redirected on the basis of periodic assessments of progress with emphasis on identification of constraints and changing needs.

(4) Skilled, knowledgeable manpower is basic. The initial efforts in the seed program should be scaled to developing manpower resources. Conversely, manpower resource development through training must be accorded high priority in the time frame of over-all development. Since skilled, knowledgeable manpower will be limited in most countries, initial implementation must also be limited.

(5) Early development efforts are concentrated. Diffusion of effort, fragmentation of resources, and dispersion of operations are not ways to build a program. Initial efforts and available resources must be concentrated, centrally managed and closely coordinated until the program attains the "critical mass" stage and becomes self-sustaining. Only then can the program be broadened rapidly in an orderly, efficient and successful manner. Until the program demonstrates the capability of producing 100 tons of good quality seed, 10,000 tons should not be attempted or programmed!

(6) The quality of inputs into the program is more important than their quality. If a program is built with makeshift, piecemeal and haphazard inputs then its outputs are unlikely to be different. Construct the program with quality inputs - good workers, good equipment, good organization, good support.
Should resources be insufficient to support more than a very modest but good effort - then settle for that.

(7) The time-frame is realistic. The "crash program" approach to building a seed program/industry has not succeeded. Ample time for development must be allotted. A modest base solidly constructed a few years in advance of the anticipated urgent need for large volume seed production is the best approach.
Figure 1. Layout of La Molina, Peru, maize seed plant.
Figure 2. Maize seed drying system, La Molina, Peru.
Figure 4. Flow of seed in San Pedro Sula, Honduras, facility.