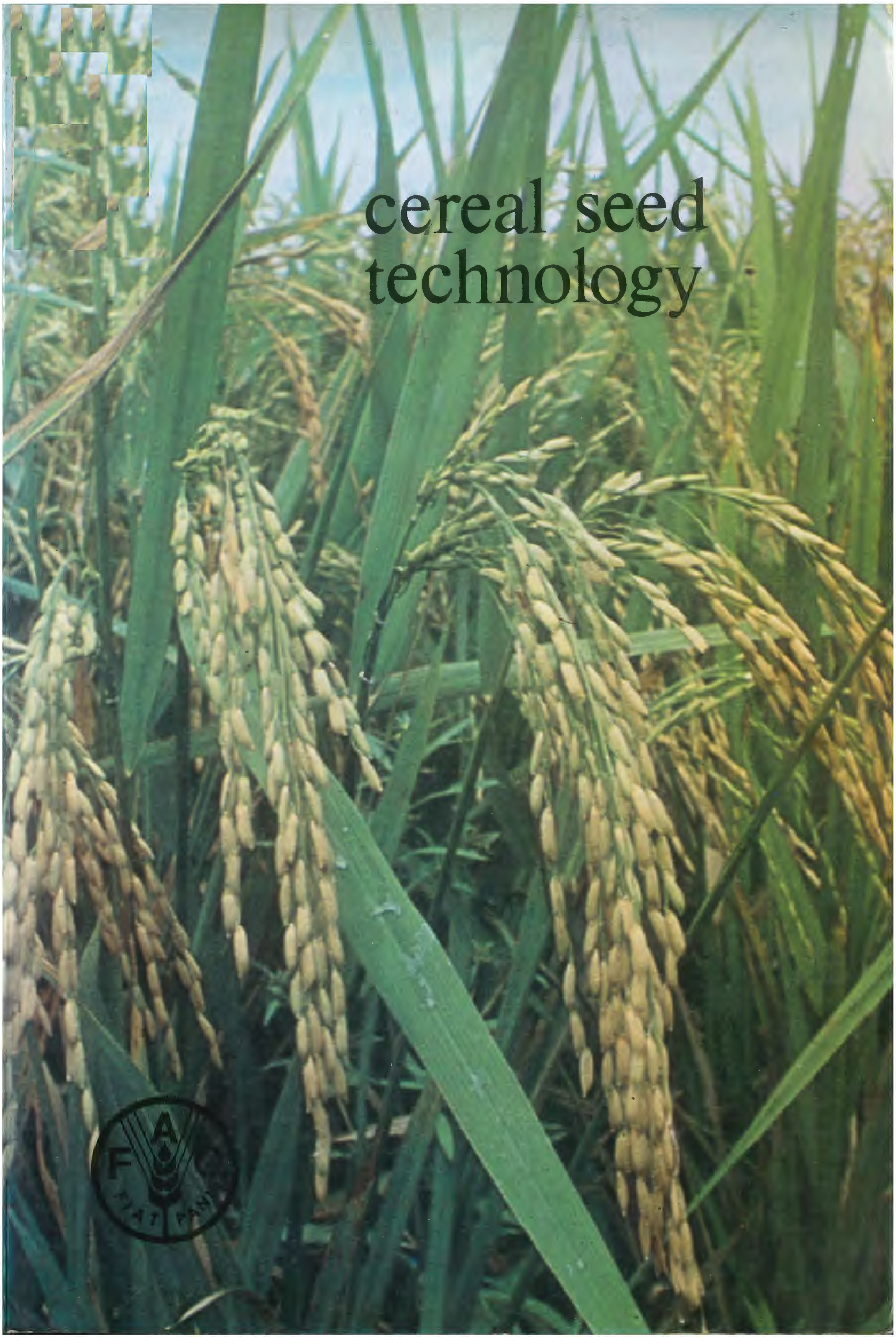
cereal seed technology



Seed technology comprises the methods of improving the genetic and physical characteristics of seed. It involves such activities as variety development, evaluation, and release and seed production, processing, storage, and quality control. These are the main components of a healthy seed industry, still limited to the world's developed countries. But crop farmers in the developing countries are also relying more on bought seed, actually the least costly of their basic production inputs. This manual therefore presents the latest findings on cereal seed with particular reference to the developing countries, where increased agricultural production, especially of food crops, remains a major goal and crop failures can cause human and economic disaster.
The text, contributed by cereal seed experts, is aimed at plant breeders, seed growers and processors, quality control officers, seedsmen, extension agents and students. Chapters 1, 7, and 8 are accompanied by appendixes containing more technical details. Specialists and students will benefit from the chapter by chapter list of references and further reading.

CEREAL SEED TECHNOLOGY

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CEREAL SEED TECHNOLOGY

A MANUAL OF CEREAL SEED PRODUCTION, QUALITY CONTROL, AND DISTRIBUTION

edited by
WALTHER P. FEISTRITZER

Plant Production and Protection Division, FAO

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The information in this manual is derived from technical papers prepared for the 4th FAO/SIDA Training Course on Cereal Seed Production, Quality Control, and Distribution. While it presents knowledge obtained from research and experience, it is not possible for the Food and Agriculture Organization of the United Nations to assume responsibility for statements contained herein, nor does the mention of any product constitute its recommendation.

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FOREWORD

FAO has received requests from many member countries to place greater emphasis on the production and distribution of quality seed, which they now recognize as one of the main inputs required to achieve increased crop productivity, yields, and cropping intensities. The expanded use of quality seed in conjunction with other inputs, such as water and fertilizers, is essential to the progressive intensification of agriculture; however, the production and utilization of quality seed are still limited in many developing countries owing to inadequate technical knowledge.

This volume attempts to provide a world-wide review of the principles and objectives, organization, and methods of cereal seed production, quality control, and distribution. In addition, the reader may find the bibliographical references and further reading for each chapter (see pages 231-238) helpful for deepening his knowledge in this field.

Technical papers prepared by recognized authorities and presented at the 4th FAO/SIDA Training Course on Cereal Seed Production, Quality Control, and Distribution have been used in this manual. This course was financed by the Swedish International Development Authority and organized under the auspices of FAO and the Swedish State Seed Testing Institute in Lund, Sweden, from 1 June to 30 September 1972.

FAO is grateful to SIDA for its interest in and support of the development of technical and managerial skill in quality seed production and supply and to the many people who collaborated in this effort, in particular to Prof. H. Esbo, Director of the Swedish State Seed Testing Institute and his staff.

This volume, which was prepared with financial assistance from SIDA, discusses the latest findings on cereal seed and pays particular attention to the situation in developing countries. It is designed primarily for those involved in cereal seed production and utilization, including plant breeders, seed growers, processors, quality control officers, dealers, and exten sion agents; it will also be of value to agricultural students.

FELIX ALBANI, Director
Plant Production and Protection Division

PREFACE

About nine thousand years ago, somewhere in the foothills of the Zargos mountains in the Near East, men began to put cereal seeds into the soil with a view to harvesting crops. The early Egyptians stored seeds, under governmental supervision, for sowing during the following crop season. The early Romans recognized the advantages of pure seed for crop production. The first organized seed trade started in Germany, France, and Great Britain late in the 17th century and early in the 18th century. The first seed testing station was established in Germany approximately one hundred years ago.

Since then, remarkable developments have been made in seed technology. Yet, functioning seed industries have been limited mainly to the world's industrialized countries with highly developed agriculture. The main problem of developed countries today is not to increase agricultural production, but to decrease the number of people depending upon agriculture and provide those remaining on the farms with higher incomes. Under these conditions, seed of the highest quality is required to make the new technology profitable and to maximize productivity.

In developing countries, increased crop production is the main issue, as the food supply will have to be increased annually by 4 percent to keep pace with population growth and to meet the demand for food; however, in most developing countries the increases have been well below this level in recent years.

A provisional seed-status review made in 1970 by FAO, covering ninety-seven countries, indicated that more than 90 per cent of the seventy-three developing countries studied would need to develop or strengthen their seed production and supply systems.

Seed differs from other inputs in highly significant ways, and these differences create special problems which have to be taken into account in seed industry development. Most important, seed is a living thing, subject to genetic and other transformations and death. Therefore, the maintenance of genetic characteristics and physical quality demands well-defined procedures and control from breeding to farm delivery.

Quality seed is a produce of specialized farming and thus does not lend itself so well to purely mechanical controls, as may be exercised with most other agricultural inputs. In addition, as agricultural systems develop and as needs increase or change, seed varieties must be replaced rapidly at the farmer level. These facts determine, to a very large degree, the particular nature of the seed industry's development.

The present manual endeavours to specify the essential functions of a seed industry and their logical sequence in terms of national seed programmes. The subject matter covered may be divided into ten broad divisions: variety evaluation, variety release, seed production, seed processing, seed storage, seed marketing, seed testing, seed certification, seed legislation, and extension.

The outline for this manual was prepared by an FAO working group of seed specialists, but the selection of the various subtopics and the allocation of space were left to the discretion of the editor.

In any publication of multiple authorship, it is not easy to maintain uniformity between individual chapters. Therefore, it should be borne in mind that the statements and emphasis in the individual chapters primarily reflect the views of the editor and coordinators and may not strictly adhere to those of the contributors.

The editor wishes to express his sincere appreciation to the coordinators and contributors of the individual chapters for their cooperation. The editor is greatly indebted to Dr. D. Böringer, President, Bundessortenamt, Bemerode, F.R. Germany, and Mr. C. Hutin, Director, Institut national de la recherche agronomique, La Minière, France, for their constructive comments on the chapter *Variety Release*. Special thanks are extended to Dr. H.J. Mittendorf of the FAO Marketing and Credit Service and to Mr. E.A. Summers of the FAO Education and Training Service for their respective reviews and valuable comments on the chapters *Seed Marketing* and *Extension Programme for the Promotion of Quality Seed*. The linguistic editing assistance given by Mr. A.F. Kelly, Deputy Director of the National Institute of Agricultural Botany, Cambridge, England, is gratefully acknowledged.

WALTHER P. FEISTRITZER, EDITOR

CONTRIBUTORS

H.A. AL-JIBOURI, FAO Regional Office for Asia and the Far East, Bangkok, Thailand

A.H. BOYD, College of Agriculture, Mississippi State University, Mississippi, U.S.A.

R. BRADLEY, FAO/UNDP, Montevideo, Uruguay

H.F. CREUPELANDT, Agricultural Services Division, FAO Headquarters, Rome, Italy

J.C. DELOUCHE, College of Agriculture, Mississippi State University, Mississippi, U.S.A.

G.M. DOUGHERTY, College of Agriculture, Mississippi State University, Mississippi, U.S.A.

J.E. DOUGLAS, The Rockefeller Foundation, New Delhi, India

H. ESBO, Statens Centrala Frökontrollanstalt, Solna, Sweden

W.P. FEISTRITZER, Plant Production and Protection Division, FAO Headquarters, Rome, Italy

E.J. FUENTES, Seminarios Panamericanos de Semillas, Santiago, Chile

B. HALLERSTRÖM, Agricultural College, Department of Agriculture, Engineering, Uppsala, Sweden

L. KÅHRE, Statens Centrala Frökontrollanstalt, Solna, Sweden

O. LANDENMARK, Statens Centrala Frökontrollanstalt, Solna, Sweden

M. LEIN, FAO/UNDP, Khartoum, Sudan

W.D. MAALOUF, Rural Institutions Division, FAO Headquarters, Rome, Italy

R.K. MATTHES, College of Agriculture, Mississippi State University, Mississippi, U.S.A.

A. MUDRA, FAO/UNDP, Bucharest, Romania

P. NEERGAARD, Danish Government Institute of Seed Pathology for Developing Countries, Copenhagen, Denmark

F. OGADA, National Agricultural Research Station, Kitale, Kenya

H. POTTS, College of Agriculture, Mississippi State University, Mississippi, U.S.A.

K.W. RUSHING, College of Agriculture, Mississippi State University, Mississippi, U.S.A.

A. SINGH, Indian Agricultural Research Institute, New Delhi, India

T.Y. SUNG, FAO/UNDP, Teheran, Iran

O. SVENSSON, FAO/UNDP, Bangkok, Thailand

J.R. THOMSON, Agricultural Scientific Service, Department of Agriculture and Fisheries for Scotland, Edinburgh, Scotland

W.H. VERBURGT, Kenya Seed Company Limited, Kitale, Kenya

K.P. WAGNER, Plant Production and Protection Division, FAO Headquarters, Rome, Italy

A. WOLD, International Seed Testing Association, Ås, Norway

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CEREAL SEED TECHNOLOGY

1. VARIETY EVALUATION

by A. Mudra

The term *variety*, equivalent to *cultivar*, is defined in the International Code of Nomenclature of Cultivated Plants (1969) as "an assemblage of cultivated plants which is clearly distinguished by any characters (morphological, physiological, cytological, chemical or others), and which when reproduced (sexually or asexually), retains its distinguishing characters."

The agronomic value of a variety depends on many characteristics, the most important of which are:

(*a*) high yielding ability;
(*b*) high response to improved cultivation methods (e.g., fertilizers);
(*c*) high quality of the products;
(*d*) resistance to diseases and pests;
(*e*) resistance to adverse environmental factors (frost, drought, lodging, etc.);
(*f*) suitability for mechanized cultivation and harvesting methods.

In the assessment of new varieties, several steps may be distinguished. The first is the evaluation carried out at the breeding station by the breeder himself. Normally the breeder handles many experimental lines. By observation and by employing various testing methods over several years he selects the most promising and develops them into new varieties.

The trials in the breeding station are not sufficient, however, for objective determination of the agronomic value of the new varieties. Therefore, a second step must follow: the varieties are tested in several localities outside the breeding station. These trials are conducted either by the breeder or by a public or private agency.

In a third step the new varieties are tested for adaptability at a large number of locations with a wide range of soil and climatic conditions. In most countries these trials are conducted by a neutral agency, to ensure objective comparison of the new varieties with commercial varieties already on the market. The object is to make sure that only those varieties having a higher agronomic value than the best existing varieties are released.

Finally, in a fourth step, the released varieties are continuously tested to check whether they maintain their original characteristics during the whole period of their commercial use.

Organization

Variety evaluation agencies

The organization of variety evaluation varies from one country to another. The most common form is an independent governmental agency charged with final evaluation of varieties. In some countries the agency has its own experimental stations, but in most cases the trials are conducted under agency supervision at the experimental centres of other organizations (e.g., governmental institutions for agricultural research, universities, agricultural schools).

In countries that have no special agency for variety evaluation the task is performed by the governmental organization for agricultural research at its experimental stations.

In a few countries variety evaluation is conducted by private agencies, (e.g., breeders' or seed growers' associations). These private agencies may be government controlled, but if they are not, the growers of the varieties must rely on the integrity of the private agencies.

The best form of organization is undoubtedly the establishment of a governmental agency, or at least an independent committee, charged with supervision and control of all activities related to variety evaluation.

Variety field trials

Regardless of the form of organization, the task of variety evaluation is the conducting of comparative trials with new varieties. Called "variety trials," these are field experiments in which the new varieties are compared with the best commercial varieties. The comparison is made through field observations during the growing period, yield determinations, and laboratory analyses (Fig. 1).

The trials must be performed in the area where the new varieties are to be grown, and at least one experimental centre (e.g., an experiment station) must be in charge. In addition to trials at the centre, there must be trials at a large number of locations in the area surrounding the station.

FIGURE 1. Comparative yield trials of rice varieties.

Thus the tasks of a centre are:

(*a*) to conduct variety trials at the centre;
(*b*) to select suitable testing locations in the area;
(*c*) to choose the experimental design for the trials and to prepare plans for the experiments;
(*d*) to prepare the seeds, the necessary equipment, and the means of transportation to the testing locations;
(*e*) to lay out the trials and supervise them up to harvesting and threshing;
(*f*) to analyse the experimental data and interpret the results.

To enable a variety testing centre to fulfil its tasks properly, its location must be carefully chosen. It must be representative for soil and climatic conditions in the area and of sufficient size, with the conditions as uniform as possible. In irrigated areas sufficient water must be available.

Apart from the technical requirements, due consideration must be given to the living conditions of the staff. Thus the centre should be easily accessible and not too far from a bigger locality with schools, hospitals, recreation facilities, and other amenities. There is no need to emphasize the importance of suitable buildings (for laboratories, storehouses, residential quarters, etc.), water, and electricity. Also, adequate equipment is needed (see pages 14-17).

A testing location outside the centre may be no more than a piece of land in a farmer's field that is large enough to lay out a simple variety trial. It is most important that these locations be as numerous as possible. The results obtained from simple trials conducted at a large number of locations may furnish more reliable information on the agronomic value of the varieties than a sophisticated, highly accurate trial at one centre only.

The evaluation of varieties at the centres and testing locations should be continued for a period of at least two and preferably three years before final assessment.

Manpower costs

The cost of experimental work is extremely variable, not only from one country to another, but also at different locations within a country; therefore it is impossible to give a cost estimate that will be generally valid. The following estimates of the man-hours required for wheat variety trials at the Research Institute for Cereals, Fundulea (Romania) are given for a single variety sown in six replicates on plots of about 10 m^2 — that is, for an experimental area of about 80 m^2 including paths.

Work	*Man-hours*	*Conditions*
Seedbed preparation	0.20–0.40	Big tractor, good conditions; small tractor, average conditions
Fertilizer spreading	0.05–0.50	Once or twice, by machine or by hand
Marking the plots	0.15–0.50	Nursery side: 5 ha–1 ha
Seed preparation	0.10–0.20	Metering for Øyjord drill by volume, by weight
Seeding (by Øyjord)	0.10–0.20	Twin set or single drill
Labelling	0.20	

Work	*Man-hours*	*Conditions*
Spraying herbicides	0.05–0.30	7.5–m or 2.5–m boom sprayer
Cleaning paths	0.10–1.00	Twice to five times; small or wide paths
Harvesting (by combine)	0.30–0.40	12 plot runs or 6 plot runs
Weighing	0.05	

Thus the manpower requirements per variety vary from 1.30 to 3.75 man-hours depending on the given conditions.

At the Research Institute in Fundulea, the field plot work is highly mechanized, which explains the low man-hour requirements for such operations as sowing and harvesting. Sowing by hand would increase the man-hour requirements ten times; however, this does not mean that by using the Øyjord seeder the cost of experimental work can be generally reduced. The cost of depreciation, maintenance, and operation of the machines is usually higher than the savings achieved by reducing labour time. The use of machines in experimental work has technical rather than economic advantages.

Methods

Planning variety trials

In a variety trial the greatest attention must be given to the correct determination of *yielding ability*, not only because this is the most important variety characteristic, but also because it is extremely complex and affected by many genetic and environmental factors. Yielding ability, although genetically controlled, may be altered by external factors. Therefore the accurate determination of yield is a rather complex statistical problem, which can only be solved by giving due consideration to statistical methods in the planning and execution of experiments.

Planning variety trials includes the choosing of the experimental design, the size and shape of plots, and the number of replications. Discussion of the various experimental designs is not within the scope of this publication, but this information may be found in textbooks on field plot techniques

(Cochran and Cox, 1957; Linder, 1953; Panse and Sukhatme, 1954; Quenuille, 1953; Vessereau, 1960). Here, only some brief indications of the principles of planning yield trials of wheat, rice, and maize are given.

The choice of experimental design is mainly dependent on the number of varieties to be tested. For a small number (e.g., four to six varieties) the *Latin square* is the most suitable design, particularly at testing locations. When about ten to twenty varieties are to be tested, a *randomized block design* may be chosen.

For still higher numbers of varieties (e.g., over twenty-five to several hundred) it is recommended that a design with *incomplete blocks* be selected; otherwise the blocks will grow too large and the variation within the blocks will bias the results. A suitable design is the triple lattice with either three or six replications. The layout of this design is not difficult, and the analysis requires fewer calculations than most of the other designs with incomplete blocks. Such designs should be used only at the testing centre, not at the trial locations, where the number of varieties should be kept small and the design as simple as possible.

The *size* of the plots should be neither too small nor too large. On plots that are too small the variations of individual plants will affect the results. Plots that are too large unnecessarily increase the experimental area and the cost of the various operations (soil preparation, sowing, harvesting, etc.). In general, the plot size varies from 5 m^2 to 15 m^2 for wheat and rice and from 15 m^2 to 25 m^2 for maize. The *shape* of the plot should be long and narrow rather than squarish.

In considering the *number of replications*, the following must be borne in mind: the true yield of a plot is always either higher or lower than the recorded yield. To eliminate this error, the plot yields from the replications of the same variety must be averaged. Obviously the mean yield of several plots provides a better estimate of the true yield than the yield of a single plot. The number of replications may be chosen freely with some designs (e.g., randomized blocks), but with others it is determined by the design type. For most variety trials the number of replications is four to six. Using more than six replicates increases the accuracy of the results, but the gain in accuracy is not always in reasonable relation to the increased amount of labour and cost.

As mentioned before, the yielding capacity of a variety is greatly influenced by environmental factors, including the cultivation method. The response of the varieties to improved cultural practices differs, however. To assess the varietal response (e.g., to nitrogen fertilizer or other improved practices), it is recommended that trials be conducted with combinations of varieties and different treatments, at least at the centres. For such trials *factorial* or *split plot* designs may be employed.

Execution of variety trials

In the conduct of variety trials the following technical operations are necessary.

The first operation in the field is *land preparation*. The system used should not be too different from that which is generally applied in the area. Cultivations must be performed carefully, however, bearing in mind that experiments are sown by implements which require a better soil structure than those used in sowing commercial fields. It is particularly important that the soil should have an even surface and a crumbly structure.

The next operation is *marking* plots, blocks, and replications within the experimental area. This may be done by hand, but it is more practical to use machines, such as tractors fitted with a suitable marking device or even a large drill on which a few coulters have been spaced at intervals corresponding to the plot width. At first the field is marked for plot widths along the whole length of the experiment; then by driving the machine at right angles to the plots, the paths separating the blocks are marked.

The third operation is to *label* the plots. The labels bearing the plot numbers are placed temporarily, and after the completion of sowing, they can be inserted in their final places, usually in front of the first row of each plot.

Sowing is the next operation. This must be done extremely carefully, since it greatly influences the accuracy of the trial. Sowing may be done in different ways: by hand in rows marked by hand or machine; row by row with one-row seeders; with plot seeders of conventional type; and with special plot seeders, which make sowing to some extent automatic. These seeders (Fig. 2) have the advantage of reducing very substantially the time required for sowing, so that seeding may be performed quickly when weather and soil conditions are best. A further advantage of the special machines is that the plants emerge and grow more uniformly, thus considerably reducing experimental error. If rice variety trials are not sown but *planted*, this is done by hand, since no machines for planting experimental plots are available at present.

Weed control on the experimental plots is usually done with herbicides. Mechnical weed control is carried out by hand in wheat and rice trials, while machines may be used in maize trials.

For *harvesting* and *threshing* experimental plots, machines of different types have been developed, particularly for wheat and rice. By using plot combines, harvesting and threshing are done simultaneously with a considerable saving of time and labour. Also, losses during transport of unthreshed material to the threshing place can be avoided.

FIGURE 2. Sowing with a special plot seeder.

Wheat and rice must be *cleaned* after threshing. Maize must be *shelled* (except when harvested by combines) and cleaned. For these operations various machines are available.

If the moisture content of the grain exceeds a certain limit (e.g., 14 percent), the harvest must be *dried* before weighing. Mobile drying units have proved very suitable for this purpose. For *weighing* the plot yields, automatic dial scales are recommended. These allow quick weighing with sufficiently high precision for field trials.

FIELD OBSERVATIONS AND LABORATORY TESTS

Although yield is the most important consideration, it is only one of the various characteristics determining a variety's agronomic value. Other characteristics must also be assessed by field observations and laboratory analyses. Field observations are carried out by taking notes on various characteristics (Fig. 3); some of those for wheat, rice, and maize are given in the following lists.

Wheat

Field observations are made of the following:

Date of seedling emergence
Winter survival (frost resistance)
Development in spring
Tillering capacity
Date of heading
Resistance to diseases such as stripe or yellow rust (*Puccinia striiformis*), leaf or brown rust (*P. recondita*), stem or black rust (*P. graminis*), mildew (*Erisiphe graminis*), loose smut (*Ustilago nuda*; syn., *U. tritici*), covered smut or bunt (*Tilletia caries*; syn., *T. tritici*), *Septoria* spp., and *Fusarium* spp.
Resistance to pests such as frit fly (*Orscinella frit*)
Resistance to lodging
Tolerance of soil salinity
Resistance to drought

FIGURE 3. Making observations and recording data in an experimental wheat plot.

Resistance to shattering
Resistance to sprouting
Date of maturity
Number of days from seedling emergence to maturity.

The conventional system of note-taking for most characteristics uses scores from 0 to 9, where 9 is the best score. Particular systems have been worked out for evaluating disease resistance. Correct use of these systems requires thorough training and experience.

The field notes should be completed by a description of the *morphological* characteristics of the varieties, including plant height and head length, head density and the presence or absence of awns, glume characteristics, and grain colour and size.

In the laboratory the quality of the grain, flour, dough, and bread is analysed. Quality is determined by a large number of individual characteristics, and depending on the available facilities, the following may be determined:

Thousand-kernel weight
Gluten content
Gluten quality (e.g., by the sedimentation test)
Milling properties
Dough quality (e.g., by farinograph, extensograph, mixograph)
Baking quality (baking test, bread volume, porosity, etc.)
Chemical composition (e.g., ash, starch, protein, lysin)

Rice

Field observations are made of the following:

Date of seedling emergence (planting)
Development
Tillering
Resistance to diseases such as blast (*Piricularia oryzae*), leaf spot (*Cercospora* or *Helminthosporium* spp.), and white tip (nematodes, such as *Ditylenchus augustus*)
Resistance to insect pests, such as stinkbug (*Leptocorisa varicornis*)
Tolerance of cold irrigation water
Resistance to lodging
Resistance to drought
Resistance to shattering
Uniformity of grain ripening

Date of maturity
Days from seedling emergence (planting) to maturity

Morphological characteristics worth noting are plant height, length of inflorescence, number of grains, thousand-kernel weight, and shape and colour of grains.

In the *laboratory*, cooking tests are performed and the palatability is evaluated.

Maize

Field observations are made of the following:

Date of seedling emergence
Cold tolerance
Tillering
Resistance to lodging
Resistance to drought
Resistance to diseases such as leaf blight and leaf spots (*Helminthosporium* spp.), Stewarts diseases (bacterial wilt), stalk and ear rots(*Diplodia*, *Gibberella*, and *Fusarium* spp.), smut (*Ustilago maydis*), and rust (*Puccinia* spp.)
Resistance to pests such as ear worm (*Heliothis ormigera*), European corn borer (*Pycausta nubilalis*), and grasshoppers (*Melanophus* and other spp.)
Date of silking
Date of tasselling
Date of maturity
Days from seedling emergence to maturity

Important *morphological* characteristics of maize are plant height, insertion height of the first ear, size and shape of ear, number of grain rows, and colour, type, shape and size of grains.

The *laboratory* analyses normally include the following determinations:

Thousand-kernel weight
Hectolitre weight
Grain consistency
Starch content
Protein content
Oil content
Content of lysin and other amino acids

It is recommended that field notebooks and other lists and registers for entering data on varieties be uniform within the whole country or within a region. The establishment of a punchcard system may also be very useful.

Statistical analysis of data

Any data collected from a variety test may be subjected to statistical analysis, but usually only the yield data are analysed. Statistical analysis of the yield data has a fourfold purpose:

1. To calculate the mean yield of the replicated plots of a variety — which is the nearest value to the true yield.
2. To calculate the experimental error. The magnitude of error greatly depends on how carefully the experiment is carried out, but it is present in any experiment, even the most accurate one. The error shows to what extent the averages may be considered reliable.
3. To carry out the "test of significance," by which are found the limits between which a yield difference may be considered as existing or may be disregarded.
4. By statistical analysis of series of experiments — that is, of variety tests carried out at several localities during several years — it is also possible to calculate some values which indicate the ecological adaptability of the varieties.

The method of statistical analysis depends on the type of design used in the experiment. Every design requires a particular method of analysis, as described in the relevant textbooks. Statistical analysis of the yield data without using mechanized means is difficult and time-consuming. The experimental centres in charge of the analyses should therefore be equipped with electric calculating machines or, better still, with electronic computers, of which inexpensive desk types are now available. In some countries statistical analysis is done at computer centres.

Appendix to Chapter 1: Variety Evaluation

MECHANIZATION OF VARIETY TESTING

by M. Lein and B. Hallerström

Conditions for mechanized work

A well-trained and experienced field staff is essential if the trials are to be efficient. It is particularly important that the supervisor be a good organizer and be able to make decisions concerning the work rapidly and independently.

Good field machinery and an efficient workshop are necessary. Much of the equipment is so specialized that it is impossible to rely on normal maintenance facilities, and special reserves of spare parts and other essentials must be acquired. Hints for the design and equipment of an adequate workshop are given in an FAO Agricultural Development Paper (1960), which deals with some of the fundamental principles of machinery-workshop location, design, and management, including storekeeping and replacement parts control, and lists the essential tools and machines required to maintain in full production the field equipment used on projects.

The design of the trial must be adapted to the available equipment. This often requires that the plots be rectangular with long runs for the machines.

Advantages of mechanized field plot work

The sowing and harvesting periods are the most intensive periods of work in field trials, and it is these that should be mechanized first. If a batch seed drill is used, a larger number of plots can be sown per unit of time. This type of machine cleans itself. A plot combine saves a considerable amount of work.

Saving labour is not so important, however, as the achievement of accurate and uniform trials. As a rule, a certain machine or series of machines will give the required uniformity. The problem is to utilize these to the greatest extent. Rapid transport with convenient loading and unloading facilities is also highly important.

Selection of equipment

Every effort should be made to acquire uniform machinery for all basic operations, such as sowing and harvesting. It may be necessary to use simpler implements in more remote areas, but on the whole the trial results are far more reliable if the methods of working are as uniform as possible. Specially designed machines are mainly used in trials with small plots. Trials with larger plots may often use farm-scale machines, although these generally have to be modified to suit requirements of the trials.

If the yield harvested from the trial is to be used for further selection or seed multiplication, it will be necessary to use specially constructed equipment to keep the harvests separate. Normally, the combination of seed multiplication and yield trials is not recommended.

Standardization of working width

There are several reasons for standardizing plot widths, but considerable difficulties are encountered before this can be completely achieved. First of all, the field equipment is very often used for several different kinds of trials. Another of the main obstacles to the introduction of standardized plot widths is the frequent variation in the working widths of standard machinery. The same problem occurs even with specially designed machines, although not so frequently.

The size of the plot is more or less governed by the precision with which the work can be carried out. A standard working width of 1.25 m has become widespread for cereals and other narrow-spaced crops, and specially built crop machinery for this standard is available on the market.

List of machines

A useful publication is the *Handbook on mechanization of field experiments* (IAMFE, 1972), which contains a list of various types of equipment with short descriptions and the addresses of manufacturers. Another useful reference is *Tools for progress* (The Intermediate Technology Development Group Ltd., 1968), a guide to equipment and materials for small-scale development.

The following list should provide readers with useful information on field plot machinery, but it is not to be regarded as complete or as recommending any particular machine, manufacturer, or country of origin.

Drills for small grain

Øyjord (Norwegian Institute of Agricultural Engineering): batch-type, self-cleaning plot drill, distributing a limited quantity of seed (batch) completely and evenly on a limited area (plot) without any seed remaining. A filling funnel allowing continuous operation, without any stops between plots. Track width adjustable between 112 and 160 cm or between 160 and 210 cm (depending on type); two to fourteen coulters; plot length adjustable from 2 to 15 m or from 2 to 23.5 m (depending on type). Hopper with fluted feeder converts the plot seed drill into a conventional seed drill for continuous sowing. Can be tractor mounted or self-propelled.

SD 5-8 T (Walter and Wintersteiger KG): conventional fluted-wheel metering principle, with easy dumping of unused seed into a tray. Two-wheeled self-propelled machine, lightweight construction. Biggest version (SD 8R) has eight coulters and track width adjustable between 120 and 150 cm.

Hassia plot seed drill: conventional fluted-wheel metering principle. Two-wheeled machine, available as self-propelled machine or for pulling by animals. Biggest version has 125-cm track width and nine coulters.

Seedmatic Elite (Walter and Wintersteiger KG): used for single-head progenies only (e.g., for testing homogeneity of varieties). Machine with automatic cartridge feeding. Self-propelled, 125-cm track width, and six coulters. Six single-head progenies (one per coulter) sown at once on row lengths of 70-300 cm.

V-belt drill (Craftsman Machine Co.): used for single-head progenies. A rubber belt forms a V trough, into which the seed is fed. Belt moved by means of a gear from the drive wheel, distributing the seed on the desired row length. Several versions, ranging from one-row hand-pushed drill to multi-row power-driven drill.

Sembdner: one-row sowing machine, useful for many purposes.

Ordinary tractor-mounted seed drills: preferably with cogged feed rollers and a gearbox for regulating the rate. (As the hopper must be well-filled to ensure accurate delivery, at least 1 kg of seed should remain after the sowing is completed.)

Drills for maize

Plot drills for maize are all based on commercial drills, with different alterations, in particular for quick dumping of unused seed. Plot versions are available locally as "tailor-made" machines.

Fertilizer distributors (broadcasting)

Conventional tractor-mounted spreaders are used for ordinary top-dressings.

Disc fertilizer spreaders with tray-shaped discs give very even distribution, except on hilly land.

Distributors with cogged rollers work more accurately on hilly land. Some models have a variator for regulating the rate.

Recently an Øyjord seed drill has been converted into a batch-type fertilizer spreader, which appears to be working well.

Sprayers

Plot sprayer PSG 600 (Walter and Wintersteiger KG) is an accessory to the

SD 8R plot seed drill, onto which it can be mounted. It has a 50-litre container, a piston pump, and a 6-m sprayboom.

Dusters

Knapsack engine-driven mistblowers are best suited for general dusting and even spraying of the entire trial area.

Cutterbar mowers

Cutterbar mowers should be selected for use with one-axle garden tractors. The mower attachment should be symmetrically front-mounted. There are various solutions to the problem of collecting the mowed material.

Threshers

Vogel (Allan Machine Co.): self-cleaning universal (all-crop) thresher, with peg-drum cylinder (optional: bar drum) 50 cm in width, straw shaker, and fan. All-

FIGURE 4. Threshing wheat and cleaning the grain from an experimental plot.

steel construction on a one-axle chassis (Fig. 4). Thresher powered by a combustion engine. The thresher can be used also for rice experiments.

2 TD (Saat und Erntetechnik GmbH): self-cleaning cereal thresher (except rice) of unconventional design, with two enclosed bar drums. Straw and threshed grain blown by a powerful fan into a cyclone separator. Completely enclosed thresher.

Combines for small grain plots

The plot combines mentioned here are produced commercially. All of them are claimed to be self-cleaning.

Sampo 10 (Rosenlew and Co.): conventional farm combine with 2.14-m cutting width and a compressed-air cleaning system.

MF 30 System Rautenschlein (Massey Ferguson GmbH): conventional farm combine with 1.75-m cutting width and a compressed-air cleaning system. (Other conventional farm combines can also be rebuilt for use in field trials.)

Hege 125: specially designed plot combine with 1.25-m cutting width, VW-engine powered. Self-cleaning by means of a conveyor belt which transports the cut crop to the bar-drum threshing cylinder, and a second conveyor belt which transports grain, chaff, and short straw to the air duct of a winnowing fan.

Seedmaster Universal (Walter and Wintersteiger KG): with exchangeable headers on cutting tables 1.25, 1.50, and 1.75 m in width. Working principles similar to Hege plot combine.

Maize pickers

Several commercial pickers have been locally adapted for plot harvest as specially made machines.

Maize shellers

Piccolo maize sheller (Amos): small, compact sheller with beaters, the 360° concave consisting of round iron rods. Riddle box with sieves attached. A few corners where grain may remain can easily be smoothed to make the sheller self-cleaning. Powered by electric motor or combustion engine.

Bamby maize sheller (Ets. Bourgoin Siki): conventional working principle with beaters in a sieve-bottomed housing, cob-ejecting pegs on the same axle, and winnowing fan. The basic unit is produced in many versions as regards drive (electric motor, combustion-engine power take-off), transport (stationary, transportable, tractor-hitch), and feeding and grain delivery (gravity, auger).

2. VARIETY RELEASE

by O. Landenmark

The primary aim of plant breeding is to create new cultivars which can increase the production of crop per unit area. When a new and superior variety has been bred, it is important that it come into wide use as soon as possible. Thus it should be released with the least possible delay. The organization of plant breeding differs from country to country; new cultivars may be developed by governmental institutes, by private research institutes or firms, or by private persons. Between the creation and marketing of a cultivar it must be subjected to some form of release procedure. In many countries release is restricted by laws or regulations, whereas in others it is left solely to the breeders' discretion. The concept of the term "release" in this connection thus ranges from mere appearance on the market to an elaborate process involving official agencies.

Official agencies become involved in cultivar release for two opposite reasons: one is to protect the farmer against new cultivars which have been insufficiently tested; the other is to protect the breeder against misuse of his cultivars. Both reasons have initiated governmental action, particularly in countries with private plant breeding. In developing countries, where plant breeding is mostly governmental, special release regulations are rare. The need for official regulation of cultivar release and how far restrictions should be imposed can be argued. The United States of America and Sweden are examples of countries which differ widely in their attitudes to this question. In the United States there are almost no restrictions for marketing a new cultivar, whereas in Sweden the marketing of a new cultivar of an agricultural crop is forbidden until it is approved by a government committee.

Official regulation of the release of cultivars is a modern concept. National rules on this matter are quite new in many countries. In some European countries, however, they have existed for forty years or more, as is simply demonstrated by the predominant use of the breeder's name as a variety denomination in both older and newer cultivar lists from the different countries. Moreover, the cultivar name has remained the same regardless of continuous genetic changes in the cultivar, and this is still a dominant feature of plant breeding in many countries. It should, however, be clearly separated from the breeding and release of new and distinct cultivars. To clearly distinguish between these two aspects of breeding, the definition of a cultivar (synonymous with "variety") in the International Code of Nomenclature of Cultivated Plants (1969) should serve as the basis on which to formulate cultivar release regulations.

Release in countries without official marketing regulations

Before a breeder decides to market a new cultivar he has to test its qualities and obtain information about its agricultural or horticultural value. On the basis of preliminary tests the breeder selects the best lines for comparative trials, which are often placed at different locations in order to get a first idea of the adaptability of the cultivar to different climatic conditions. If the breeder finds that the test results are good enough according to his own judgement, he can decide to multiply the cultivar and release it. The extent to which the use of a cultivar will spread depends upon how it is accepted by the farmers, who choose according to their own preferences.

In countries without regulations for cultivar release a notable feature of the seed trade is the flourish of advertisements, pamphlets, and other publicity at the first marketing of a new cultivar. This is especially true for the United States, but it is also common in other countries where plant breeding is partly private, partly official.

A plant breeder is always interested in gaining official recognition of his cultivars, which will in turn support his own activities in publicizing them. Therefore, even in countries without regulations for cultivar release, breeders often optionally seek to have their cultivars tested officially. In fact, this has led to the development of systems of cultivar release regulations.

The system of cultivar release without any kind of official restrictions can function very well in practice. This is especially true in countries with several competing private plant breeders or breeding institutes. The release of poor cultivars will cause financial losses to the plant breeder, and his reputation will suffer. Therefore, under this system, farmers generally have a good choice of reliable cultivars, and there is no special need for protection of the buyer, provided that the average farmer has a good education. On the other hand, when plant breeding is concentrated in one governmental institute and multiplication is organized through an official seed programme, often only very few cultivars are available; therefore farmers cannot always be sure that these cultivars are reliable enough for all possible growing conditions in the country. Thus, for the protection of the farmer, regulations for cultivar release are important in countries where plant breeding is governmental. The prevailing use of a single cultivar without proven superiority over a number of years creates risks of failure — for instance, from disease epidemics.

Release in countries with official marketing regulations

Official regulations for release are combined with some form of registration, which can be voluntary or compulsory and may be based on varietal distinctness or agricultural value or both. In the case of voluntary registration, unregistered cultivars may also exist on the market. This is not permitted where registration is compulsory. The only provision for registration based on varietal distinctness is that the cultivar be distinct, homogeneous, and stable. Requirements for homogeneity and stability vary between different countries and different species. Provisions also vary for the agricultural value of a cultivar. Some countries have no requirements, and some have moderate requirements, while still others register only new cultivars which are superior to all those previously registered.

Compulsory registration of cultivars based on both varietal distinctness and agricultural value, with strict requirements for homogeneity and stability, as well as high standards for yielding capacity, is the most rigid form of cultivar release. It is in every case advantageous to the owner of the cultivar. Registration based on both criteria — especially compulsory registration — protects seed buyers from the risks of purchasing poor cultivars.

Variety release committee

Decisions on registration are usually entrusted by law to an official committee. The members are normally selected from official agencies or institutes connected with crop husbandry or horticulture. They should be independent from those plant breeders whose cultivars they have to decide upon. It is important, however, that at least one member of a release committee has a good knowledge of plant breeding.

Release committees normally meet at regular intervals. Varieties are considered after application by the owner of the cultivar, and the release committee makes decisions on the basis of different kinds of information, the most important consisting of cultivar description and results of field trials. The extent to which a release committee takes a plant breeder's own tests into account differs from system to system. In voluntary registration schemes much attention is usually given to the breeder's own tests. In compulsory registration schemes only official tests are generally considered. The committee also decides upon the denomination of a cultivar, taking into account the applicant's proposal.

FIGURE 5. Row-by-row sowing, with a one row seeder, of tests for distinctness, homogeneity, and stability.

Tests and requirements

Two kinds of tests can be prescribed in countries with release regulations:

1. Tests for distinctness, homogeneity, and stability (Fig. 5).
2. Tests for agricultural or horticultural value.

If release is restricted to registered cultivars, only tests of the first kind are necessary. If, however, release can be granted only to registered cultivars of high agricultural or horticultural value, the second category of tests also have to be undertaken.

The aim of the tests for distinctness, homogeneity, and stability is to check the cultivar description provided by the breeder and to determine the degree to which these criteria are met. It is of great importance for the decision committee to know whether or not a new cultivar can be distinguished from all other approved cultivars, as the possibility of distinguishing a new cultivar provides the means of control that is necessary for protection. Obviously, registration of cultivars without any tests of distinctness is meaningless, although this is still practised in a few countries.

Tests for distinctness, homogeneity, and stability can be delegated to a university department, a seed testing institute, or to other official bodies that are independent of the plant breeders. The tests have to be conducted for at least two seasons.

As the botanical characteristics used to distinguish cultivars from one another are often difficult to observe and evaluate correctly, they must be recorded by specialists. Such tests are difficult and time-consuming to perform. Check plot tests are needed to make possible the study and comparison of cultivars during the entire growing season. Useful plant characteristics are listed and described in guides provided by the International Union for the Protection of New Plant Varieties (UPOV) and OECD (1969). There have recently appeared cultivars which are particularly difficult to distinguish, as single disease-resistance genes are the only distinguishing characteristic from the mother varieties. Hybrid varieties of wheat and barley will also cause problems in the future. Measures other than check plot tests must be used, as have already been introduced in some cases.

In systems with voluntary registration the requirements for distinguishing cultivars are normally not very strict. There may often be no or few official tests, and the release committee decides mainly or entirely on the basis of plant breeder's tests.

Official tests of agricultural or horticultural value — like those for distinctness, homogeneity, and stability — are normally delegated to an official institute with resources for undertaking trials of yield and other characteristics at different locations. To meet certain value criteria in systems with official requirements for cultivars, a testing period of two or three years according to species is normally prescribed. The plant breeder's own tests are often taken into account by the release committee, especially if they are well distributed over the country or region in question.

Yield trials are performed also in countries without official evaluation of new cultivars by a release committee. These are performed, for example, by plant breeders, local extension authorities, and experimental farms.

Variety lists

Cultivar lists are distributed in most countries. The aim of these may be:

- to inform the seed buyer about different cultivars;
- to promote the seed trade;
- to limit official certification to listed cultivars;
- to limit the seed trade to listed cultivars.

According to aim, cultivar lists can be divided into two kinds:

- Recommendatory and descriptive lists
- Restrictive lists

Cultivar lists which recommend are published by breeders, extension agencies, seed growers' associations, or similar bodies. They are informative and aim to promote interest in good cultivars among farmers. They normally compare cultivars both for appearance and for agricultural or horticultural value. Recommendatory lists are mainly of national or regional interest, but they can also serve as good information sources for other countries. International cultivar lists also exist, such as the Organisation for Economic Co-operation and Development's lists of varieties of cereals, herbage crops, and sugar and fodder beets (OECD, 1972). These lists aim to promote trade in seed and include cultivars that are officially recommended in the member countries.

Cultivar lists issued by official release committees normally have a restrictive function. Many countries limit official seed certification to listed cultivars, which usually have a proven high or reasonably high agricultural or horticultural value, although cultivars that are not listed are normally permitted on the market. However, in some countries (e.g., Sweden) the sale of cultivars not on the official list is forbidden in accordance with release regulations or obligatory seed certification rules.

Denomination of cultivars

It is important that cultivars be given denominations which are short and simple and which prevent confusion with the names of plant genera, species, or other cultivars. It is also important to exclude from denominations every kind of descriptive element referring to the quality of the variety. Such descriptive elements very often become outdated and increase the risks of error and confusion, especially in translation.

The release committee normally has to decide on a definitive denomination on the basis of proposals made by the applicant. The earlier procedure of using the plant breeder's name or trademark for cultivar denominations is no longer permitted for official registration in most countries. According to the International Code of Nomenclature of Cultivated Plants (1969), "a cultivar name must be a fancy name, that is, one markedly different from a botanical name in Latin form."

Release of legally protected varieties

All four alternative kinds of official release regulations described earlier offer a kind of national cultivar protection. The degree of protection afforded to the breeder on the one hand and to the consumer on the other is dependent on regulations made under the seed law, the seed certification scheme and the seed marketing pattern in the individual country. The kind and extent of governmental support to plant breeding is also an important factor in international seed programmes.

Different national systems of legal cultivar protection have evolved, and an international system has been introduced: the Convention for the Protection of New Varieties of Plants (BIRPI, 1961).

Convention for the Protection of New Varieties of Plants

The convention was initiated by private breeders in western Europe. Thus far, six countries (Denmark, France, Federal Republic of Germany, Sweden, the Netherlands, and the United Kingdom) have ratified the convention and become members of the International Union for the Protection of New Plant Varieties (UPOV Secretariat, 32 chemin des Colombettes, 1211 Geneva 20, Switzerland).

Members of UPOV must adopt a "plant breeders' protection act," which regulates in detail the rights and duties of plant breeders. Membership in the Union is of little significance, however, unless the whole seed industry of a country (plant breeding, seed production, quality control, and marketing) is highly developed. Within reasonable limits the plant breeder is allowed to fix licence fees, which are charged to those who make use of his cultivars. The procedure for cultivar release in UPOV member countries is basically the same as the earlier mentioned voluntary registration based on varietal distinctness, but, in addition, legal protection is granted. Some requirements are more strict because legal protection necessitates positive certainty about the distinctness of a new cultivar. Another requirement is that the cultivar must not be marketed in the country before the date of application for protection. The same procedure for release by a cultivar release committee on the basis of tests of distinctness, homogeneity, and stability also applies when cultivars are legally protected. Since the convention does not mention agricultural or horticultural value, the legal protection offered by it bears some resemblance to patent rights.

According to the convention, UPOV member countries must keep a register of protected cultivars. This does not prohibit the inclusion of protected cultivars in recommendatory or restrictive cultivar lists.

The denominations of cultivars within the UPOV protection scheme create special problems. Since proposed denominations have to be checked and approved on a Union-wide basis, linguistic difficulties also arise. Consequently strict rules are necessary, and a special working group has been established within the Union to deal with such questions.

3. SEED PRODUCTION AND HARVESTING

by W.P. Feistritzer (Coordinator), R. Bradley, and F. Ogada

When a plant breeder has developed a new and superior variety, it is important that its seed be multiplied and made available in quantity as soon as possible so as to benefit the farmer. The released varieties must be maintained in such a way that stocks of pure propagating seed are constantly moving into commercial channels.

Production and delivery to farmers of good-quality seed of improved and adapted varieties which is healthy and genetically stable is an exacting task, calling for technically and financially sound organization. Usually, countries with successful variety development programmes have well-defined seed production practices and systems.

The role of seed production in the development of agricultural crops cannot be overemphasized. In many developing countries where agriculture follows traditional practices the peasant farmers tend to continue using their own unimproved seed even when there are better alternatives. In these countries there are instances of crop varieties bred and developed at research stations never finding their way onto the farms simply because seed production has never been organized, as a consequence of which seeds cannot be supplied, maintained, or kept pure. In seed production, strict attention must be given to the maintenance of genetic stability and varietal purity in order to justify the years of work by plant breeders and the high costs of creating, testing, and introducing new varieties.

Production of seeds of adequate quality must be conducted under standardized conditions. Many of the qualities of the end product are unknown before the crop is sown or even before it is harvested. The only way of ensuring adequate quality in seed for market distribution is to organize and supervise properly the different stages of production.

Based on the experience that, in general, succeeding crop generations progressively produce seed of lower standard, well-defined seed production practices have been developed. These are based on a generation system, with an associated limitation on multiplication within the same seed class.

According to internationally accepted nomenclature, the stages of seed multiplication are as follows:

1. *Breeders' seed* is normally grown for one or more generations and is directly produced or controlled by the originating institution or plant breeder; it provides the source for the increase of basic seed.

2. *Basic seed* is produced under the responsibility of the breeder or his authorized agent (sometimes a governmental agency) and is intended for the production of certified seed. Standards to which basic seed must conform should be defined in the regulations of each country; fulfilment of these conditions must be confirmed by official examination.

3. *Certified seed* descends from basic seed and is intended to be used (*a*) for the production of certified seed for one or more generations and (*b*) for crops grown for purposes other than seed production, such as food or fodder.

Generations from basic seed are known as "certified seed, first generation," "certified seed, second generation," and so on. Each generation must conform to official standards, and the number of generations should be limited, particularly in cross-fertilizing species.

It should always be remembered that maintenance of genetic purity protects previous work and investment and establishes a firm quality base for the seed programme. The small quantities of breeders' and basic seed produced must be suitable in quality for the production of larger volumes of certified seed in subsequent generations.

All seed marketed for crop production use which has not been produced under a certification scheme should be regarded as *commercial seed.* It is quite possible for commercial seed to play an important role in crop production in cases where seed increase is difficult and where production of certified seed cannot keep up with demand. With cereal seeds the role that commercial seed could play and the policy to be adopted on this issue by developing countries merit careful consideration. In areas where varieties or hybrids superior to local or traditional ones have been identified or developed it would be unthinkable to adopt any policy that would perpetuate the existence of the inferior genotypes as commercial seed, particularly if it is possible to produce enough certified seed to meet demand.

Seed grown with every care may become valueless as quality seed if precautions are not taken to maintain its identity and viability during harvesting, processing, and storage. In addition to proper cultivation and isolation measures, special precautions are necessary when cleaning equipment.

Organization

In western Europe, the United States, and Canada many organizations are involved in seed production. Seed growers' associations aim to assist their members in technical questions, while seed growers' cooperatives and private firms handle large-scale seed production. Generally, breeders' and basic seed is produced by the breeders. Certified seed production is based on contracts between firms, seed merchants, and cooperatives on the one hand and farmer-growers on the other. Also, some individual seed growers produce and distribute seeds on a private basis.

In many eastern European countries, seed is produced according to state plans. State breeding stations produce breeders' seed, while basic seed is increased on state farms specialized in seed production. From there, basic seed is distributed to farmers' societies at the village level for the production of certified seed, which is then distributed according to an overall scheme for the production of market crops.

Many developing countries aim at the production of breeders' seed on state breeding stations, basic seed on government-owned land, and certified seed by contract growers. The contracts are made between the government or one of its agencies and the farmer-growers. Too often the principle is recognized, but the means of carrying out such activities are inadequate.

Thus seed production programmes may be official, semiofficial, private, or a combination of these. The scope and magnitude of each programme can only be decided within the country itself. The basic decision as to whether seed production should be developed jointly by both the public and private sectors or exclusively by one sector is likely to depend on social and political circumstances.

TYPES OF SEED PRODUCTION PROGRAMME

Official seed production

Probably all seed programmes in the world have started with government participation. Several countries have elected to continue this type of programme in the belief that higher quality seed can be made available to farmers with more certainty and at lower cost.

Experience in developing countries has shown that, in general, government departments are not very efficient seed production agencies. Many of the personnel may be political appointees and their qualifications therefore quite variable. There is seldom concern for return on investment, nor even for covering the costs of the exercise. Such programmes are often subject to political pressures and usually to frequent personnel changes.

The need for a public-sector production programme for initiating seed multiplication must be recognized. As the seed programme progresses and as more technicians and seed producers with better training and more experience become available, other organizations should be encouraged to assume responsibility. Where variety development has been conducted by public agencies, breeders' seed and sometimes basic seed also have to be produced by them.

In Kenya the National Agricultural Research Station at Kitale was the only centre for the development of maize inbred lines and initially had full responsibility for maintenance and for small- and large-scale bulking of inbred lines. In addition, all single-cross seed was produced at the station, and only the final stage of production was entrusted to the Kenya Seed Company, a private firm, which produced the certified double-cross, three-way cross, and variety-cross seed. Subsequently, the National Agricultural Research Station had difficulty coping with the increasing demand for certified seed in the country, in addition to its major responsibilities for agronomic research and plant breeding. Therefore, in 1966 it was decided that the station retain only maintenance of inbred lines and that the rest of the production stages be taken over by the Kenya Seed Company.

Semiofficial seed production

In some countries the government has established a national agency to produce, process, and distribute seed. This is a more remote form of government participation. Such an agency may be established at the initiation of a programme or at a subsequent phase of less direct government participation. In general, such agencies contract seed production to selected, qualified farmers, who operate as autonomous units and are usually financed by government bank credit. They are more commercial in nature and management than governmental units and usually more efficient in operation.

There are countries where a national agency has almost a monopoly, being the only source of seed or by far the major producer and distributor.

Private seed production

Private enterprises, as in the United States and western Europe, prefer to handle production and distribution of hybrid seed, as private enterprises must be able to exist and compete. Since hybrid seed must be purchased anew each time the crop is to be sown, seed sales are stable and profitable. On the other hand, in the case of self-fertilizing crops —

wheat for example — whose seed do not have to be renewed each year, only some private enterprises in western Europe have been long involved in seed production, because of the legal protection provided for privately developed varieties. In recent years, with the introduction of variety protection acts in several other countries, including the United States, private agencies have increased their efforts to develop self-fertilized crop varieties.

Seed production unit

A point to consider in organizing seed production is that the concentration of field activities in seed-producing districts with favourable climatic conditions permits the use of capital on an economic scale for the purchase of equipment for cultivation, storage, and processing, as well as for operation. Units should be large enough to support the employment of trained personnel for advising farmers on seed production and crop protection techniques; this also helps in harvesting operations, quality control, seed certification measures, seed processing, and marketing.

In seed-producing districts it is advisable to arrange for the zoning of varieties, which for cross-fertilizing crops facilitates isolation and for self-fertilizing crops prevents admixture and simplifies crop handling. It is recommended that no more than one variety of the same species be grown on a seed farm. Special attention should be given to the environmental conditions for varieties of cross-pollinating crops in order to avoid natural selection.

Village seed farm

In some countries seed production on one farm per village has been tried. It was assumed that creating village seed farms would have the advantage of reducing transportation costs and be favourable to demonstration of recommended varieties. It was found, however, that the risk of failure in crop production was great, and when failure occurred, farmers lost interest in renewing seeds and applying improved technology.

Seed grower

When selecting a seed grower, it is important to consider his technical ability and personal reliability and such matters as farm size, cropping system, size of the seed multiplication field, and, in particular, previous crop and available facilities for mechanization, transport, and storage.

Manpower requirements

Major items to consider when assessing manpower requirements for supervision and for advising on seed production activities are the total area, the number of individual fields and their distance from the control centre, and the level of experience and education of the seed growers.

The Kenya Seed Company, for example, has one supervisor per 500-750 ha of seed multiplication fields for certified maize seed production. In 1972 maize seed production in Kenya covered a total area of 3 200 ha, scattered within a radius of about 45 km from the seed processing centre, with individual seed multiplication fields of 8 to 80 ha.

For self-fertilizing crops, as wheat and barley, a report from Austria indicates that one supervisor is necessary per 800-1 000 ha, with an average field size of 20 ha and an average distance of 40 km from the processing centre.

The greatest manpower requirement seems to be that for the detasselling of maize, which in most developing countries is a hand operation. In Kenya about four men are required to detassel 40 ha (Adelham, 1972). To reduce hand labour requirements, detasselling machines are used in some developed countries. Where a male, sterile seed parent is used, the detasselling operation can be eliminated almost entirely.

Input requirements

Good farming practices are a prerequisite for successful seed production. In addition to natural factors, such as climate and soil, agricultural practices markedly influence productivity: the greater the human influence through good land preparation, fertilization, irrigation, crop rotation, and other practices, the higher the production level and the less dependent the farmers on climate and soil type. Thus, where farming practices are well conducted, production is limited not so much by natural conditions (e.g., a certain soil type) as it is by economic considerations and the availability of input requirements in a specific location.

Equipment requirements

The same equipment is required for seedbed preparation for wheat, barley, maize, and dry-land rice seed production. For maize there is frequently less land preparation after ploughing, as a "minimum tillage" or even a "plough-plant" type of operation may suffice. The exact type of equipment for seedbed preparation may vary from country to country and according to the customs of the farmers in an area. The capacity of the equipment will be governed by the size of the operation and by equipment availability. Basically, the requirements are those given in the following paragraphs.

Equipment for seedbed preparation

1. Tractor.
2. Plough: disk or furrow type.
3. Disk harrow.
4. Spike or spring-tooth type of harrow.
5. Under difficult conditions of soil preparation, a plain roller or the cultipacker type of roller with corrugations or ridges may be necessary for breaking up large lumps of soil. The "pulvimulcher" is a tool combining the action of a spring-tooth harrow and a cultipacker, having in addition a front gang of very narrow wheels with metal protrusions on the sides known as "crow feet"; it is the most effective equipment for satisfactory seedbed preparation of lumpy soil.
6. Fertilizer-spreading equipment (if the seeding equipment is not adapted for applying fertilizer during the sowing operation).

For the production of flood-irrigated rice, in addition to the equipment listed above, a large land plane is needed for levelling the seedbed. Also, survey equipment will be necessary for marking the grades and contours. Establishing contour ridges and making or reconstructing existing canals and ditches usually require larger bulldozers and tractors than are normally necessary for other production operations.

Equipment for sowing

Wheat and barley are normally sown in rows, using a grain drill of either the disk or hoe type. The distance between rows is usually about 15 cm. It is sometimes preferable to equip the drill with fertilizer-application accessories.

For dry-land rice production in rows, the same type of equipment used for wheat and barley will serve. For irrigated rice, it may be necessary to use other sowing methods, depending on whether water is applied before or after sowing. On large areas, aerial sowing is practised in some countries. If aerial equipment is not available, broadcast seeders mounted on tractors may be used. These seeders consist of a seed box and one or two horizontally rotating impellers with vertical flanges or ridges. The seed falls from the discharge openings under the seed box into the impellers and is flung in a circular pattern from the seeder. The impellers are usually operated by the power take-off shaft of the tractor. The width of the seeding pattern depends on the diameter and speed of rotation of the impellers.

Sowing in rows on a previously flooded seedbed may also be accomplished by drills of either the hoe or disk type mounted on the three-point linkage of tractors. The power for operating the drill mechanism is usually provided by a chain drive from one of the rear tractor wheels or by a special drive wheel which contacts the soil when the drill is lowered for sowing.

Maize seed, particularly the round grades, can be sown quite successfully using the same type of grain drill if enough seed-distributing tubes are blocked off to obtain the desired distance between rows. The distance between rows is normally 75 cm or more. It is recommended, however, that maize be sown with a specialized type of drill with horizontally rotating plates below the seed box. These plates have precision-made holes or pockets for a specific size grade of seed. Accurate seed rate and precise spacing of seed in the soil is possible with this type of drill and properly graded seed. It is particularly important that maize drills be equipped to apply fertilizer at sowing time, as proper placement of the fertilizer in relation to the seed is more important than for wheat and barley.

This type of specialized equipment does not serve for other cereal crops, but it can be used for such crops as soybeans and sunflower and with adaptations for certain small seeded crops. Therefore the investment does not have to be justified solely by maize seed production.

Equipment for operations after sowing

1. Herbicide application equipment.
2. Insecticide application equipment (if insects are normally a problem and aerial application is not practical).
3. Tractor-mounted cultivation equipment for maize with fertilizer side-dressing attachments.

Equipment for harvesting

It is preferable to harvest wheat, barley, and rice with a combine, either of the trailer or self-propelled type. If combines are not available, the crop can be harvested by mechanical binding for later threshing by stationary equipment. Standard grain combines present no problems in the harvesting of dry-land rice; but with irrigated rice, even though the water is drained off before harvest, very wet soil conditions usually exist, and therefore combines designed solely for rice harvest are normally equipped with oversize wheels and tires or track propulsion.

If land labour is relatively cheap, small or medium-size production areas of maize for seed can probably be harvested most satisfactorily by hand. On large production areas or in more developed countries, mechanical harvesting equipment may be used. These machines, either trailer- or tractor-mounted, snap the ears from the stalks and usually also remove the husks, after which the ears pass to a wagon towed behind the equipment. As this specialized equipment can be used only for maize harvesting, the production area must be large enough to justify the investment. Harvesting with grain combines adapted for maize or with picker-shellers is not recommended for seed production: frequently the moisture content of the seed is high, and thus these types of harvesters cause much damage to the seed; also, in all seed operations there should be hand sorting of the seed ears in order to remove off-types before shelling.

Seed production costs

Production costs must be kept as low as possible. The seed producer will not deliver seed unless the price he receives allows him a reasonable profit.

In calculating production costs based on the capacity of the existing area and equipment, the capital investment in land and equipment is excluded and no allowance is made for amortization or depreciation. Production costs are broken down into fixed and variable expenses. Fixed expenses remain constant as the volume of production changes, while variable expenses change in direct or indirect proportion to the volume of production.

In wheat production, fixed expenses may include levelling (once in twenty years), ploughing, disk harrowing, furrowing for irrigation, making main ridges for irrigation, and sowing. Variable expenses may cover seed, yearly levelling, smoothing after sowing, irrigation, fertilizing, weeding, and harvesting.

Table 1, based on a survey carried out in Iran in 1966 (Feistritzer, 1968), shows that the application of capital-intensive techniques requires a certain minimum output level in order to be profitable. Costs were not met until a production level of 1 500 kg/ha was reached, whereas worthwhile returns were realized only at 3 000 kg/ha. The results of the marginal analysis in Table 2 are more or less linear, the average marginal return being equal to 1.5 rials for each rial of added input.

Further field tests with higher inputs of fertilizer, water, and other factors might reveal diminishing returns; however, it should be noted in Table 1 that these inputs, including harvesting, represented the highest costs per unit. Theoretically, according to the law of diminishing returns, the rate of increase in output would be expected to differ for different inputs. In

TABLE 1 — WHEAT PRODUCTION COSTS AND REVENUE IN RIALS PER HECTARE*

Output level	1	2	3	4	5	6
Yield: Grain (kg)	800	1 000	1 500	2 000	3 000	4 000
Straw (kg)	800	1 000	1 500	2 000	3 000	4 000
Value of output (grain, 7.7 rials/kg; straw, 1 rial/kg)	6 960	8 700	13 050	17 400	26 100	34 800
Fixed operating expenses:						
Land levelling	960	960	960	960	960	960
Ploughing	450	450	450	450	450	450
Disking	250	250	250	250	250	250
Ridging	400	400	400	400	400	400
Main ridges	100	100	100	100	100	100
Sowing	250	250	250	250	250	250
Total fixed operating expenses	2 410	2 410	2 410	2 410	2 410	2 410
Variable operating expenses:						
Seed	1 000	1 160	1 110	1 280	1 280	1 280
Yearly levelling	—	—	500	500	500	500
Smoothing after sowing	—	250	250	250	250	250
Fertilizing	—	250	250	250	500	750
Weed spraying	—	—	—	—	250	500
Irrigation (labour)	150	350	350	550	750	850
Harvesting (combine)	1 050	1 310	1 960	2 620	3 930	5 240
Fertilizer	—	650	1 320	1 930	2 650	3 260
Spraying material	—	—	—	—	200	400
Water (1 rial/m^3)	2 500	3 500	3 500	5 500	7 500	8 500
Tax (10% of value of grain)	620	770	1 160	1 540	2 310	3 080
Total variable operating expenses	5 320	8 240	10 400	14 420	20 120	24 610
Total costs	7 730	10 650	12 810	16 830	22 530	27 020
Net income	—770	—1 950	240	570	3 570	7 780

* Rials 75 = US$1.00

TABLE 2 — MARGINAL ANALYSIS OF WHEAT PRODUCTION COSTS IN RIALS PER HECTARE

Output level	1	2	3	4	5	6
Value of output	6 960	8 700	13 050	17 400	26 100	34 800
Added values		1 740	4 350	4 350	8 700	8 700
Total costs	7 730	10 650	12 810	16 830	22 530	27 020
Added costs		2 920	2 160	4 020	5 700	4 490
Value/cost return rials per rial		0.60	2.01	1.08	1.53	1.94
Production cost per kilogram of grain	9.7	10.6	8.1	8.4	7.5	6.8
Return per rial of expenses	0.90	0.82	1.07	1.03	1.16	1.29

other words, when the first units of input are added, the output should increase; the rate of increase should become greater for each subsequent unit of input added up to a certain point, after which the rate of increase diminishes until, finally, additional inputs may cause a decrease in output. The above data are not sufficient to test fully this theoretical concept, but they do indicate the relation of increasing output to increasing input.

Calculations of costs per hectare in Uruguay were as follows: for certified wheat seed at a yield of 1.70 tons per hectare, US$106.21 (1970/71 season); for certified rice seed in a flood-irrigated area at a yield of 3.50 tons per hectare, $160.89 (November, 1969); and for certified hybrid maize seed at a yield of 1.03 tons per hectare, $96.88 (1970/71 season).

For calculation of these production costs the following components were used:

Wheat seed	*Cost*
Labour, including seedbed preparation and sowing (8 hours), herbicide application (0.3 hour), roguing once (11 hours), cleaning combine once (6 hours) harvesting (3 hours)	US$13.90
Equipment, including fuel, lubricants, depreciation, and maintenance	17.91

Wheat seed	*Cost*
Seed	11.20
Fertilizers	18.45
Herbicides	1.45
Insecticides	1.28
Bags	9.12
Airplane spray	4.72
Harvest rental of combine, including operator	9.32
Interest on capital	10.86
Land rent	8.00
Total	$106.21

Rice seed	*Cost*
Construction of canals, ditches, water-retaining contour ridges, land levelling, and field layout (3.7 hours)	$18.55
Machine repair and maintenance	16.09
Seedbed preparation (9.6 hours)	10.19
Seed	26.82
Sowing and covering seed (3.2 hours)	3.71
Irrigation (25 hours)	23.96
Roguing once (15 hours)	7.35
Cleaning combine once (6 hours)	3.19
Harvesting (14.9 hours)	8.87
Bags	22.43
Miscellaneous	19.73
Total	$160.89

Maize seed	*Cost*
Labour, including seedbed preparation and planting (5.3 hours), herbicide application (0.2 hour), roguing once (0.8 hour), detasselling (48 hours), harvesting by hand of seed rows only (37 hours)	$40.43
Equipment, including fuel, lubrication, depreciation, and maintenance	15.23
Seed (female parent only)	9.00
Fertilizer	12.80
Herbicide	0.67
Bags (for seed parent only)	6.82
Interest on capital	7.18
Land rent	4.75
Total	$96.88

In 1972 the cost range for producing maize seed in Kenya was from US$185 per hectare at a yield of 2.7 tons per hectare to about $296 per hectare at a yield of 6.7 tons per hectare (Adelham, 1972). Thus the cost per ton fell by about a third, from $68.52 to $44.18 per ton, as yield was more than doubled.

Methods

General considerations

Seed of self-fertilizing crops, such as wheat and rice, may theoretically be resown for several generations without genetic deterioration. In practice, however, progressive deterioration of the original stocks occurs rather rapidly through dilution by mixture with other varieties and species. Therefore, every four to six years new seed produced under strict control is required to maintain the yield potential of an improved variety.

Seed of cross-fertilizing crops has to be replaced more frequently, since mixing as a result of natural cross-fertilization with other varieties in adjacent fields is common. Seed of synthetic and composite varieties of maize may have to be replaced after three to five years, whereas hybrids must be renewed each year if their original yield potential is to be maintained. The term *synthetic variety* designates the advanced generations of a multiple hybrid that is increased by open pollination (Sprague, 1955). The lines are not necessarily stable, but should be distinguishable.

Poehlman and Borthakur (1969) report that composites generally include various breeding materials that have been put together on the basis of yield potential, maturity, disease resistance, or other known characteristics. Usually the seed is mixed and planted at several dates to ensure good cross-pollination between all of the components, which confers great stability in different environmental conditions.

For these reasons, seed production practices have been developed for maintaining the genetic constitutions of crop varieties.

In many countries official standards have been introduced in order to safeguard the quality of basic and certified seed. The requirements for producing breeders' seed are normally left to the discretion of the plant breeder, but they may be even stricter than for the production of basic seed.

The quantity of seed required for each seed class depends upon the number of generations permitted for increase and can be calculated by working backward from the last generation permitted. In determining the area needed for each seed class to be produced, a conservative seed yield figure should be used; this should take into account rejection of seed increase fields which are not up to standard, as well as seed shrinkage during drying and seed waste during processing. Normally the computations for each generation are made backward to the amount of breeders' seed required to plant the requested area of basic seed. In practice, this procedure is not always possible, as it may be necessary to accept the seed quantities that are available from the breeder and endeavour to expand to the needed volume by other means.

Production planning

In certain advanced seed programmes, particularly those working with specialized agencies for the production of basic seed, a system of reserving seed for delivery after harvest has proved successful. With this system those who are responsible for supplies of basic seed can plan production quite precisely since they know the quantities they are committed to deliver, and those purchasing basic seed for certified seed production have more flexibility in adjusting their seed requirements.

In maize seed production the seed requirements of inbred lines, single crosses and double or three-way crosses, cannot logically be discussed separately. For ease of understanding a hypothetical case will be considered, calling for the production of 1 000 tons of certified seed of a double-

FIGURE 6. Field for the production of certified seed of hybrid maize, showing male and female rows.

cross hybrid composed of four inbred lines: A, B, C, and D. The two single crosses required are (A×B) and (C×D). Assuming that the single-cross seed parent is (A×B) and that its seed yield is 25 quintals per hectare, the land requirement for producing 10 000 q will be 400 ha. With a planting pattern of 6:2 or 3:1 female to male rows (Fig. 6), the 400 ha are divided as follows: (*a*) 100 ha for the male (pollen parent) single cross (C×D); (*b*) 300 ha for the female (seed parent) single cross (A×B).

Assuming further that the seed rate for planting the single cross is 25 kg/ha, then the seed requirements for A×B and C×D will be 75 q and 25 q, respectively. Using inbred A and inbred B as seed and pollen parents, the A×B single-cross production will require 6 ha, assuming a yield of 12.5 q/ha from the inbred seed parent. Similarly the land required for producing 25 q of single cross C×D would be 2 ha. Taking the planting pattern to be 2:1 for seed parent and pollen parent, the land requirements for the four component inbred lines would be as follows: (1) inbred A (seed parent), 4 ha; (2) inbred B (pollen parent), 2 ha; (3) inbred C (seed parent), 1.33 ha; and (4) inbred D (pollen parent), 0.67 ha.

After determining the respective areas of land required for each inbred line in the single-cross production field, the next stage is to ascertain the seed requirement of each component inbred in the single-cross production. Assuming again a seed rate of 25 kg/ha, the seed required would be 100, 50, 33.3, and 16.6 kg, respectively, for inbreds A, B, C, and D. With the same multiplication rate, or a yield of 50 g per inbred plant, the respective amounts of inbred seed could be produced from about 2 000 plants

Table 3 — Land and seed requirements at the different stages of a certified hybrid maize seed production programme

(1) ⟶ Type of certified hybrid seed	(2) ⟶ Parental material	(3) ⟶ Certified seed required	(4) ⟶ Yield of seed parent	(5) ⟶ Land required at 3:1 planting ratio	(6) ⟶ Seed required for planting in area (5)
Double-cross hybrid (four inbred lines, *e.g.*, A, B, C, and D)	Two single crosses (*e.g.*, AB and CD)	10 000 q or 1 000 tons	25 q/ha	Total 400 ha (300 ha AB seed parent, 100 ha CD pollen parent, double-cross production)	75 q AB 25 q CD (seed rate, 25 kg/ha)
Three-way cross (three inbred lines)	One single cross; one inbred line (*e.g.*, AB and C)	10 000 q or 1 000 tons	25 q/ha	Total 400 ha (300 ha AB)	75 q AB 25 q C (seed rate, 25 kg/ha)
Variety cross	Two open-pollinated varieties (*e.g.*, V_A and V_B)	10 000 q or 1 000 tons	25 q/ha	Total 500 ha (375 ha V_A, 125 ha V_B)	93.75 q V_A 31.25 q V_B (seed rate, 25 kg/ha)

of inbred A, 1 000 plants of inbred B, 667 plants of inbred C, and 333 plants of inbred D. From these figures it is possible to work out the size of the isolated plots required by using a given spacing for planting. Assuming that the plant spacing is 30 cm by 80 cm, or 2 400 cm^2 per plant, the areas of land required are 480 m^2 for inbred A; 240 m^2 for inbred B; 159.8 m^2 for inbred C; and 79.9 m^2 for inbred D.

The land and seed requirements are interdependent at all stages of seed production; therefore, planning for both must go hand in hand. Obviously, integrated planning of seed and land requirements for maize seed production would not be complete without due consideration of the time scale for

TABLE 3 — LAND AND SEED REQUIREMENTS AT THE DIFFERENT STAGES OF A CERTIFIED HYBRID MAIZE SEED PRODUCTION PROGRAMME (*concluded*)

(7) ⟶ Land required to produce seed in (*6*)	*(8)* ⟶ Land required for each parent used in (*7*) at 2:1 planting ratio	*(9)* ⟶ Seed required for (*8*), at seed rate of 25 kg/ha	*(10)* ⟶ Number of plants required to produce seed in (*9*)	*(11)* ⟶ Land required to grow the number of plants in (*10*) (Area per plant = 2 400 cm^2)
(Yield 12.5 q/ha) A×B – 6 ha C×D – 2 ha	A – 4 ha (seed parent) B – 2 ha (pollen parent) C – 1.33 ha (seed parent) D – 0.67 ha (pollen parent)	A – 100 kg B – 50 kg C – 33.3 kg D – 16.7 kg	(Yield 50 g/plant) A – 2 000 plants B – 1 000 plants C – 667 plants D – 333 plants	A – 480 m^2 B – 240 m^2 C – 159.8 m^2 D – 79.9 m^2
(Yield 12.5 q/ha) A×B – 6 ha C – 2 ha	A – 4 ha (seed parent) B – 2 ha (pollen parent) C – 1.33 ha (only for seed increase)	A – 100 kg B – 50 kg C – 33.3 kg	(Yield 50 g/plant) A – 2 000 plants B – 1 000 plants C – 667 plants	A – 480 m^2 B – 240 m^2 C – 159.8 m^2
(Yield 20 q/ha) V_A – 4.68 ha V_B – 1.56 ha	Same as in (7)	V_A – 117 kg V_B – 39 kg	(Yield 125g/plant) V_A – 936 plants V_B – 312 plants	V_A – 224.64 m^2 V_B – 74.88 m^2

the different generations and stages of production. Meaningful long-term estimates of requirements for land and seed can only be made after the time factor has been built into the planning (Table 3).

This discussion of seed and land requirements has demonstrated the magnitude of the problem. The example used considered a double-cross hybrid with four inbred lines. If the objective were the production of certified seed of a three-way-cross maize hybrid or a variety-cross hybrid, the planning method would be similar, but there would be differences in detail mainly arising from the multiplication rate from one generation to the other.

Land requirements

The region for seed production should have a suitable climate, and especially the severity of winter temperatures must be considered. The selected area must also have a suitable previous cropping history. Particularly for the first seed generations, fields should be of suitable soil type, fertility, and drainage and be free of weeds and soilborne diseases and pests.

All cereals yield more if they are sown in a well-prepared seedbed with 5-8 cm of mellow surface soil. A good seedbed will help the young plants to emerge vigorously and compete with the weeds. Except for maize seed production under the "plough-plant" minimum tillage system, seedbed preparation should start well in advance of the sowing season. Ploughing should be performed with great care to allow satisfactory tilth preparation.

Frequent cultivation kills germinated weeds when they are small and brings new weed seeds near the soil surface for germination and destruction before the crop is sown. The depth of cultivation is governed by moisture conditions and the need to conserve soil moisture. Repeated cultivation prior to planting tends to firm the soil. A firm seedbed is necessary for ensuring proper contact of the seed with the soil, so as to utilize soil moisture for rapid germination. Smoothing for sowing might be done with combinations of the disk harrow, cultipacker, tooth harrow, and rotary hoe. Wheat, maize, and upland rice respond similarly to soil conditions and fertilization. Rice grown under lowland conditions requires different techniques.

The oldest and simplest method of sowing is broadcasting, but drilling is the most efficient. The aim is to deposit the seed in the desired amount at a uniform depth. Wheat, rice, and maize should normally be planted 4-6 cm deep. Wheat and maize are sown on dry soil, whereas rice can be either broadcast or drilled on mud, broadcast in water, and drilled on dry soil.

Maintenance of equipment

The cleaning of planting equipment involves more than merely removing the remaining seed from the seed box. The fertilizer box must also be cleaned, as seed frequently spills into this compartment. All cracks and crevices in the seed box, as well as around and under the collecting and distributing mechanism must be cleaned with a stiff wire or small rod with a flattened point. The seed- and fertilizer-distributing tubes must be inspected, and any material caked or compacted with moisture must be removed, as should all dirt or mud adhering to the frame of the machine or to the hoe or disk coulters.

Sowing methods

Rice grown in paddies is either sown directly or from seedlings raised in a special seedbed before transplanting in the fields. For raising seedlings the wet-bed, dapog, and dry-bed methods are used. Dapog seedlings can be transplanted after 9–14 days, while wet-bed and dry-bed seedlings are ready for transplanting about 20–30 days after sowing (Macalinga and Abordo, 1970). In countries with well-controlled irrigation systems, such as the United States, Portugal, Italy, and Greece, direct sowing is very common. In most Asian countries transplanting is used.

The sowing method influences the seed quality and density. The seed rate is generally 100–200 kg/ha for wheat and direct-sown rice, 45–65 kg/ha for transplanted rice, and 20-30 kg/ha for maize.

Weed control

Weeds are one of the main obstacles to good seed production. If weeds are not controlled, they may contaminate the seed and reduce seed quality and quantity. Planting on clean fallow or in good rotation will reduce weeds, but there will always be some to control. Since many crops are poor competitors with weeds at an early stage of growth, thorough weed control before planting is necessary. Most of the potential weed population can be controlled through proper cultivation techniques and herbicides.

Weed competition is often serious in seed crops in humid zones, where crops are planted just before the rains, because the weed growth is very rapid after germination. In arid and semiarid zones herbicides have a limited effect. Soil herbicides, which should cover the soil in a thin layer, are often useless, since the soil tends to crack as it dries out, allowing the weeds to come through the cracks. The efficiency of plant herbicides is also limited because of very high evaporation.

Seed production of wheat and rice

Breeders' seed

New breeders' seed is obtained by sampling the variety to be maintained or purified. Two methods are generally possible:

1. Single plants typical of the variety are pulled from a plot of breeders' seed. The single heads or panicles of these plants are threshed separately, although sometimes wheat heads are kept unthreshed.

2. In some breeding stations single heads or panicles typical of the variety are harvested from plots of breeders' seed and threshed separately. Wheat heads may be bagged separately.

When a newly developed variety is intended to be purified for possible increase and first release, single plants, heads, or panicles may be taken from the central rows of variety trials; but subsequently the plots of breeders' seed should be used.

Land and isolation requirements. Breeders' seed should be grown on clean, fertile land at an experiment station in the region or area for which the variety is recommended. The land must be suitably prepared and the plot isolated so as to make sure that there is absolutely no danger of genetic contamination by volunteer plants; of mixture with seed from adjoining plots or fields; of mixture with seed transported by birds or water; or of contamination through cross-fertilization by wind-borne pollen. Successful production of breeders' seed is more effectively accomplished when it is separated from the regular breeding and testing programme.

Previous cropping requirements will depend on the intensity of winter temperatures and cropping patterns. Usually breeders' seed should be produced on land which has not produced the same crop species for at least two years. Wheat and dry-land rice production areas should be isolated from other crops of the same species by at least 2 or 3 m or by physical boundaries which will prevent mechanical mixture. When breeders' seed is produced under irrigation, the seed plots should not receive water which has passed through other plots of the same species.

Sowing. Breeders' seed may be sown by hand or with small-scale plot equipment since production areas are usually small. The rows should be sufficiently spaced to permit easy passage of a person between them. In the rows the plants should be spaced far enough apart to permit easy observation of the characteristics of each plant for the purpose of removing any plant that is not typical of the variety. When single heads are used, the soil should be properly levelled and posted with a marker before they are laid out at intervals of 60 $\times$ 60 cm.

Seed dormancy in rice can be a problem when seed production plots have to be planted immediately after harvest. In general, Indica-type varieties have varying periods of dormancy, while Japonica-type varieties, mostly grown in temperate regions, are not dormant.

Dormancy in rice seed can be broken artificially by heat and chemical treatment. Highly dormant varieties may require treatment at 50°C for up to ten days, whereas for moderately dormant varieties treatment at

50°C for only five days may be sufficient to break dormancy. Soaking seed in nitric acid (NHO_3) solution for 16–24 hours, followed by drying to 14 percent moisture content and storage in dry conditions for five to seven days, has been found effective for breaking dormancy.

Cultivation can be done by hand or machine. Weed control by chemical methods is usually not practical unless hand sprayers or plot-sized application equipment is available.

Roguing. Roguing is the act of removing by hand undesirable individual plants from a plot of a variety. Seed production plots of breeders' seed must be carefully rogued to remove any off-type plants or any admixtures which may be present. No one is better qualified for this work than the breeder himself. If he cannot personally rogue the plots, the work should be done under his close supervision. The breeder's careful attention to the roguing work is important both for making sure that all off-type plants are rogued and that no typical variants of the variety are removed. If such typical variants are extensively removed or continue to be removed during repeated multiplication cycles, the resulting plant population may be considerably different from the original release, as well as inferior in performance. When the roguing work is completed, every remaining plant should conform to the description of the variety. Depending upon the number of different off-types and the quantity of each to be rogued, the plot may require roguing several times. Usually there is a distinct period in the development of the plants when undesirable characteristics can be most readily observed, and roguing should coincide with the most opportune time. The entire plant must be removed, including all of the tillers. Plants which have been rogued should be taken away; they must not be dropped in the plot. Roguing can always be more thorough and intensive in small areas of production; therefore, it is more easily and thoroughly accomplished in breeders' seed production areas. If possible, plots should be rogued before pollination. When plants are removed after they have flowered, all surrounding plants within 0.5 m should also be pulled and discarded (Fig. 7).

Harvesting. It is seldom possible to harvest and thresh breeders' seed with field-size equipment, as it is impractical to clean such equipment thoroughly and the volume of material is usually insufficient for efficient functioning. Harvesting and threshing may be done entirely by hand, or the harvesting may be done by hand and the threshing with a plot-size portable or stationary thresher. If the threshing equipment is not constructed for rapid and positive cleaning, it is important that it be modified to permit easy cleaning between seed lots. Since every kernel of high-

FIGURE 7. Roguing in plots of breeders' seed of wheat with head to row planting.

quality breeders' seed must be saved, there must be no wastage or unnecessary damage to the seed during harvesting and threshing.

Carry-over seed. The breeder must carry over at least enough seed to safeguard against loss of the variety if there is a complete failure during the basic-seed multiplication phase. Even a few grains will do. In addition, the breeder should further safeguard his variety by arranging to have a portion of the seed originally released stored under the ideal conditions provided by germ plasm banks or centres. Those responsible should plan to produce sufficient breeders' seed at one time to meet the requirements of two or three productions of basic seed. The production of breeders' seed is a very expensive process, with associated risks of contamination by repeated multiplication and of loss due to adverse growing conditions. These risks can be reduced and the continuity of the seed programme better assured by the carry-over breeders' seed. Such carry-over seed must be stored under optimum conditions in order to maintain its vigour and viability.

Basic and certified seed

Basic seed should always be produced in the defined area of adaptability for the variety so as to ensure that the genetic stability and the phenotype of the population do not change because of climatic pressures. To avoid selection pressures from agronomic practices, which might conceivably alter the stability of composition of the variety, it is necessary to follow recommended practices for date of planting and so on. Certain varieties of wheat and barley are sometimes grazed early and subsequently allowed to produce a grain harvest, but this practice is not recommended with crops for basic seed production; moreover, uneven or partial grazing can exert selection pressures and influence the predominance of certain plant types. Unless several generations are permitted, certified seed can normally be produced in seed production areas outside the defined area of adaptation of the variety without danger of population shifts.

Isolation. Isolation requirements for the maintenance of genetic purity must also be in conformity with internationally acceptable standards. The distances required for the production of basic seed may be slightly lower than those for breeders' seed, but must be appreciably greater than those for certified seed. If the first or second generation of certified seed is eligible for sowing to produce further generations, the isolation requirements may be somewhat less than for basic seed, but must be more strict than for the last generation of production permitted. Isolation is not only important for the maintenance of genetic purity, but it is also necessary for certain crops and varieties in some countries for the control of such diseases as loose smut on barley, caused by *Ustilago nuda*; loose smut on wheat, caused by *Ustilago tritici* or *Ustilago nuda*; and dwarf bunt of wheat, caused by the *Tilletia* species.

These diseases cannot be controlled by normal seed treatment, but require special methods, such as hot-water treatment of the seed. Fields planted with specially treated seed must be adequately isolated from other fields of the species planted with untreated seed. Where the treatment of basic seed gives sufficient control during subsequent generations, crops for producing certified seed must be adequately isolated from other grain or seed fields planted with different seed stocks. If this precaution is not taken, the effect of the special treatment for control of the disease may be lost in one growing season.

Sowing. Basic seed production fields should always be planted in rows to facilitate roguing. For wheat and rice the space between rows that are sown with a conventional grain drill may vary from approximately 15 cm, when sufficient breeders' seed is available, to several times this distance, when it is necessary to extend small quantities of breeders' seed so as to obtain the maximum quantity of basic seed possible. When an insufficient quantity of breeders' seed is available, experience has proved that a greater increase of seed harvested in relation to the seed sown can be obtained by spacing rows wider than normal or by reducing seeding rates. Fields

FIGURE 8. Roguing of wheat basic seed plots. Note spaces left between drill widths to facilitate roguing of off-type plants.

for the production of certified seed are normally sown at the seeding rates recommended for the country. These rates may frequently be slightly less than those customarily used for grain production. In fields of basic and certified seed of wheat, barley, and rice that are being sown with grain drills at the conventional row spacing of approximately 15 cm, it is recommended that the mouth of the centre grain-distributing tube of the drill be closed off. This will leave a blank row in the middle of the drill width, to serve as a path for the roguing party. It will also help to keep the roguing party properly oriented and spaced, particularly when the wind is causing considerable movement of the plants (Fig. 8).

Roguing. Roguing must always be considered a necessary part of the basic-seed production operation. The amount of material to be removed and therefore the intensity of the operation depend upon how thoroughly the plot producing breeders' seed was rogued and upon the precautions taken from the harvest of that seed to the establishment of the basic seed field. If any off-type plants or admixtures are removed during the first roguing of the basic seed field, the necessity for a second pass is certain. When plants of several distinct types or particular weeds are to be removed, experience has shown that several passes should be made through the field, each time with the objective of removing a distinct type, rather than all off-types, as people are able to concentrate for longer periods on the removal of one type of plant. Several more rapid passes always result in more successful roguing than one prolonged operation which attempts to remove everything at one time.

As was emphasized previously, roguing is more effective on smaller areas of production. It is impractical and uneconomical to plan to rogue efficiently hundreds or thousands of hectares at the stage of certified seed. The basic seed multiplication phase, therefore, represents the last effective chance, if necessary, to put the variety in order. Since even the basic seed production phase is apt to be too large for the personal attention of the breeder, the person responsible for the basic seed production, together with trained field personnel, must assume responsibility for proper roguing. The breeder should be informed as to what plant types and admixtures have been found necessary to remove, and his counsel should be sought whenever needed. If proper roguing is done at the breeders' and basic seed production stages, and the necessary precautions are taken to prevent mixtures during harvest and seed-handling operations, theoretically there should be little need for roguing of certified seed production fields of genetically stable varieties. It is recommended, however, that a roguing party pass at least once through fields for certified seed production.

Harvesting. For the production of basic and certified seed the fields are normally large enough to permit the efficient use of combine harvesters. The availability of equipment and the stage of development of the country will naturally determine how harvesting and threshing are finally done. Seed production should certainly be mechanized at least to the point of using mechanical reapers or binders and stationary threshing equipment. A successful, long-term, large-volume seed production programme cannot be based on manual labour and animal power.

The proper adjustment and cleaning of threshing equipment is essential. Inexperienced or improperly trained operators know little about the proper adjustment of a combine. If the machine is improperly adjusted, a large proportion of the seed crop may be lost or the seed may be severely damaged to the point that vigour and germination are greatly reduced (Fig. 9).

With cereal crops the greatest seed losses are normally due to the following:

(*a*) Too rapid forward motion of the combine. When this occurs, the volume of material in the combine is greater than the separating capacity of the riddles and sieves, which means that good seed is carried out of the back of the combine together with the straw.

(*b*) Incomplete threshing of the seed heads. This is due to improper

FIGURE 9. Harvesting by combine.

cylinder speed or improper clearance between the cylinder and the concaves.

(*c*) Too much wind due to improper fan adjustment. This causes good seed to be blown out of the back with the straw.

(*d*) Improper adjustment of the top separating sieve, together with improper fan adjustment. This causes good seed to be discharged from the back of the combine, as well as an excess of threshed seed to be returned to the threshing compartment by the tailings auger.

During combining the operation of the machine should be periodically checked by a person who follows behind with a container to catch the material being discharged below the straw. The material gathered should be checked for the presence of good seed. Also the straw should be examined, to determine whether complete threshing is being accomplished.

Many combine operators, even those with experience, are not sufficiently aware of seed damage and the necessary adjustments for avoiding it. Harvesting high-quality seed requires far more attention to proper adjustment than commercial grain harvesting does. The resiliency of seed — that is, its ability to withstand shock without permanent deformation or rupture — is an important factor in determining the proper cylinder speed and the distance between the cylinder and concaves. Wheat, barley, and rice seeds are easily damaged. During harvesting it is easy to detect broken seeds caused by improper adjustment. Moreover, in addition to this visible damage there may be an equal or greater number of seeds that will not germinate because of breaks in the seed coat, which may not be visible without magnification. This is due to excessive cylinder speed or insufficient distance between the cylinder and concaves.

Combining conditions vary from field to field and from morning to night. A skilful operator checks his combine several times during the day and makes the necessary adjustments. In contrast, poor seed growers and unskilled combine operators are apt to adjust the combine at the beginning of the season and make no further adjustments until harvesting is completed.

Inexperienced personnel may spend hours cleaning a combine, but it will still not be sufficiently well cleaned for harvesting basic or certified seed. The parts of the machine which may still harbour contaminating seed, even after supposedly thorough cleaning, are usually the following:

(*a*) In the threshing compartment, behind the cylinder bars. These bars in many makes of combines are recessed at the back, thus permitting an accumulation of dust, dirt, and seed. These recesses must be scraped and cleaned thoroughly.

(*b*) The cross-auger in the bottom of the machine, which conveys the threshed seed to one side and into the seed elevator. Without extensive dismantling of the machine this is the most difficult area to clean, even with vacuum equipment or forced air. If there is not an accumulation of compacted material in the bottom of the auger trough, this area can easily be cleaned with water, preferably under pressure. The side of the combine opposite the discharge end of the auger should be elevated by running one wheel of the combine onto a block of wood. The clean-out door at the bottom of the seed elevator is opened. Water is then hosed into the auger and flows freely out of the elevator boot, carrying all loose seed with it.

(*c*) The tailings auger, which on all combines is the rearmost horizontal auger and delivers material to a side elevator for return to the threshing compartment. Although it is more accessible for cleaning than the seed auger, it can also be cleaned easily by elevating one side of the machine and using water.

(*d*) The "scour-kleen" attachment, on combines having this accessory, which cleans out weed seeds as the seed passes from the discharge end of the seed elevator to the seed tank or bagging attachment. Broken or small kernels of the previously harvested crop are frequently found wedged in the perforations of the screen.

After the cleaning process has been completed, the combine should be run for several minutes before entering the seed crop, to observe whether contaminating seeds are still being discharged. During this time the combine should be operated at below normal and above normal threshing speeds.

Carry-over seed. As with breeders' seed, continuity of the seed programme will be greatly assured if basic-seed production plans provide for carrying over about 50 percent of the estimated sowing needs for the next season. This policy is a safeguard against the possibility of complete or partial crop failure owing to uncontrollable conditions. As a further safeguard in basic seed production, it is recommended that production risks be divided by *not* sowing all of the seed production of a variety with one producer or in one area. The philosophy of not "putting all your eggs in one basket" is very appropriate.

Carry-over should not be the objective of a well-functioning certified-seed programme, except when further generations of certified seed are allowed. Proper planning of the volume of seed production, accompanied by effective seed distribution and use of the seed by farmers, should ensure that practically all supplies of certified seed are normally disposed of each growing season. The carry-over of large amounts of seed by producers or distributors is very expensive in terms of the capital invested, the additional storage costs, and the attention required. Under some conditions there may be a good chance of total loss of investment due to a loss of seed vigour and viability. Producers and distributors soon become discouraged with the programme if they are confronted annually with the problem of large seed carry-overs.

Commercial seed production

Commercial seed is generally considered to be that which is produced outside a seed certification programme, although occasionally it may come from fields which have failed to meet certification standards. It may be one or more generations removed from certified seed, or the origin of the seed sown for commercial seed production may be unknown or unrelated to certified seed. The crop from which the seed was derived may have been sown for seed production, or it may have been nothing more than a grain crop that was decided to be used as seed at or after harvesting.

The producers of commercial seed do not normally observe the precautions required for maintaining varietal identity and genetic purity during the production of certified seed. Exceptions are known when producers, seed companies, and distributors take considerable pride in the product and by implementation of their private "control programme" endeavour to supply their customers with a quality product. In general, however, the only quality controls of commercial seed are the seed laws and regulations governing minimum quality standards for seed distribution. Some countries do not have such regulations, and in many of those that do, the regulations are not effectively enforced. The long-term objectives of successful seed programmes should be to obtain a high proportion of certified seed, thereby reducing to a minimum the need for commercial seed.

Seed production of maize

Breeders' seed

The maintenance of genetic stability is more important at this than at any other stage of seed production. Purity and genetic stability in the later stages of maize seed production — single cross, three-way cross or double cross — depend on the stability of the inbred-line parents which are maintained and increased at the breeders' seed stage. Keeping maize inbred lines calls for great care, as cross-pollination endangers purity. Mutation and delayed segregation are the other causes of changes in stability or breeding behaviour and may introduce off-type plants. Mechanical mixtures are also possible. All these contaminations must be carefully eliminated at the maintenance and increase stages.

The specific measures adopted for maintaining maize parental material depend on the nature of the material. Inbred lines are either maintained by sibbing or selfing, both of which are done by hand-pollination. Maintenance by sibbing is preferred by some breeders because it does not reduce the vigour excessively; however, if a change in breeding behaviour is noted, then selfing is used as a means of stabilizing the inbred. It is preferable to maintain some parental materials by alternate selfing and sibbing from one generation to the next. The maintenance plots should be grown as ear-rows in order to keep track of any instability which may occur. Noninbred breeders' seed is always maintained by sibbing.

Seed and isolation requirements. Generally, only a limited amount of seed of inbred lines is maintained by hand-pollination for producing the next stage: single-cross seed. It is therefore imperative that the seed be increased to meet the single-cross production requirements. These requirements have to be planned in such a manner as to satisfy the projected production of certified seed of released varieties (see *Production planning* on p. 38).

If the quantity of breeders' seed required means growing a larger number of plants than can be hand-pollinated, the crop is usually allowed to sib-pollinate in an isolated field. It is important at this early stage that the crop be very well isolated. Isolation can be effected either by distance or time. Distance isolation is very commonly used to increase, or bulk, inbred lines of maize. Where space isolation is not possible, however, time isolation can be used just as effectively. The limitation of time isolation is set by length of season. In temperate climates there is the danger of sowing too late and running into frost; in other climates the limit may be determined by drought or simply by reduction in yield due to late sowing. The isolation distance depends on various factors, such as the nature of the material to be protected by isolation, the nature of that from which isolation is sought, and the direction of the prevailing wind. Gacitua (1946) suggests that what is considered to be adequate isolation is mostly based on practical experience in particular situations, rather than on experimental evidence. In principle, however, it is generally agreed that breeders' seed of maize inbred lines, for example, requires much more stringent isolation than the later stages. Jugenheimer (1958) suggests that the minimum isolation for inbred lines should be 400 m from any other maize.

The methods used for growing inbred lines do not differ much from those used for other maize, except for the isolation requirement. It seems to be most important that inbred lines be given good growing conditions so that they may have a chance to show their genetic potential. It is not always possible to provide the best growing conditions for inbred lines because the choice of growing conditions is limited by the necessity of meeting a specific seed requirement and the need to spread growing risks. In addition, the isolation requirement itself imposes a limit on the choice of growing conditions.

Roguing. Despite all the efforts made to maintain purity in inbred lines by hand-pollination and by adequate isolation, it is still not possible to achieve perfection by these means alone; the isolated fields for bulking inbreds must also be carefully rogued and checked for off-types prior to shedding pollen. Fortunately it is very easy to recognize the out-crossed rogues because they are normally much more vigorous and stand out quite clearly in an inbred field. There are, however, other off-type plants which are not easily detected, particularly in bulk planting. These off-types are more easily distinguished when the inbred ears are sown in ear-rows, but this system can only be used during the early stages of maintenance and increase. The problems of roguing, particularly the removal of off-types from isolated inbred bulking fields, require an experienced person who knows the inbred lines extremely well. This is a responsibility which requires a continuity of staff working with the material.

Harvesting. Harvesting and shelling of maize seed, including breeders' seed, are mechanized in the developed countries. But it cannot be stressed too strongly that if harvesting and shelling machines are not reliable, then, hand operation, where labour is cheap, is best and safest. The disadvantages of using mechanical shellers include the possibility of admixture and of cracking the seed. Harvesting may be done by machine, provided that the losses are not excessive, since at this stage the need to provide a certain quantity of seed can be critical. If machine harvesting is used, the opportunity to check on the ear characteristics of the particular inbred should not be lost in the process. The time between harvesting and shelling can be used effectively to eliminate any off-type or doubtful type ears from the inbred.

Carry-over seed. The handling of breeders' seed (inbred lines) of maize must be efficient because of the great importance of genetic stability and its likely influence on the more advanced stages of maize seed production. Nevertheless, seed production of inbred lines can be prone to accidents and unpredictable disasters, so a system for carrying over seed is the best insurance against failure. Essentially, carry-over seed is extra seed which is retained for a year or longer if needed as a safeguard against unforeseen shortages. The effect of a shortage at the breeders' seed stage will not be felt by the consumers of certified seed until two or three years later, but it is unwise to disappoint consumers who have developed confidence in a supplier of a popular commodity. Once confidence is lost, great effort may be needed to regain it. Carry-over seed is therefore desirable. The percentage of production that should be retained as carry-over depends on the risk factors, which can only be known from practical experience.

Basic and certified seed

The methods of handling basic and certified seed may be less strict than those applied to breeders' seed, but all are essentially aimed at preserving genetic purity and stability. Purity is important at the basic and certified seed stages; if there have been mistakes, this is the last opportunity to rectify them. For maize these stages of seed production comprise single-cross production followed by double-cross or three-way-cross production. The standards of production adhered to for the single cross are generally higher than those for the double cross. Effective purity-control measures can be applied more easily to the single-cross production fields, as rogues and off-types can easily be removed from the less vigorous inbred parents. The control of genetic purity at the later stage of double-cross seed production is more difficult as most of the characteristics of the original inbred parents are usually masked at the single-cross stage. There is, however, an opportunity at the certified double-cross seed production stage to prevent major mistakes which might result in the certified seed not being genetically representative of what was intended to be produced.

Isolation and field operations. The seed requirements for the inbreds making up a single cross depend partly on planting ratio. In single-cross production this is normally 2:1, seed parent to pollen parent, and the inbred seed requirement therefore follows the same ratio. The amount of seed produced at the single-cross stage sets a limit on how much seed can be produced at the double-cross stage. In double-cross production fields the planting ratio is normally six rows of seed parent to two rows of pollen parent. This ratio can be varied depending on the pollen-production capacity of the pollen parent.

The isolation required for both single-cross and double-cross seed production is a minimum of 200 m from any other source of maize pollen. This can be modified, however, according to the particular set of circumstances under which the seed is produced. The Kenya system serves as a good example of the modifications which may be necessary where the individual areas of the production units (or fields) can be as small as 13 ha or less.

In Kenya it is stipulated that seed production fields of 30 acres (13 ha) or less shall be isolated by a minimum distance of 200 yd (183 m) from any other maize sown during the season, whether on the same or an adjoining farm. Where isolation is the minimum required, four effective pollen border rows must be planted between the seed-parent rows and the potential source of contamination. If the isolation is 300 yd (274 m) or more, the number of pollen border rows may be reduced to only one. Four pollen border rows across the ends of the seed field are also required if the distance from the possible source of contamination is 200 yd (183 m) or more, but this precaution is not necessary where the possible source of contamination is 300 yd (274 m) or more from the field.

The minimum isolation required for larger seed fields of over 30 acres (13 ha) is 150 yd (137 m) from any other maize sown during the season; at this distance a minimum of eight effective pollen border rows are required between the seed parent and the potential source of contamination. For these larger fields the pollen border rows may be reduced to only four if the isolation distance is 200 yd (183 m) or more. At an isolation distance of over 300 yd (274 m) only one pollen border row need be grown.

Sowing. Sowing is an important operation requiring the utmost care. It is generally recommended that the entire seed parent in a production field be sown within five days, so that the spread of silking is well within the pollen-shedding period of the pollen parent. Pollen rows and seed-parent rows can be easily distinguished by using marker posts or by sowing marker seed, such as sunflower. It is also important to make sure that seed is not mixed between rows by rain, water wash, or cross-harrowing.

Roguing. As was stated earlier, a single-cross production field is easier to rogue than a double-cross field. The idea is to remove all obvious rogues, off-type plants, and other doubtful plants before they have a chance to shed pollen or to be pollinated. It is important to stress that all this is done in the interest of seed purity and genetic stability. Most of the roguing problems that may arise can be minimized by observing the standard requirement that seed must be produced on land which was not used for a maize crop in the previous season.

Harvesting. After the early field operations, such as roguing and detasselling, have been completed and the field has been inspected for certification, the last field operation is harvesting, when the crop has reached physiological maturity. In harvesting great care must be taken to prevent mixing ears from the two parents. As a rule, all the pollen-parent ears are removed from the field prior to harvesting the seed-parent plants. Every care must be taken at this stage to make sure that the two parents are kept entirely separate during the handling of ears and seed. Harvesting should be started after maturity is attained and the kernels in the seed parent are properly filled. Airy (1955) lists the following advantages of early harvesting at 35–25 percent moisture:

1. Loss of seed in the field due to mechanical pickers is avoided.
2. The risk of delays in harvesting due to rainy weather is reduced.
3. There is less risk of abnormally low temperatures prior to completion of harvesting all seeds.
4. Further development of ear-rot fungi is prevented.
5. Insect damage from corn borers and ear worms is halted.
6. Severe shelling losses from handling low-moisture grain are avoided.

Obviously these advantages do not apply in all seed production situations.

In Kenya, for example, the main advantages of early harvesting would be the reduction of losses associated with very wet weather during the harvesting period. On the other hand, the losses associated with mechanical picking and shelling are not important, as both of these operations are done by hand. Where there is no risk of encountering wet weather at harvest time, it may be advantageous to allow the seed crop to dry a little longer in the sunny weather, rather than to harvest early and meet the cost of drying artificially; but, even where the weather is likely to be favourable for natural drying and later harvesting, there may be danger of infestation by grain weevils when the maize is left too long in the field. Once infestation has started, control measures cannot be applied effectively in the field.

In developed countries a combination of factors usually creates a situation in which mechanization becomes necessary. Among these factors are labour scarcity and cost, the scale and site of production, and the necessary pressure of time in competitive situations. As labour costs continue to rise, the advantage of machine harvesting and shelling cannot be ignored in developing countries. In view of the general increase in the demand for certified seed, hand labour may not be sufficient. Also, in large-scale production the problem of supervising hand labour becomes important, and mistakes must be avoided. Effective mechanization is possible only when the various machines are properly adapted and adjusted to the material to be harvested or shelled. To avoid losses due to the use of unsuitable machinery, judicious importation of equipment from developed countries is important.

Carry-over seed. Planning for certified seed production in developing countries can be difficult, particularly where rapid expansion is taking place. Neither the present demand nor the rate of its increase can be estimated accurately. In contrast, planning is simpler in countries where the potential market for improved seed is already saturated, because the requirement is fixed, varying by only small, fairly predictable percentages. The need for carry-over seed arises in planning situations where unpredictable and unforeseen circumstances are likely to arise. As the seed yield may fluctuate from year to year, it is important to carry over about 50 percent of the estimated sowing needs of basic seed for the following season, as a safeguard against fluctuations due to weather. Another factor to be considered is a possible sudden upsurge in demand for seed. Of course, there is a limit to the amount of carry-over seed which can be handled, as it is costly to carry over large quantities. In some countries one of the most important reasons for carry-over, apart from those already mentioned, is that certain ecological zones in the country have seasons that are far out of phase with those of the area where the seed is produced. It is important to store carry-over seed under good conditions, so that the viability is not seriously affected. It is always desirable to make germination tests before planting.

Commercial seed

The first section of this chapter briefly discussed commercial seed, and it should be reiterated here that certified seed is regarded as the ultimate goal. In the self-pollinating cereals, which remain relatively stable genetically for a longer period, the sale of noncertified seed might be allowed to fill a shortage. For maize, commercial seed that comes nowhere near the requirements for certification may be genetically mixed beyond recognition.

Under the circumstances existing in some developing countries, where major effort is still devoted to teaching farmers the value of improved seed, the policy adopted should be that which sells the most improved seed — that is, certified seed. This policy would classify commercial maize seed or noncertified maize seed as unimproved maize, which is associated only with the type of low-level farming that everyone is trying to surpass.

4. SEED DRYING AND PROCESSING

by A.H. Boyd, G.M. Dougherty, R.K. Matthes, and K.W. Rushing

Seedsmen who dry and process seed (drier-processors) play an important part in agricultural development, as farmers and seed producers depend on them for the preparation of seed. Their ability to render this service effectively and efficiently is influenced by the types of equipment available, their skill in operating the equipment, their knowledge of seed characteristics and how they relate to drying and processing, and their knowledge of quality marketing standards for seed.

Manufacturers have developed excellent products and equipment for drying and processing maize (*Zea mays* L.), wheat (*Triticum* spp.), rye (*Secale cereale*), barley (*Hordeum* spp.), oats (*Avena* spp.), rice (*Oryza sativa*), sorghum [*Sorghum bicolor* (L.) Moench], and millets (*Panicum* spp., *Pennisetum* spp., and *Eleusine* spp.). It is the seed drier-processor's responsibility to learn when, why, and how to use them best.

Seed drying

JUSTIFICATION FOR DRYING

Cereal grain seed attains physiological and functional maturity at seed moisture contents ranging from 35 to 45 percent, depending on the crop (Dale, 1956). At this stage of development the seed has reached maximum germination capacity and vigour. Consequently, the sooner seed is harvested after reaching maturity the higher the seed quality, assuming the seed can be effectively dried for safe storage to moisture contents in the range of 10–12 percent. In addition to losses in germination capacity and vigour, extended preharvest field exposure after physiological maturity frequently results in yield losses because of lodging, shattering, disease, and insect damage.

Harvesting seed at high moisture contents — for example, 30-35 percent for maize (Matthes *et al.*, 1969); 15-17 percent for wheat (Johnson, 1959), barley, and oats; and 20—21 percent for rice (*Grain drying manual*, 1969) — poses immediate and serious problems, for at these moisture contents seed will heat and deteriorate very rapidly. Seed moisture content during storage is the most important factor influencing seed deterioration (Harrington, 1959; Henderson and Perry, 1955): mould growth can begin at 12–14 percent, heating due to increased rates of respiration and micro-organism activity begins at 16 percent, and seed will begin to germinate at 35–60 percent moisture content [Delouche, 1968(b); Giles and Ashman, 1971]. The enormous influence of seed moisture content on seed longevity makes artificial drying almost mandatory in the production of high-quality seed.

FIGURE 10. A high-capacity cereal seed processing plant.

FUNDAMENTALS OF DRYING

All seed is living hygroscopic material with a very complex and heterogeneous structure, of which water is a fundamental and ubiquitous part. Since seed is hygroscopic, its moisture content depends upon the relative humidity and temperature of the air. The determining factor in this relationship is the water-vapour pressure which exists in the seed and in the air surrounding it (*Grain drying manual*, 1969; Hall, 1957; Haynes, 1969; Henderson and Perry, 1955). Whenever the vapour pressure within the seed is greater than that of the surrounding air, vapour will move out of the seed (Shortley and Williams, 1953). If the vapour-pressure gradient is reversed, the movement of moisture is also reversed — that is, into the seed. When the two vapour pressures are equal, there is no net movement of vapour, at which point the moisture content of the seed is in a state of equilibrium with the surrounding atmosphere.

Drying takes place when there is a net movement of water out of the seed into the surrounding air. The rate at which seed will give up this moisture (rate of drying) is determined by how fast moisture migrates from the interior to the surface of the seed and by the speed at which the surface moisture is transferred to the surrounding air. The rate of moisture migration from the centre to the surface of a seed is influenced by seed temperature, physical structure and chemical composition of the seed, and seed-coat permeability. The rate of moisture removal from the surface of the seed is influenced by the degree of surface saturation and the relative humidity and temperature of the drying air. It has been well established that drying-air temperatures higher than 43°C are detrimental to seed quality.

DRYING SYSTEMS

The type of drier that is best suited for a particular situation depends upon the volume of seed to be dried in a season, the length of the drying season, the number of varieties to be handled, the size of seed lots, and the handling or transportation methods to be used. There are several types of driers from which to choose.

Bag driers

Bag driers are well adapted for use when many varieties are handled or when seed lots are small in size and the seed is received from the field in jute bags. Excellent air flow with minimum static pressure is possible because the drying bed is only one sack deep. Typical design criteria provide 25–40 m³ of air per minute per cubic metre of seed at a static air pressure of 3 cm or even less. Construction is simple and inexpensive (*Honduran seed program*, 1966; Matthes *et al.*, 1969).

Box driers

The box drier is a modified bag drier. It is well adapted for use in basic seed-drying operations. With box driers the identity of small seed lots can be maintained despite bulk handling. The boxes, generally constructed of locally available materials, are fitted with perforated metal or woven wire bottoms. After the seed is dried, the filled boxes are removed from the drier and placed in a temporary storage area, thus making room on the drier for additional boxes. Obviously this type of drier requires that enough specially constructed boxes be maintained (Fig. 11).

Bin driers

When seed is received from the field in bulk or seed-lot yields exceed 5 tons, perforated floor drying bins are very practical. Bins of this type, which can usually be obtained at reasonable cost in most countries, are widely used. The roof, sidewalls, and perforated flooring are generally purchased together; the base wall, which serves as a plenum chamber and upon which the bin is mounted, is constructed of concrete. A fan and heater must also be purchased. A drying system comprised of bin driers will satisfy the needs of most seedsmen. Drying bins in a multiple bin installation can be arranged in a number of different patterns. In a drier installation designed in 1969 for rice seed (Bunch *et al.*, 1969) the bins were arranged in a U-shaped configuration (Fig. 12).

Flat storage drying

When seed lots are large, and mostly of one variety, flat storage drying should be considered. Air pressure and air-flow requirements for flat storage drying and bulk bin drying are similar. An existing warehouse-type building can be converted quite easily into a flat storage drier (Fig. 13).

Continuous-flow tower drier

Tower driers have a limited application for drying seed. They are usually associated with installations handling very large quantities of grain. As they are difficult to clean, there is always a danger of contamination if the drier is used for more than one variety. Airflow rates in tower driers approximate 75–85 m³ of air per minute per cubic metre of seed.

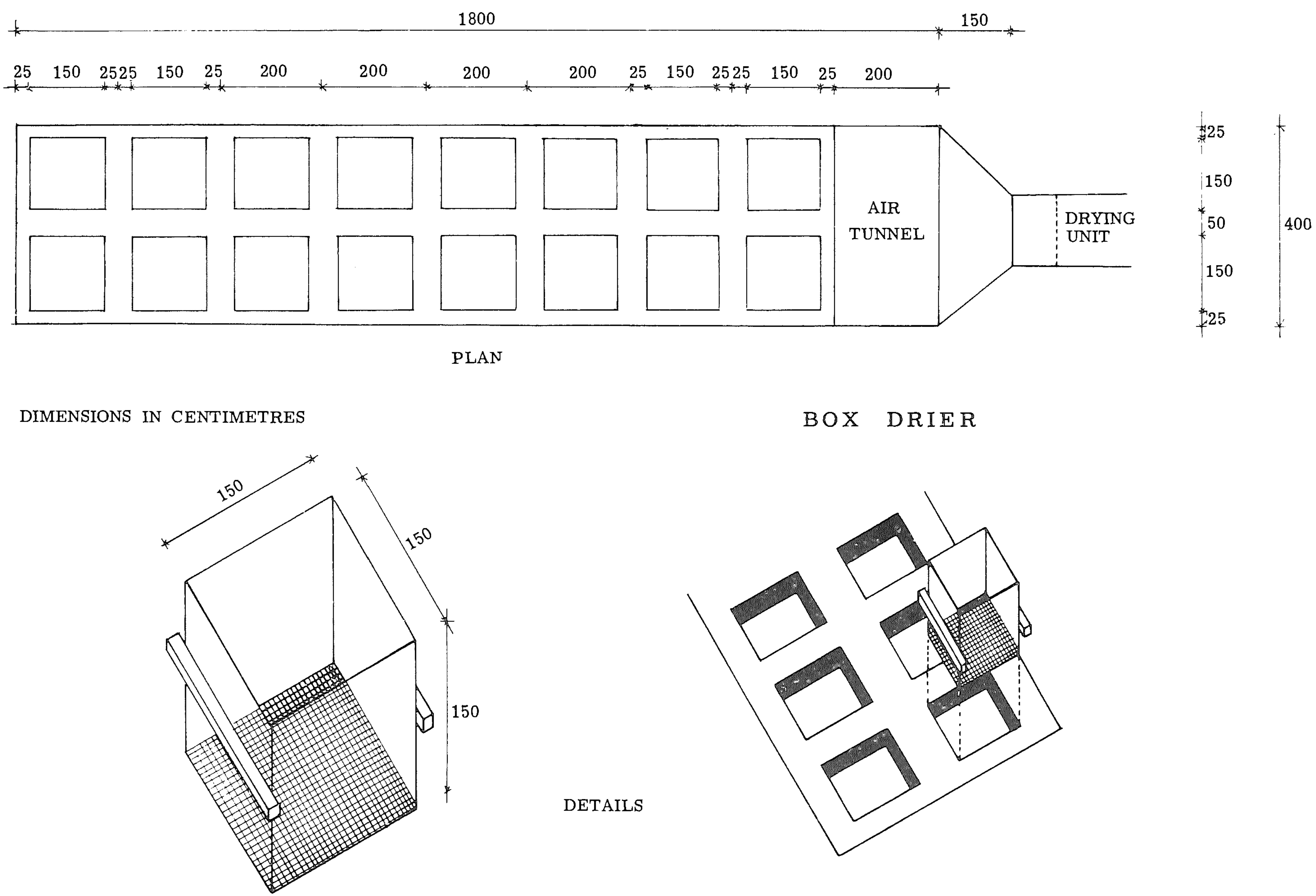


FIGURE 11. Box drier for drying and storing seed.

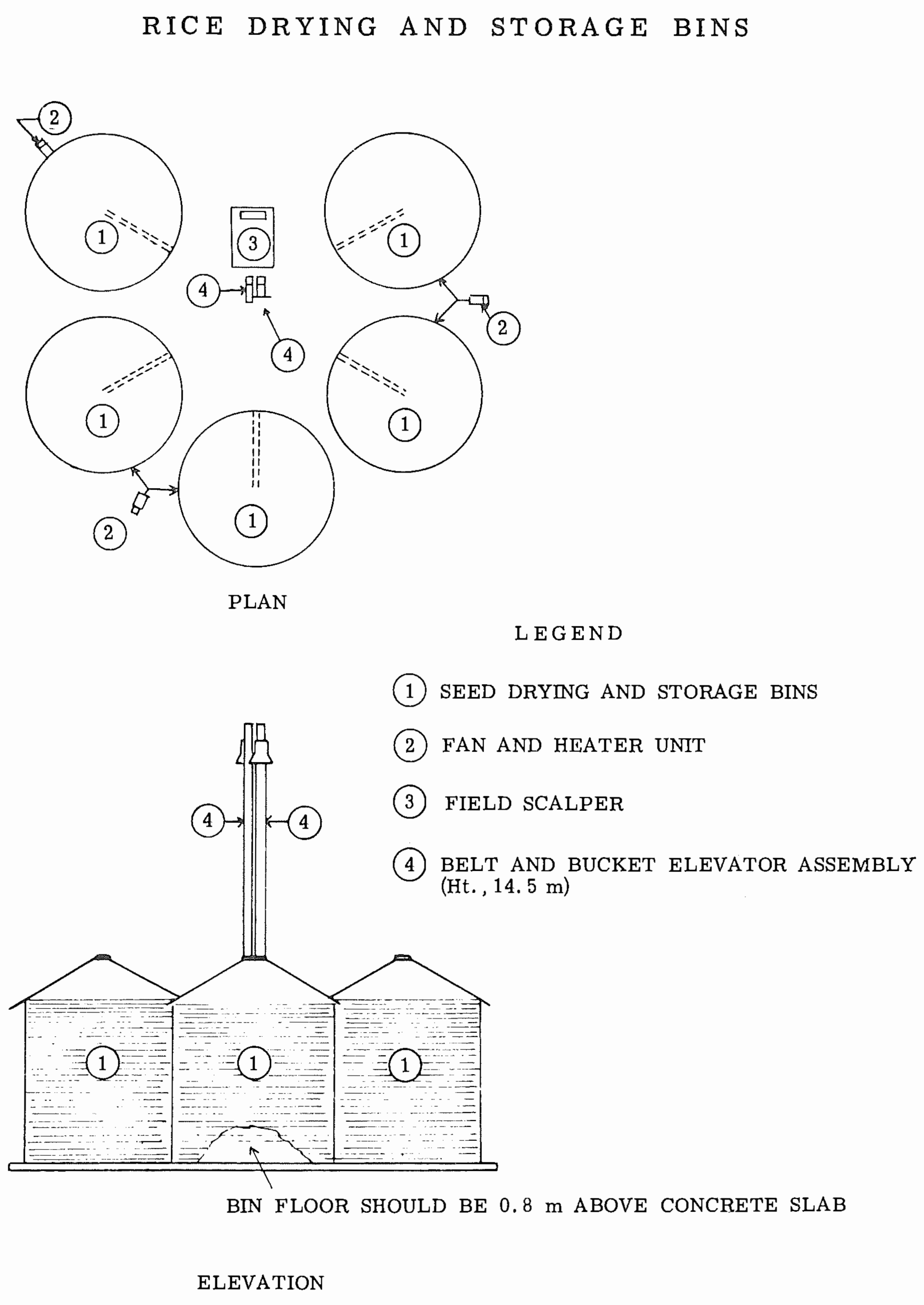


FIGURE 12. Bin drier for rice seed.

BULK RICE DRYING AND STORAGE FACILITIES

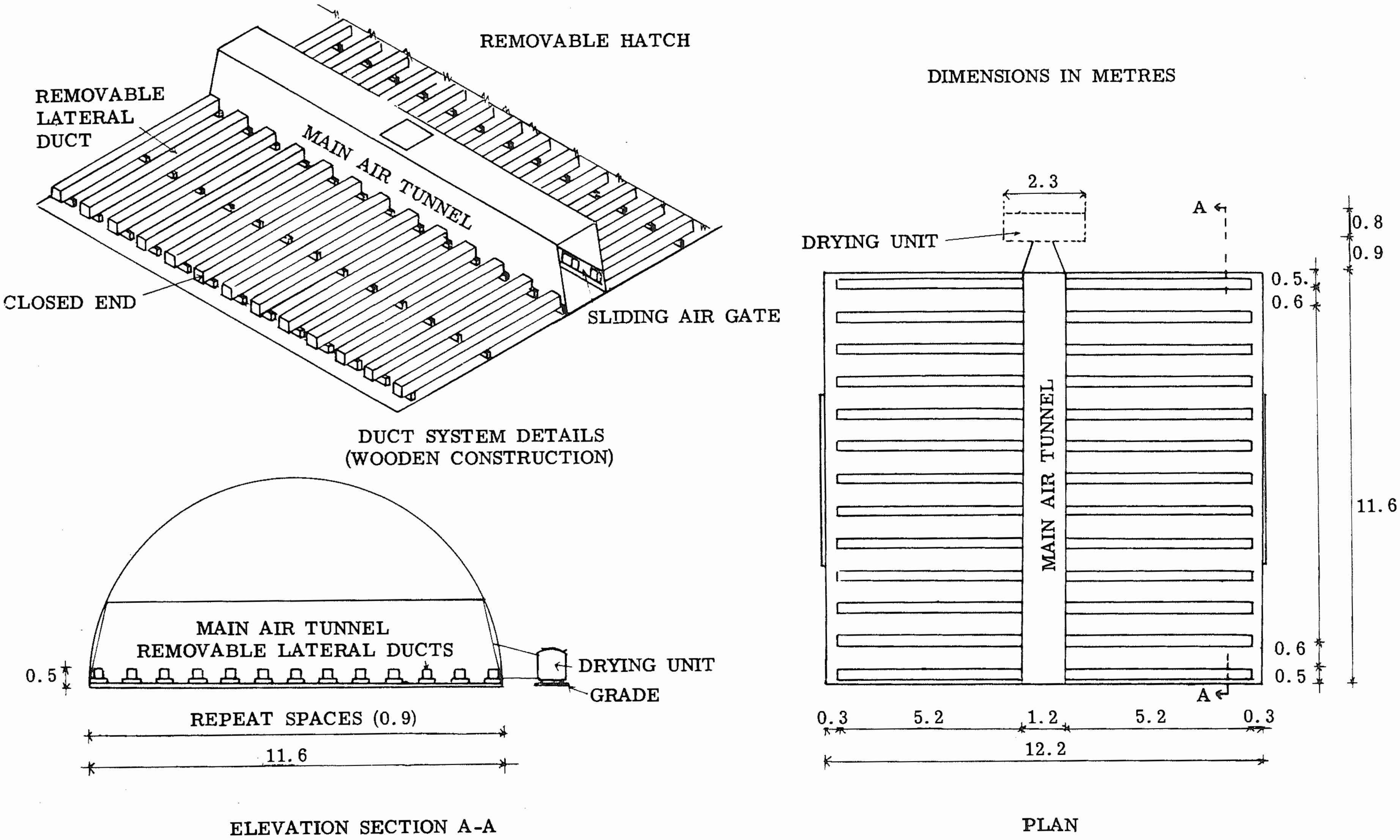


FIGURE 13. Drying and storage facilities for bulk rice.

Ear maize drier

If maize is a major crop, it is desirable to construct an ear maize drier (Fig. 14). Ear maize driers require an airflow of 15 m^3 per minute per cubic metre of ear maize (minimum), and the depth of material should not exceed 3 m.

DRYING DESIGN CONSIDERATIONS

Although there are several drying systems and many different types of physical arrangements, all have components in common. The design of seed-drying facilities must take into consideration both size and type of components as dictated by the drying systems used.

Fans

Normally a radial axial fan with backward-curved blades is recommended for seed-drying systems (*Grain drying manual,* 1969). The fan should be of sufficient size to deliver 8 m^3 of air per minute per cubic metre of seed, against a static pressure of 8.75 cm of H_2O for deep-bed seed drying in bin and flat storage driers. To obtain the required amount of drying air without exceeding 8.75 cm of H_2O static pressure, seed depths should not exceed the following: for ear maize, 2 m; for shelled maize, 1,5 m; and for all other kinds of cereal seed, 1 m (Shedd, 1953). For a bag-type drier the fan should be capable of delivering 25-40 m^3 of air per minute per cubic metre of seed, against a static pressure of 2.5 cm of H_2O when the drier is full.

Heaters

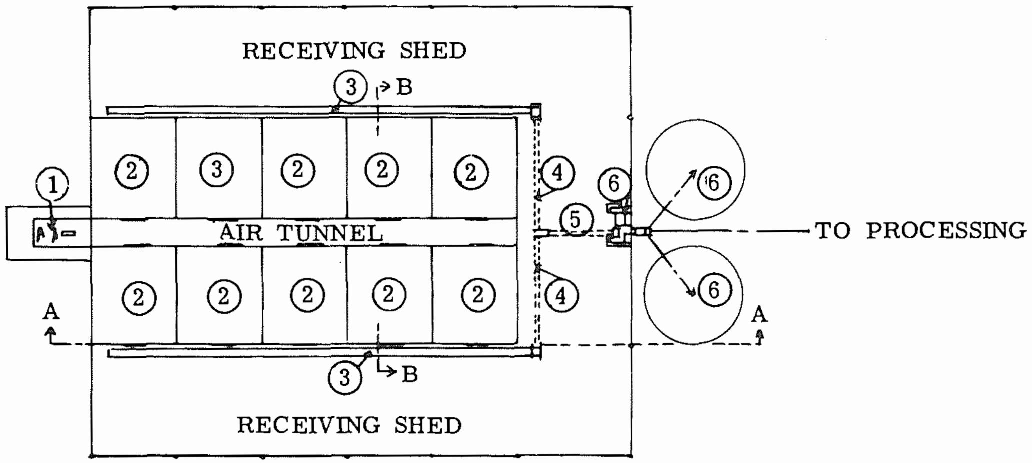
Heaters which can maintain the temperature of the drying air at 43°C should be used. Temperatures exceeding 43°C are detrimental to the viability of the seed (Harrington, 1959; Matthes *et al.*, 1969).

A direct-fired burner using natural or liquefied petroleum gas is more trouble-free where these fuels are available and their use is economically feasible. Where natural gas is not available and butane and propane gas are too expensive, fuel oil can be used. Direct-fired fuel-oil heaters are more efficient than indirect-fired heaters, and so long as they are properly designed and maintained for complete combustion of the fuel oil, they are satisfactory for seed drying. Incompletely burned fuel from an improperly operated or poorly designed burner will impart an objectionable taste and smell to the seed, precluding any salvage use of untreated seed for human consumption.

MAIZE (CORN) DRYING AND SHELLING FACILITIES

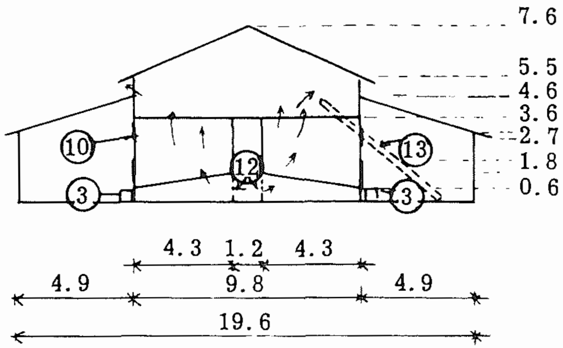
LEGEND

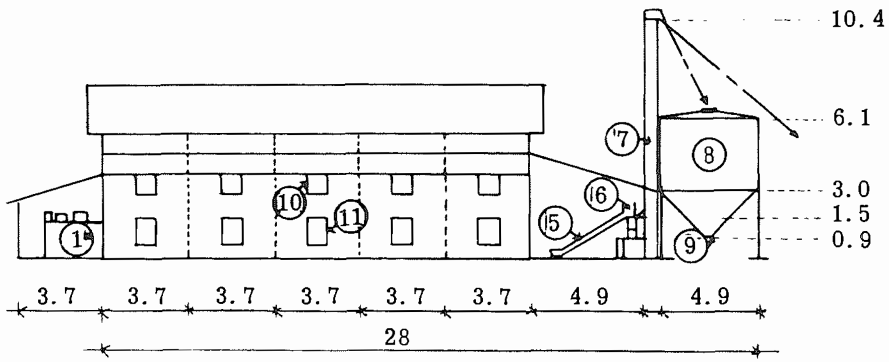
1 DRIER HEATER AND FAN
2 EAR-MAIZE BIN
3 TROUGH CONVEYOR
4 PORTABLE CROSS CONVEYOR
5 DRAG CONVEYOR
6 SHELLER
7 ELEVATOR
8 SHELLED-MAIZE BIN
9 PORTABLE CONVEYOR
10 SLIDING PANEL
11 BIN UNLOADING DOOR
12 ADJUSTABLE SLIDING DOOR
13 PORTABLE DRAG CONVEYOR



BIN UNLOADING AND SHELLING PLAN

DIMENSIONS IN METRES





ELEVATION SECTION A-A

ELEVATION SECTION B-B

FIGURE 14. Drying and shelling facilities for ear maize.

The size of the heater can be determined by the product of the total airflow, the difference between the recommended drying temperature of 43°C and the average minimum daily temperature prevalent in the vicinity, and a constant 0.07 (*Grain drying manual*, 1969). It is important that the heater be no larger than necessary, especially if it is a fuel-oil burner. A fuel-oil burner which does not burn for at least two minutes at each ignition will not get hot enough to keep the electrodes burned clean, and faulty ignition will result. This situation can be remedied by reducing the nozzle size of the fuel ejector in the burner. Ideally, a burner should have a modulating fuel valve.

Capacity

To determine the total drying capacity needed, it is necessary to estimate how long a batch of seed takes to dry in a bin. Drying time in hours can be estimated with the following adaptation of a commonly used drying equation (*Grain drying manual*, 1969):

$$t = \frac{35.44 \times MR}{F \times TD}$$

where
t = drying time in hours
35.44 = constant
MR = moisture removed (20 litres/m^3 seed)
F = air flow (m^3 air/minute/m^3 seed)
TD = temperature drop through seed (°C)

It is necessary to estimate the temperature drop for the drying air — that is, the temperature of exhaust air subtracted from the temperature of incoming air. From experimental data this drop ranges from 10°C to 15°C; thus it is surely advisable to assume that it is at least 10°C. This determines how long it takes seed to dry at a particular depth, from which the drying rate for one batch of seed can be derived. Thus, knowing the maximum rate of receiving seed, it is possible to determine how many bins will be required for drying.

Management of seed-drying operations

Seed should be dried as soon as it is received. If this is not possible, the seed should be placed in a bin equipped with a sufficient fan capacity to aerate the seed (0.5-1.0 m^3 of air per minute per cubic metre of seed) until drying can commence. Aeration will prevent heating, which can cause irreversible damage to seed viability.

Care must be taken when filling a bin drier to ensure that trash does not accumulate in any one location. This problem most often occurs under the conveyor discharge spout, where it can be alleviated by a seed spreader. Small trash has a higher resistance to airflow than seed and therefore retards drying at these areas of high concentration. Problems caused by trash are reduced by running the seed through a scalper before drying.

The temperature profile in a bin drier indicates the progress of drying in the bin. The region below the drying front is characterized by dry seed and higher temperatures and that above the drying front by moist seed and lower temperatures. The objective of bin drying is to move the drying front through the top layer of seed, thus completing the drying operation. The temperature of the top layer of seed indicates the progress of drying in that layer of seed. An increase in temperature indicates that drying has commenced in this layer, and when the temperature equals that of the incoming air, drying of the entire bin is completed. Thus a temperature monitor is also a good moisture-content monitor. Although the temperature should be used as an indicator of drying, moisture contents should be taken at random throughout the bin so as to ensure that no "wet spots" remain.

For bag drying the seed should be more than half-dried before the bag is turned — that is, if the estimated drying time per bag is 16 hours, the bags should be turned after 10–12 hours. This results in more even drying throughout the bag (Matthes *et al.*, 1969).

If seed germination drops more than 1 or 2 percent during drying, check the following conditions: excessive holding time before drying commences; insufficient airflow (less than 8 m^3 of air per minute per cubic metre of seed); excessive static pressure (greater than 8.5 cm of water); high relative humidity of drying air (in excess of 60 percent); drying air temperature greater than 43°C; excessive seed depth; uneven airflow through the seeds.

A person responsible for drying seed will learn most from the records which are kept. By keeping good records of temperature, airflow, required drying time, moisture content, different types of seed, and depth of seed drying, valuable experience is gained. Each new batch which is dried can be handled with more assurance.

Seed processing

Seed lots are processed (*a*) to remove as completely as possible such undesirable adulterants as the seed of weeds and inert materials, as well as seed that is immature, broken, deteriorated, or damaged by insects, disease, or mechanical handling; (*b*) to grade for size; and (*c*) to treat seed with

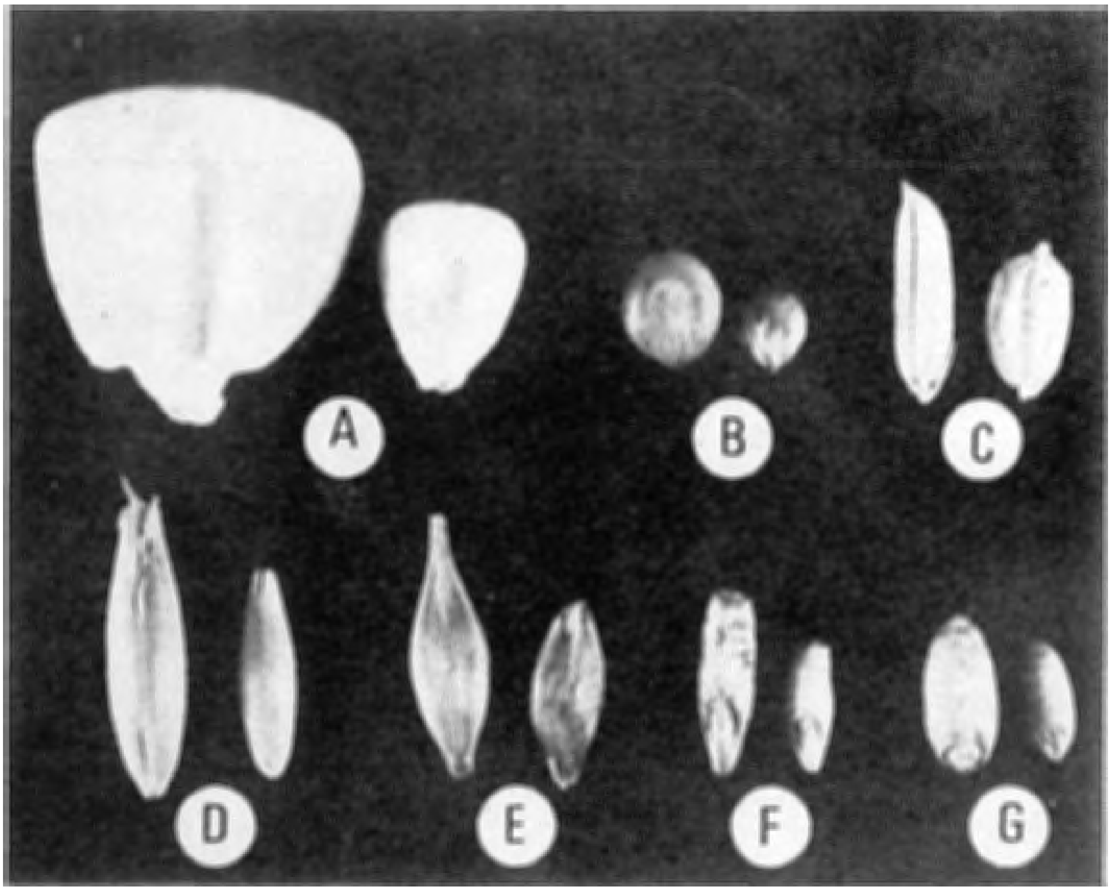


FIGURE 15. Seed of (*A*) maize, (*B*) sorghum, and (*C*) rice, showing size variations between seed of similar crop species and among seed of different crop species (*D-G*).

protective chemicals or in some other way. All seed lots, either hand or machine harvested, require some processing.

Seed processing, except for treating, is based primarily on differences in physical properties between desirable seed and adulterants. Seed and adulterants which do not differ sufficiently in some physical characteristic cannot be separated. Several physical characteristics are presently utilized in the processing of seed (Vaughan *et al.*, 1968) — for example, in the processing of cereal-grain seed lots the significant characteristics are size (width, thickness, and length) and weight (density). Size is the most prevalent difference among seed (Fig. 15) and between crop seed and undesirable materials usually found in seed lots.

Most seed lots of sorghum, millet, maize, rice, barley, oat, wheat, and rye can be processed to acceptable marketing standards with minimum expenditures of time, labour, and equipment if processing is started in the field *before* the crop is harvested. Good cultivation practices — such as

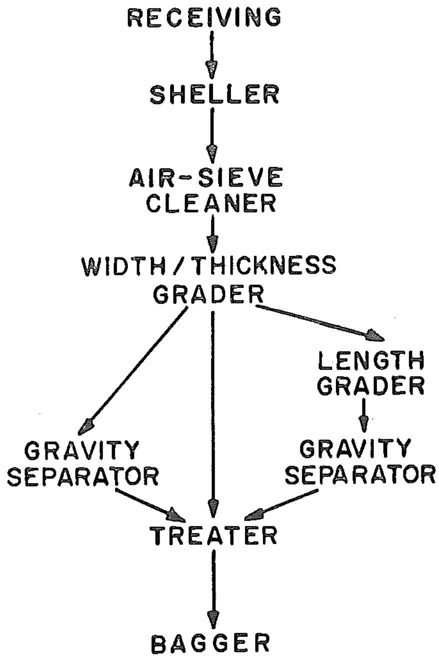


FIGURE 16. Maize seed flow diagram.

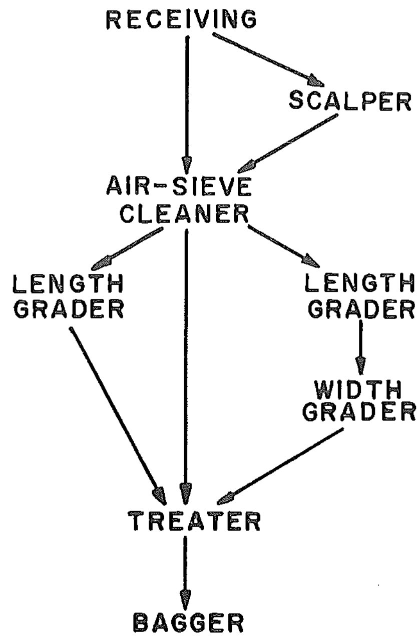
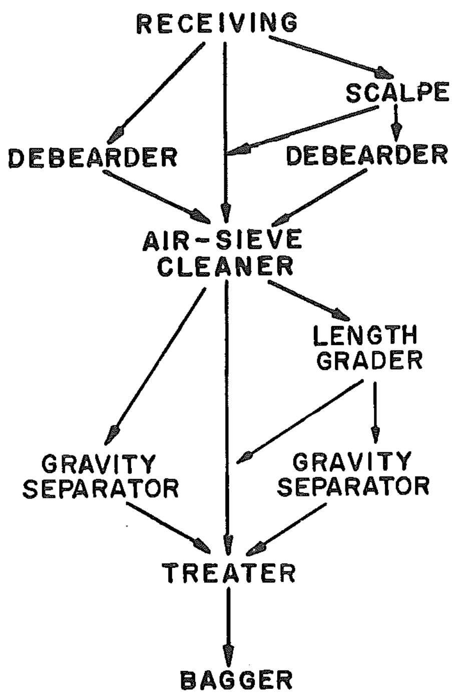


FIGURE 17. Rice seed flow diagram.

spray programmes, crop rotation, and roguing — minimize serious seed-lot contamination problems. In general, processing to acceptable standards becomes either impossible or difficult and costly when seed lots contain intervarietal or interspecific mixtures of similar-size seed or when they are heavily infested with diseased or insect-damaged seed.

Most often, satisfactory processing requires that seed lots be processed in a specific sequence through several operations. The choice of operations and machines depend on the kind of seed, the nature and kinds of adulterants in the seed lot, and the seed-quality marketing standards that must be met. (See Figs. 16-18.) The usual operations are preconditioning, basic cleaning, and finishing.

FIGURE 18. Barley, oats, wheat, and rye seed flow diagram.



Preconditioning

The term "preconditioning" is applied to operations that prepare, or condition, seed lots for basic cleaning. Shelling, for example, is a preconditioning operation in the handling of maize; precleaning and debearding (de-awning) are other examples of preconditioning operations.

Shelling

Almost all ear maize (corn) harvested for seed is either mechanically harvested with modified corn pickers, or it is hand harvested; very little is combine or picker-sheller harvested. Consequently, shelling is a required operation at almost every maize seed processing installation. Mechanical shellers are available in sizes ranging from single-ear shellers to those designed to shell in excess of 18 metric tons of ear maize per hour.

Shelling is a critical operation. Whereas maize seed is not extremely sensitive to mechanical injury at moisture contents in the range of 16–17 percent, nevertheless it can be severely damaged unless extreme care is exercised in shelling. Cold-test performance results show that as much damage occurs in shelling as in all other handling operations combined (Newlin, 1971). To minimize seed damage, maize should be shelled at a seed moisture content of 16–17 percent; the sheller should be fed uniformly, at nearly maximum load capacity, and the sheller should be adjusted to give complete shelling at the slowest possible speed. Although many commercial maize processors use specially modified shellers, satisfactory results can be obtained with most maize shellers if reasonable care is exercised in their use.

Precleaning

In precleaning, particles, usually larger in size than the desirable crop seed, are removed from the threshed or shelled seed lot. Some precleaners, in addition to removing larger-sized particles, also remove particles that are lighter in weight and smaller in size than the crop seed. Single-sieve precleaners are called scalpers, and multiple-sieve units are known as rough cleaners. Precleaners are available in many different styles and sizes. Precleaning is a high-capacity operation.

Precleaning is neither always required nor always advisable. Determining whether a precleaner is necessary and, if so, where to locate it are judgement decisions. Considered desirable by many seed processors, precleaning most often needlessly increases seed-processing costs. Hand-harvested seed lots rarely require precleaning; machine-harvested seed lots may or may not, depending on the nature and percentage by volume of adulterants in the seed lot. However desirable precleaning may appear to be, it is unlikely to be necessary unless the adulterants in the seed lot have a pronounced adverse effect on crop seed flowability. To obtain maximum benefits, precleaning should be performed before the seed enters the drier. Some processors, knowing that fewer benefits will be derived, nevertheless preclean after drying because of reduced equipment-installation costs, convenience, or necessity.

Debearding

In the processing of cereal grain crops, debearders are used primarily to remove the beard, or awn, from bearded varieties of barley. The beard, if not removed prior to basic cleaning, can interfere with seed-sizing operations and seed flowability. Debearders are also used to "clip" oats, so as to improve the appearance and increase test weight (Cutler, 1940). They can, however, be used effectively for any small grain-crop seed lot containing large numbers of incompletely threshed seed heads.

Like precleaning, debearding can be a costly operation if performed unnecessarily. Debearders require high-powered motors, of 10-15 horsepower (minimum), and can injure seed unless they are used carefully. To minimize seed injury, seed lots should be dried to approximately 12 percent seed moisture content, and the speed of the debearder should be adjusted to give the desired results at the slowest speed possible. If the debearder is to be used for multiple purposes, such as debearding, clipping, and rethreshing, it should be equipped with a variable speed drive.

BASIC CLEANING

Basic cleaning is a required operation in the processing of all seed lots. The aim in basic cleaning is to remove from the seed lot those adulterants which are larger and smaller in width or thickness than the desirable crop seed and those which are lighter in weight. Consequently, in basic cleaning, separations are made mainly on the basis of two physical properties: size and density; seed shape is also used in some separations. Frequently, aside from treatment, basic cleaning is the only processing required for upgrading cereal-grain seed lots to acceptable seed-marketing standards.

Basic cleaning is accomplished with an air-sieve (screen) cleaner. Available from equipment manufacturers in many makes, sizes, and models, the typical cleaner found in United States cereal-grain seed-processing installations has four sieves and either two or three aspiration fans (Fig. 19). With this machine, the seed flows by gravity from the hopper into a feeder mechanism that meters the rough seed into an airstream. This removes

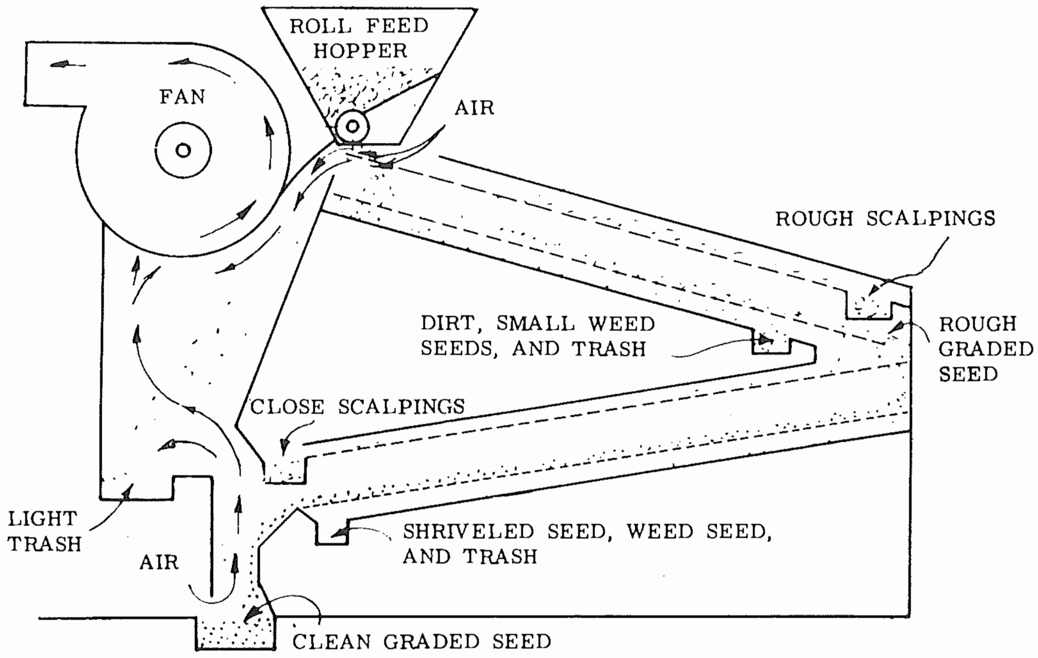


FIGURE 19. Schematic view of air-sieve cleaner (USDA Agr. Handbook No. 179).

light, chaffy material, so that the remaining seed can be distributed uniformly over the first (top) scalping sieve. The top sieve scalps or removes large material, the second sieve grades or sizes the seed, the third sieve scalps the seed more closely, and the fourth sieve performs a final grading. The finely graded crop seed from the fourth sieve is then passed through an airstream, which drops the plump, heavy crop seed, but lifts and blows lightweight crop seed, weed seed, and chaff into a trash container (Fig. 20).

Proper sieve selection and airflow is important to the achievement of satisfactory results. The two basic types of sieves used in processing cereal seed are round-hole sieves and sieves with slotted or oblong-shaped openings. Sieves with square or triangular openings have a limited application in the cleaning of cereals. Round-hole sieves separate particles on a basis of differences in width, and slotted sieves by differences in thickness. Since most seed lots contain undesirable materials that are larger and smaller both in width and thickness than the desirable crop seed, the general rule is to equip the cleaner with oblong- and round-hole scalping (top) sieves and with oblong- and round-hole, square-hole, or triangular-hole grading (bottom) sieves (Table 4). Airflow in a two-fan cleaner should be adjusted so that the top air blows out dust and light, chaffy material and the bottom air blows out lightweight, immature, deteriorated, and insect-damaged crop seed and heavier trash. With few exceptions, this type of screen arrangement and airflow setting ensures very thorough separation.

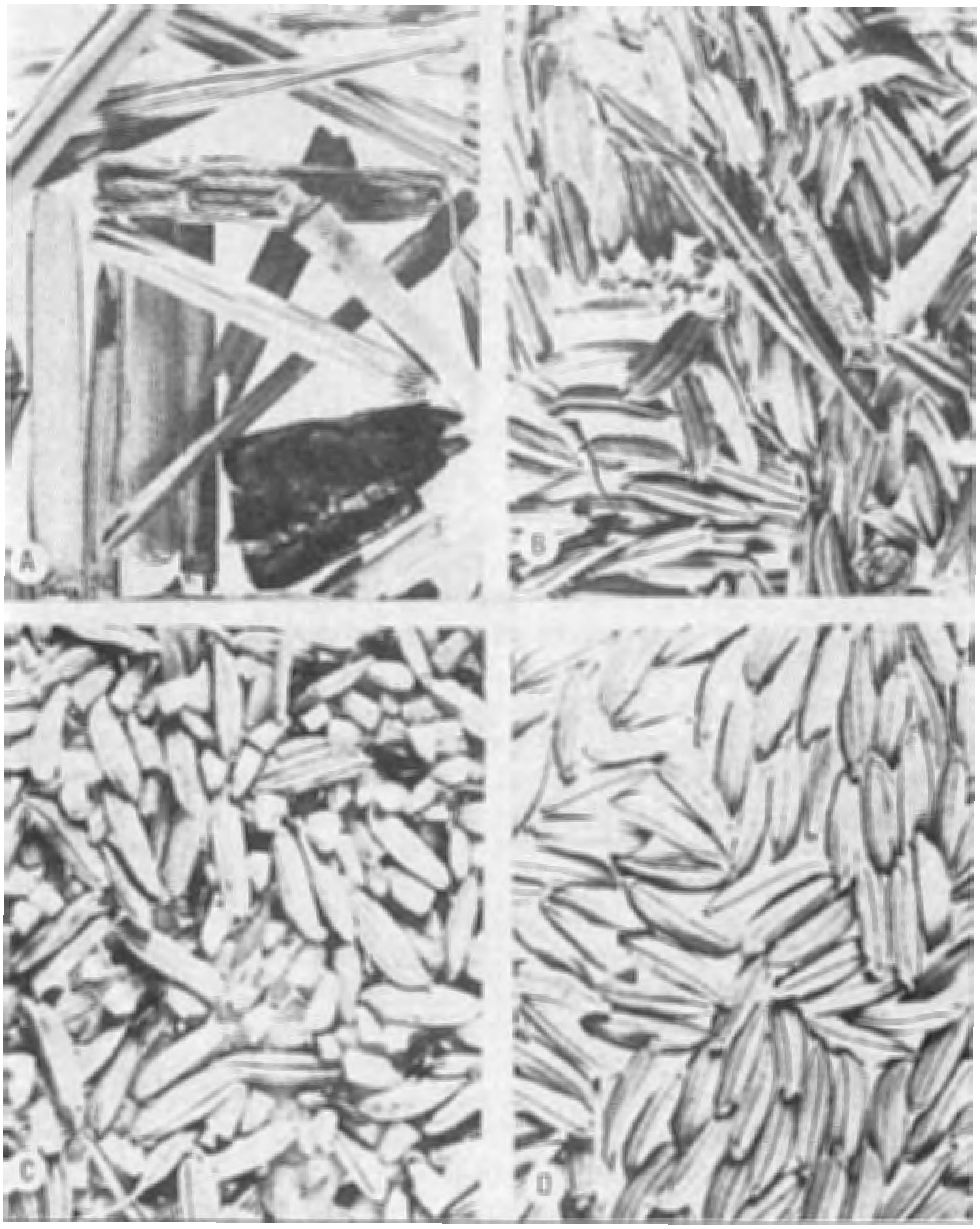


FIGURE 20. Separates obtained after cleaning rice on an air-sieve cleaner; (*A*) rejects from scalping sieves; (*B*) air liftings; (*C*) rejects from grading sieves; (*D*) clean seed.

TABLE 4. — EXAMPLES OF SIEVE SIZES (MM) USED IN A FOUR-SIEVE CLEANER FOR CLEANING CEREAL-GRAIN CROP SEED LOTS

Commodity	Top screen[1]	2nd screen[2]	3rd screen[1]	4th screen[2]
	Millimetres			
Barley:				
plump	7.54	1.95 × 12.70	3.57 × 19.05	1.98 × 19.05
thin	6.35	1.8 × 12.70	3.17 × 19.05	1.95 × 12.70
Maize (cleaning only)	12.70	4.76	11.91	5.56
Millet:				
Panicum miliaceum	3.18	1.81	2.12 × 12.70	7.70 × 1.28
Pennisetum glaucom	2.78	1.31 × 1.31	2.38	1.19 × 7.94
Setaria itacica	2.78	1.27	2.38	1.69
Oats:				
large	9.53	1.59 × 12.70	5.16 × 19.05	1.81 × 12.70
small	7.14	1.59 × 12.70	3.57 × 19.05	1.81 × 12.70
Rice:				
long grain	5.56	2.38	4.76	1.59 × 12.70
	4.76	2.58	2.78 × 19.05	1.69 × 12.70
short grain	5.56	2.38	4.76	
		2.58	3.18 × 19.05	1.95 × 12.70
Rye	4.76	1.41 × 19.05	4.76	1.59 × 12.70
			2.78 × 19.05	
Sorghum	5.56	1.95 × 12.70	5.16	2.12 × 12.70
Wheat:				
plump	6.85	1.98 × 19.05	5.56	2.38 × 19.05
			3.57 × 19.05	
thin	5.46	1.8 × 19 05	4.76	1.95 × 12.70
			3.18 × 19.05	

[1] Scalping screens. — [2] Grading screens.

Seed lots cannot always be processed to desired seed-quality standards by using the air-sieve cleaner alone. Processing operations conducted after basic cleaning are considered finishing operations. Finishing operations in the processing of cereal-grain seed lots involve length sizing, width and thickness grading, density grading, and treating.

Length separations

Seed lots are length-sized (graded), after being cleaned with the basic cleaner, for one or more of the following reasons: (*a*) to remove weed seed and cross-broken crop seed that is shorter than the desirable crop seed; (*b*) to remove materials longer than the desired crop seed; (*c*) to upgrade general appearance (*e.g.*, by making sure all crop seed are uniform in length); and (*d*) to size grade for precision planters (Fig. 21).

There are two types of length separators, indented-cylinder separators and disk separators, both of which make separations by "lifting" the shorter

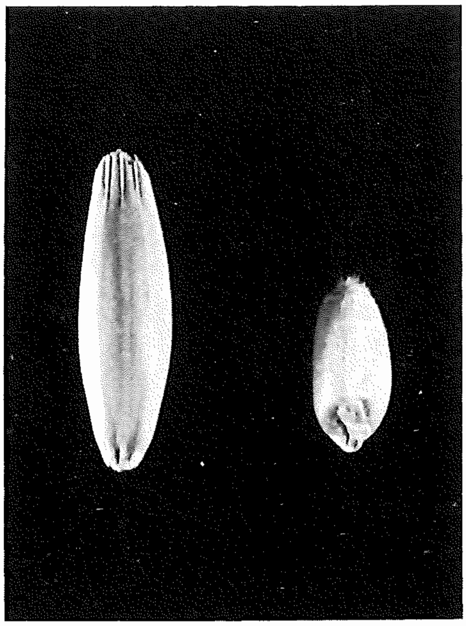


FIGURE 21. A length separator separates oats (*left*) from wheat (*right*).

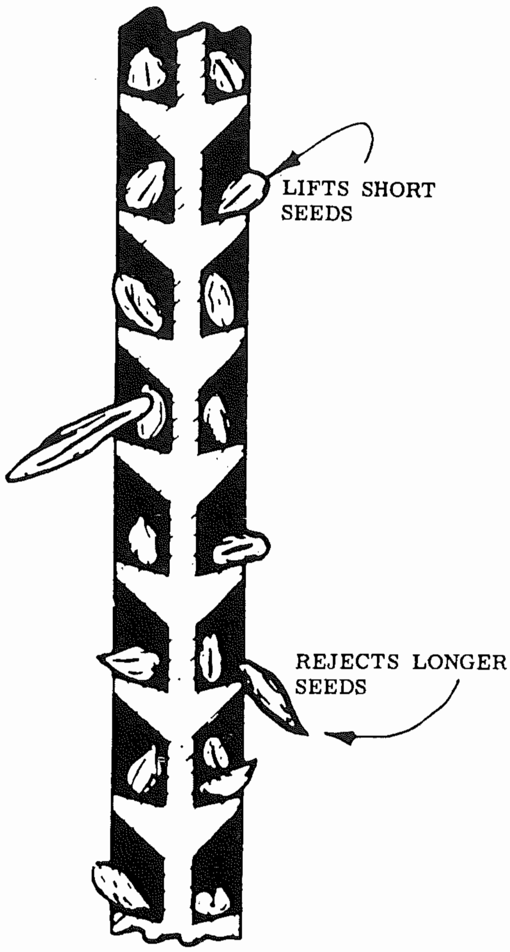


FIGURE 22. Cross-section view of an indented-cylinder separator (USDA Agr. Handbook No. 179).

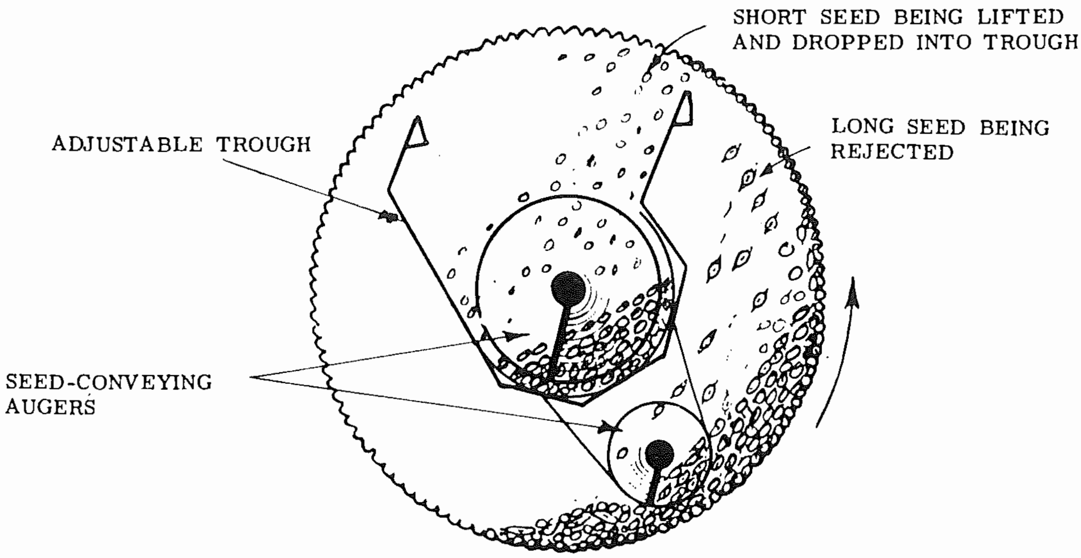


FIGURE 23. Cross-section view of a disk separator (USDA Agr. Handbook No. 179).

product out of the seed mixture (Figs. 22, 23). Length separators are available in a fairly wide range of makes, sizes, and models. Of the two separators the indented-cylinder type is the more universally used in the processing of cereal-grain seed lots; disk separators, on the other hand, cannot be used in the processing of maize (Vaughan *et al.*, 1968).

Width and thickness separations

Smaller-grained cereals, such as wheat or rice, may require additional sizing for width or thickness, in order to remove weed seed and cross-broken crop seed that cannot be removed by the air-sieve cleaner. Width and thickness separators size more precisely than air-sieve cleaners (Vaughan *et al.*, 1968). For this reason, seed of short-grain rice varieties can be separated from seed of long-grain varieties by utilizing the difference in seed width on a width and thickness grader, which cannot be done by an air-sieve machine. Mixtures of short- and medium-grain rice varieties are best separated by using a length separator.

Maize seed lots always contain desirable seeds which differ widely in width and thickness (Fig. 24). Consequently, maize that is to be planted mechanically should be size graded on a width and thickness separator. Maize is size graded into "flats" and "rounds" by using slotted or oblong-shaped sieve openings; separation into small, medium, and large size classes is accomplished with round-hole sieves. Grading maize into more size classes than required should be avoided, as size grading is expensive in terms of both time and equipment costs.

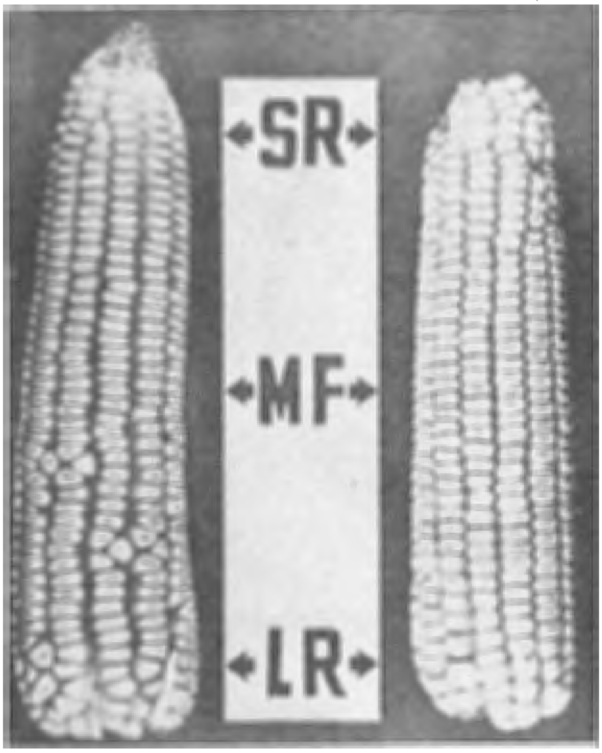


FIGURE 24. Kernels of different sizes are found on every ear of maize. Approximate locations of small and large "rounds" and medium "flats" are shown.

Density separations

Differences in specific weight (density) are common among the various components of a seed lot and among seed of the pure seed component. Although aspirators and pneumatic separators are used in the density grading of seed lots, the gravity table is the best known of the density separators (Vaughan *et al.*, 1968).

Density separators can be used to advantage with almost all cereal-grain seed lots; however, they are not always required, since the air system on an air-sieve cleaner is also a density separator. Density separators, or graders, are employed mainly to improve the germination of seed lots by removing badly deteriorated, diseased, and insect-damaged crop seed (Fig. 25). It is important that density separators be utilized after seed lots have been size graded, as a precise density separation is not possible when seeds within the lot differ in both size and weight.

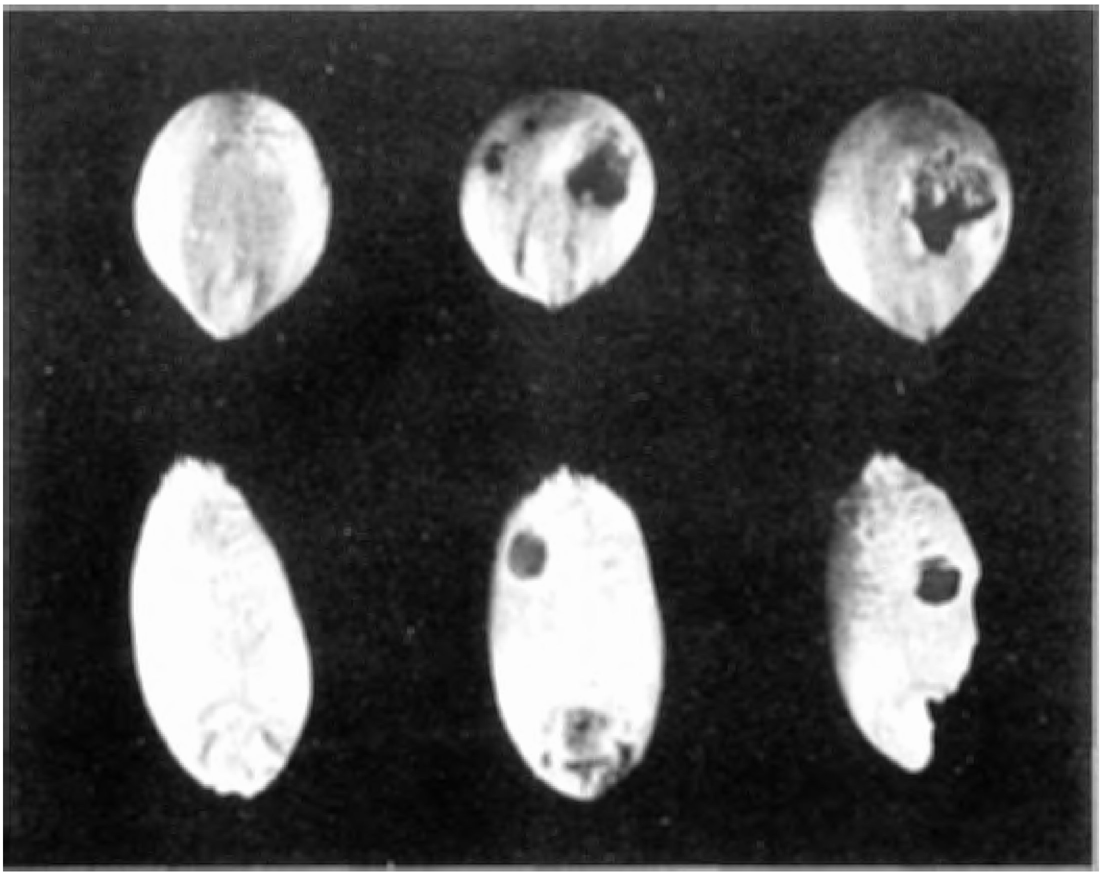
Seed treatment

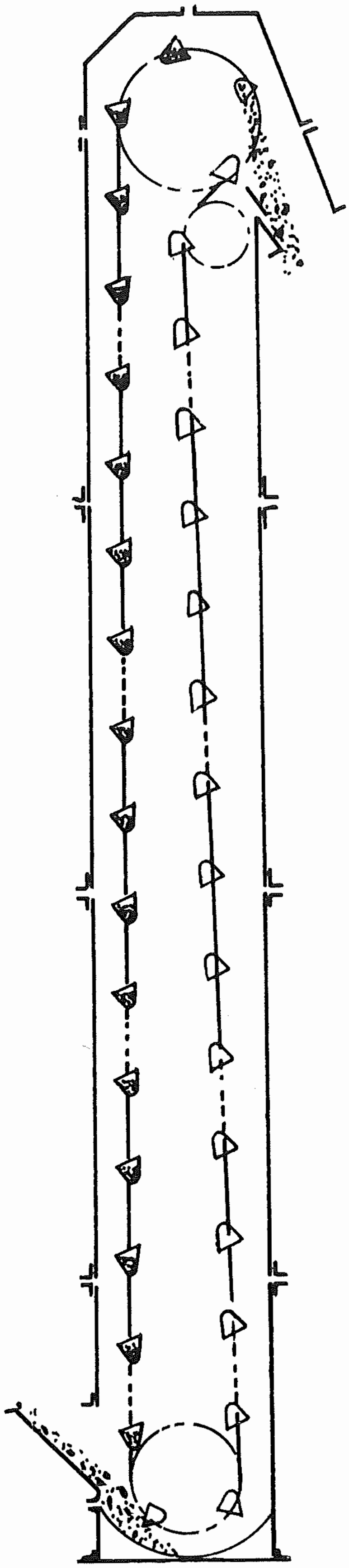
Cereal-grain seed lots are universally treated with good reason. Practically all—if not all—seeds come in contact with disease-causing organisms or with organisms in the soil that attack seed and young seedlings. On the other hand, there are reasons why some seed lots should not be treated.

Seed treatment does afford protection to weak seeds, enabling them to germinate, but it does not improve germination capacity by restoring life to dead seed. Consequently, low-germinating seed lots should not be treated, but should be used for human food or animal feed. Furthermore, as most chemicals used in treating are toxic to humans, a seed lot should not be treated unless it is to be used for seed planting.

Formulations. Seed treatment materials are available in the form of dusts, wettable powders, and liquids. Dry dusts are applied by thoroughly mixing the seed and dust in a mechanical seed treater especially designed for use with dust-formulated products. The dusty condition that usually prevails during treating and subsequent handling is one reason why the use of dusts is not more widespread. Also, dusts tend to rub off during handling, and seed treatment is ineffective unless the treatment material remains on the seed.

FIGURE 25. Insect-damaged sorghum seed (*top, centre and right*) can be separated from undamaged seed (*top, left*), and insect-damaged wheat seed (*bottom, centre and right*) from undamaged seed (*bottom, left*) on a density separator.





Dry dusts have largely been replaced by wettable powders and liquids. Wettable powders are applied to the seed in a soup-like water suspension, which is mixed with the seed in a slurry treater (Vaughan *et al.*, 1968). Seed treated with slurry does not require drying after treatment; it can be bagged immediately and placed in storage. The use of liquids is known as the "quick-wet" method of treating. Liquid products are generally concentrated solutions, and they are consequently applied at lower rates than the slurry applied wettable powders. Many of the quick-wet type seed treaters can also be used to apply the wettable powder formulated products.

Precautions. Most products used in the treatment of seed are harmful to humans; but they can also be harmful to seed. Extreme care is required to ensure that treated seed is never used as human or animal food. To minimize this possibility, treated seed should be clearly labelled as being dangerous if consumed. The temptation to use unsold treated seed for human or animal food can be avoided if care is taken to treat only the quantity for which sales are assured.

Care must also be taken to treat seed at the correct dosage rate; applying too much or too little material can be as damaging as never treating at all. Seed with a high moisture content is very susceptible to injury when treated with some of the concentrated liquid products.

CONVEYING

Seed conveying is an integral part of seed processing. Too often the convey-

FIGURE 26. Centrifugal discharge elevator.

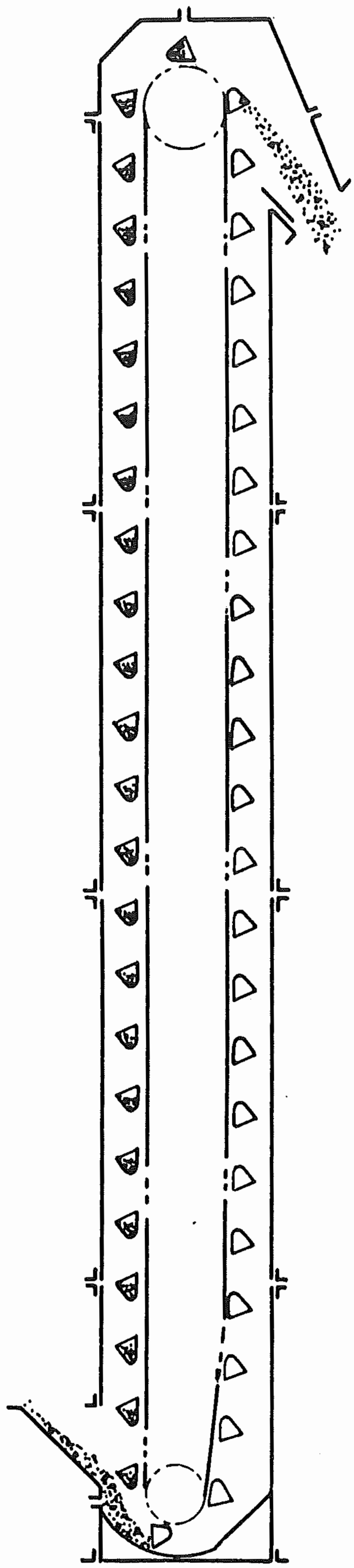


FIGURE 27. Positive discharge elevator.

ing equipment utilized is designed and installed by people who are familiar with grain handling but have little knowledge or appreciation of the special requirements for seed as living genetic material. Basically, these requirements are (*a*) prevention of mixtures, (*b*) minimum mechanical shock or abrasion, and (*c*) adequate handling capacity. In practice many compromises between the ideal and the mechanically or economically feasible are necessary.

Vertical conveyors (elevators)

The *centrifugal discharge elevator* is the most common type of vertical conveyor installed in receiving facilities and for use throughout seed processing (Fig. 26). These utilize a series of buckets, or cups, attached to an endless belt and depend on centrifugal force as the buckets travel around the head pulley to empty the buckets. The speed of the belt, the size of the head pulley, and the design of the head discharge are all important in minimizing seed damage. This type of elevator requires visual inspection of each bucket, the head, and the boot for complete cleaning between lots. Relatively inexpensive and easily constructed, it is often the only economically feasible type of conveyor, especially if the elevator must be tall.

Positive discharge elevators are constructed with buckets between two chains which run on sprockets. The head is constructed so that the buckets tip over, to ensure complete emptying into the discharge chute by gravity (Fig. 27). Since the bucket speed is relatively slow, mechanical damage is held to a minimum.

Internal discharge elevators are also slow speed, positive discharge conveyors. The buckets of the internal discharge elevator overlap at the bottom and are fed from inside the boot. The buckets, which turn upside down at the head and discharge into a hopper inside the head, are excellent for gentle handling (Fig. 28). The principal disadvantages are cost and space requirement.

Horizontal and inclined conveyors

Seed must be moved laterally at some point in almost every processing plant. As with vertical elevators, consideration must be given to possibilities of mixture and damage caused by equipment, as well as by purely mechanical problems.

Belt conveyors. Belt conveyors are characterized by high capacity for the power required, almost complete cleaning, and quiet operation. They may be flat or troughed. The maximum inclination is about 22 degrees (Tyler, 1972).

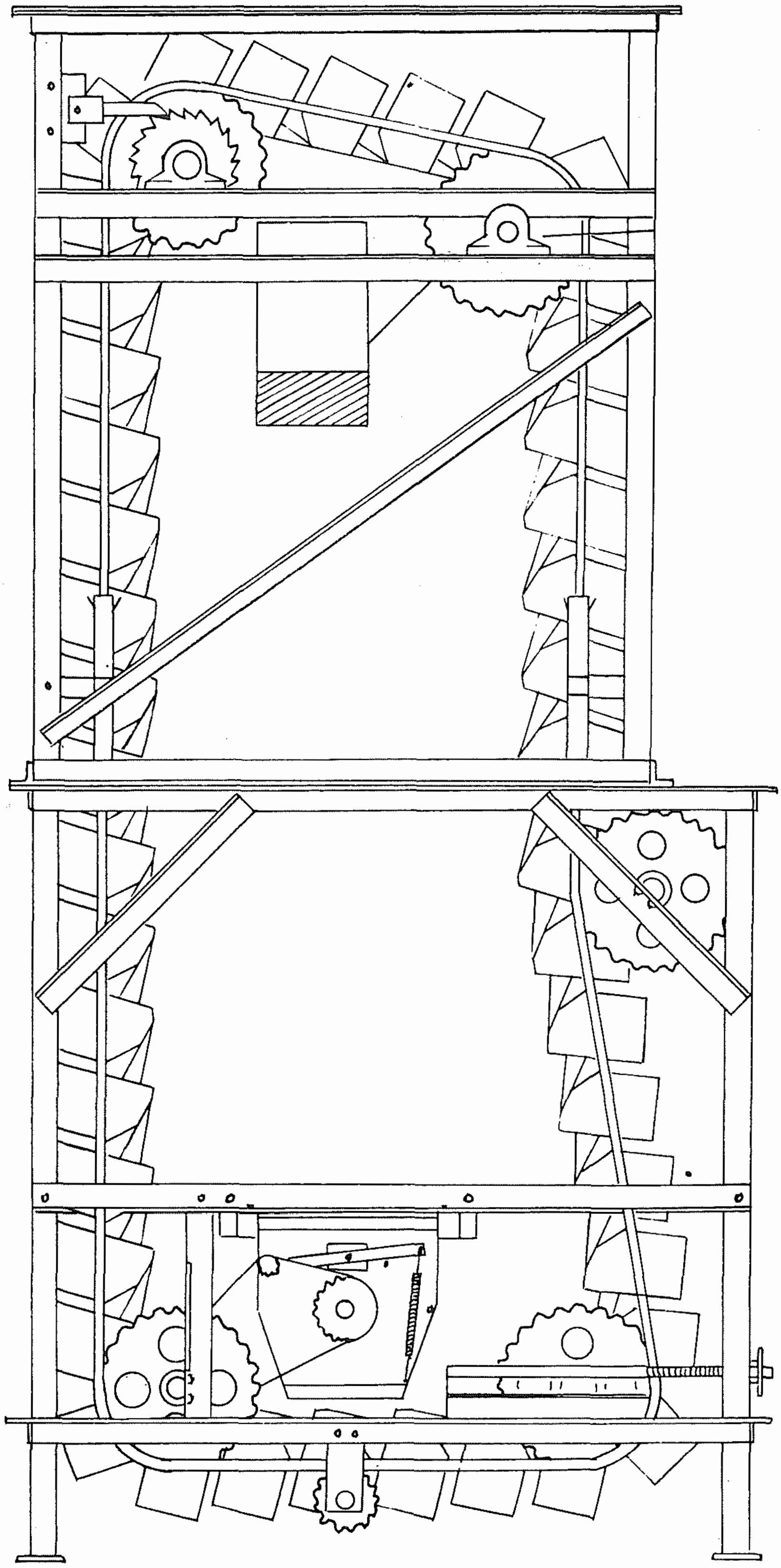
Screw conveyors. Many grain-handling installations utilize screw conveyors because they are relatively easy to install and construct; however, they are hard to clean, have a high power requirement, and cause mechanical damage by crushing seeds between the screw flights and the U trough or tube. As a general rule they should be avoided in seed-processing plants. When used for inclined conveying, a 15-degree incline will decrease capacity by 25 percent and a 25-degree incline by 50 percent (Tyler, 1972).

Vibrating conveyors. These conveyors have the distinct advantage of very gentle handling and 100 percent self-cleaning. Usually they are utilized for conveying over a distance of 30 m or less. Power and maintenance requirements are low.

Drag flight conveyors. Drag flight conveyors are built to run in a screw-conveyor U trough, the flights being shaped to fit the U. They offer an acceptable compromise between the belt and the screw conveyor. They are almost self-cleaning and for overhead installation require less support than a belt. Capacity loss on an incline is comparable with that of a screw conveyor.

Pneumatic conveying. Developments over the past two decades in pneumatic handling equipment have made possible the engineering of systems that cause very little mechanical damage, even with fairly fragile materials. They are not widely utilized in seed plants, however, because each system must be engineered to the particular application and the cost and power requirements are high for an installation that is used only seasonally.

FIGURE 28. Internal discharge elevator.



Gravity spouting. Gravity spouting can be a source of damage or poor flow problems. The following are the minimum spout angles generally designed for seed application (Tyler, 1972).

Crop	*Degree of slope*
Maize (high moisture)	45
Maize (dry, uncleaned)	37
Oats	37
Barley	33
Wheat	30
Millets	45

5. SEED STORAGE AND PACKAGING

by J.E. Douglas*

Maintenance of seed viability

Importance of seed viability

An ancient Hindu sacred writing, *Vajur Veda*, says, "May the seeds be viable." The ability of seeds to be viable from one crop season to another has been essential to the survival of mankind. Man soon recognized the need to dry and store seed. Drying seed in the sun is still common practice in many areas of the world. Experience taught farmers to use special methods of keeping seed dry and free from insect and rodent attack. Woven baskets lined with straw, gourds, and various kinds of earthen crocks have all been used to store seed. Ash has been mixed with stored seed to help maintain viability, and keeping seed near the open fire in the home has also been found useful. Investigations on how to improve local storage methods have been conducted. For example, gourds have been shown to be satisfactory airtight containers when coated with oil, varnish, or paint (McFarlane, 1970).

As agriculture modernizes, however, more farmers rely on others for their seed supply. As a result of the introduction of hybrid seeds, farmers purchase seeds annually from seedsmen. Some kinds of seeds are produced more successfully in certain areas than others. Consequently persons other than the farmer are required to store seed longer and to ensure that it is suitably packed and handled. Because of the need for more precise information on the factors involved in seed storage and packaging, scientists started investigating more carefully why seeds lost viability and what

* The author wishes to acknowledge that much of this chapter first appeared in the book *Seed storage and packaging — applications for India*, by J.F. Harrington and J.E. Douglas, published by the National Seeds Corporation, New Delhi, in cooperation with the Rockefeller Foundation. J.F. Harrington reviewed a draft of this chapter and provided useful suggestions for which the author is indebted.

FIGURE 29. Many farmers, like these Indian cultivators, still save their own seed, but agriculture in the process of modernization relies increasingly on a seed industry.

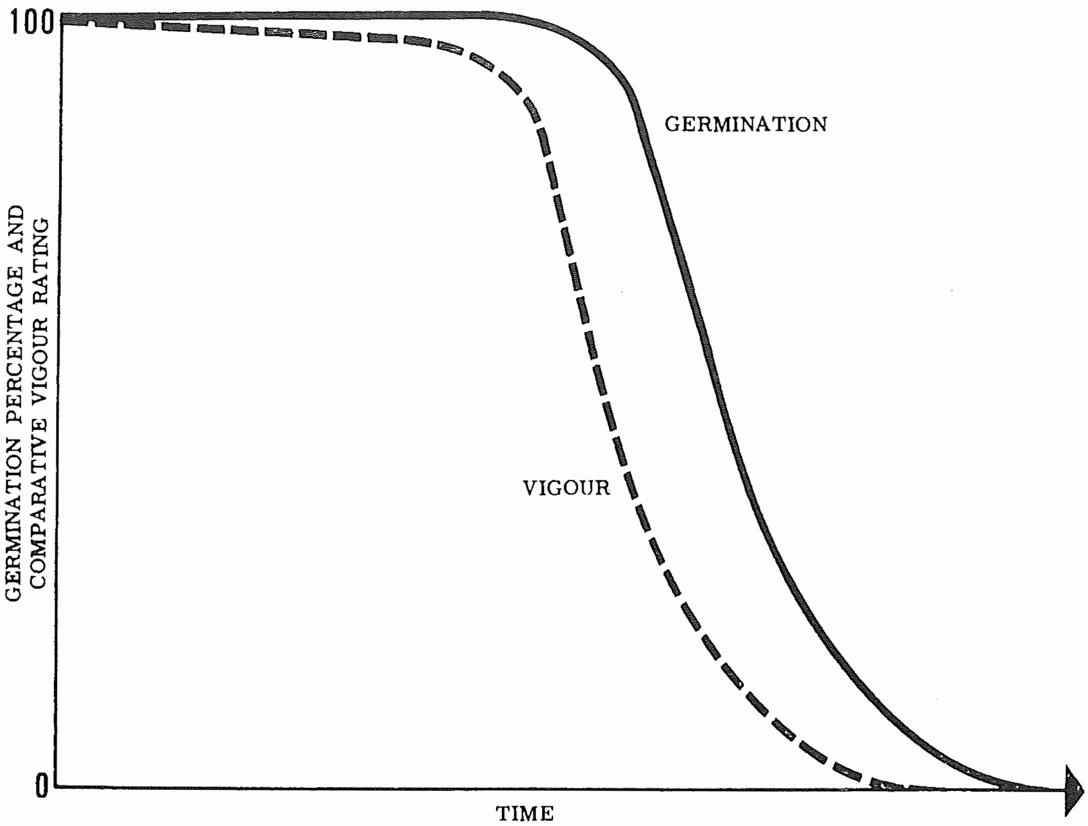
was needed to maintain it. The *Bibliography of seeds* (Barton, 1967) lists 708 references on storage investigations, plus hundreds of others on such topics as humidity, storage temperature, drying requirements, and factors affecting germination, viability, and vigour.

Investigations on the maintenance of seed viability during storage have ranged from the time the seed reaches physiological maturity until it is planted, including the following stages: (*a*) in the field before harvest; (*b*) between harvesting and processing; (*c*) after processing until dispatch; (*d*) in transit; (*e*) at retail distribution points; and (*f*) on the users' premises. Most research has centred on the period from after processing until dispatch, but all these stages involve storage. Several authors (e.g., Owen, 1957; Barton, 1961; and Roberts, 1972) have prepared excellent books dealing with the factors involved and have reviewed much of the work done. The purpose of this chapter is to focus on those practical points which seed technologists need to consider today; therefore, emphasis will be placed on protecting the seed from high temperature and relative humidity, kinds of storage, insulation, refrigeration, dehumidification, and storing different kinds of seed and seed packaging.

Seed reaches physiological maturity on the plant. At that moment the seed possesses maximum viability and vigour, which may or may not be high depending on conditions during the growth of the plant and maturation of the seed. Disease and insect damage, water stress, and mineral deficiencies are among the factors that may reduce maximum viability at maturity. From the moment of maturity until planting, the seed is stored on the plant, in a seed store, or in transit. During this storage period the seed deteriorates, aging as humans do; however, by using proper storage conditions the rate of seed aging can be greatly slowed.

A quantity of seed has a typical aging curve. In Figure 30, note that the vigour rating drops before there is a significant drop in germination; it is therefore possible to have two lots of seed, one of high vigour and the other of low vigour, both germinating at 90 percent. It must be recognized that these curves actually illustrate the decline and loss of viability of individual seeds in the population.

FIGURE 30. The loss of vigour and germination of seed as a function of time.



Seed aging and loss of germination cannot be stopped, but they can be retarded by proper storage conditions. The two most important environmental factors influencing germination loss are relative humidity, which controls seed moisture content, and temperature; the higher these are, the more rapidly the seeds deteriorate. Two simple rules are useful measures of the effect of moisture and temperature on seed aging:

1. For every decrease of 1 percent in seed moisture content the life of the seed is doubled.
2. For every decrease of 5°C in storage temperature the life of the seed is doubled.

The first rule applies quite well if seed moisture ranges between 14 percent and 5 percent. Above 14 percent, mould growth destroys seed germination rapidly; below 5 percent, physiochemical reactions which slightly speed up the rate of deterioration are able to occur. When these two simple rules are applied, the effects are geometric. If seed with a moisture content of 14 percent is compared with a second lot of the same seed dried to 13 percent, the latter seed will live twice as long; if dried to 12 percent, four times as long; and if dried to 11 percent, eight times as long. Similarly, with regard to the temperature effect, if seed is stored at 27°C instead of 32°C, it will survive twice as long; at 22°C, four times as long; and at 17°C, eight times as long; and so on. These two rules act independently and can be combined. To most people the application of these rules gives a range of seed life that seems too great to be believed, but experiments bear out these results.

This explains why no actual values for time are given in Figure 30. Until the rapid drop in vigour and germination and the death of the seed, time is a function of several factors — the two most important being seed moisture content and storage temperature. Table 5 illustrates this by giving approximate time values to the point of significant loss in germination for cereals of different moisture contents at one temperature condition. The seed must show high germination and vigour at the start of storage, and a 2 percent moisture spread is included to cover other variables.

Other factors besides seed moisture and storage temperature that affect storage life include oxygen and carbon dioxide content of the air around the seed; direct sunlight on the seed; kind of seed; previous history of the seed; number of times and kind of fumigation; effect of seed treatment; and attack by rodents, insects, and moulds.

Cereals having a moisture content below 10 percent survive longer the higher the carbon dioxide and the lower the oxygen content of the air around them. The reverse is true of cereals with a moisture content over 14 percent; this moisture content lowers the oxygen and increases the carbon dioxide in the air around the seed, thus shortening its life. The experimental evidence with cereals having a moisture range of 10 to 14 percent is conflicting.

TABLE 5. — STORAGE LIFE OF CEREAL SEED STORED AT DIFFERENT MOISTURE CONTENTS (TEMPERATURES NOT EXCEEDING 32°C)

Moisture content	Storage life
11-13 percent	6 months
10-12 percent	1 year
9-11 percent	2 years
8-10 percent	4 years

N.B.: Seed with 8-9 percent can be packed in sealed containers.

Anyone who has stored different kinds of seed has learned that even under the same storage conditions some kinds of seed lose the ability to germinate faster than others. Even with a given kind of seed there is evidence that certain varieties lose the capacity to germinate faster than others.

The previous history of a lot of seed prior to a specific storage period also influences the speed of germination loss during storage. Weathering in the field, mechanical injury during harvesting and cleaning, heat damage during drying, and previous high moisture periods may reduce the life of seed in storage. Other factors — fumigation, seed treatment, rodents, insects, and moulds — reduce the storage life of seed or destroy its germinative capacity. Each will be discussed in more detail later.

The relation of seed moisture to other factors that affect the survival of seed in storage is significant (Table 6). The drier the seed the fewer the number of factors that will be operating to destroy it. Seed should *never* be stored with a moisture content of 14 percent or more. For ideal long-term storage, where all deleterious factors are eliminated, a moisture content of below 9 percent is necessary; this will also slow the aging process.

TABLE 6. — SEED MOISTURE LEVELS AT WHICH FACTORS DELETERIOUS TO CEREAL SEEDS IN STORAGE BEGIN TO OCCUR

Seed moisture level above 40-60 percent	Germination occurs
Seed moisture level above 18-20 percent	Heating may occur
Seed moisture level above 12-14 percent	Moulds grow on and in seed
Seed moisture level above 12-14 percent	Fumigants may hurt germination
Seed moisture level above 10-12 percent	Sealed storage is unsafe
Seed moisture level above 8-9 percent	Insects active and multiply

The ideal temperature range for insect and fungal activity is 21°C to 27°C. Low temperatures prolong seed life; therefore a storage temperature as much colder than 21°C as possible is desired for long-term seed storage.

SEED MOISTURE AS A FUNCTION OF RELATIVE HUMIDITY

The amount of moisture in the seed is probably the most important factor influencing how long it keeps its high germinative capacity and remains alive. Since seed moisture is a function of relative humidity (RH), it is important to understand what is meant by RH and how seed moisture varies with changes in RH in storage.

Humidity is water in its gaseous or vapour phase in the air. At any temperature the air can hold only a certain amount of water vapour or moisture. The amount of moisture that air can hold increases as the temperature increases.

A psychrometric chart can be used to ascertain the changes in RH that occur with changes in temperature. It can also be used to determine the *dew point*, which is the temperature at which moisture condenses from a given air. If the wet-bulb and dry-bulb temperatures are determined by using a psychrometer, the RH can be found from psychrometric charts.

Since seed moisture is a function of RH, the moisture level of seeds is in equilibrium with the RH around them (Table 7). Seeds do not dry

TABLE 7. — APPROXIMATE ADSORBED MOISTURE CONTENT OF CEREAL SEEDS IN EQUILIBRIUM WITH AIR AT DIFFERENT RELATIVE HUMIDITIES AT 25°C[1]

Kind	Relative humidity					
	15%	30%	45%	60%	75%	90%
	.... *Moisture content wet basis, in percent*					
Barley	6.0	8.4	10.0	12.1	14.4	19.5
Corn (yellow dent)	6.4	8.4	10.5	12.9	14.8	19.1
Oats	5.7	8.0	9.6	11.8	13.8	18.5
Rice, rough	5.6	7.9	9.8	11.8	14.0	17.6
Sorghum	6.4	8.6	10.5	12.0	15.2	18.8
Wheat, hard red spring	6.8	8.5	10.1	11.8	14.8	19.7

[1] *Agricultural engineers yearbook, 1971.* American Society of Agricultural Engineers.

down to the same moisture content as they raise up to when reaching equilibrium with a given RH — a kind of "hysteresis" effect. Temperature also influences the equilibrium of seed moisture with a given RH. If the temperature is increased 10°C, the seed moisture will be reduced up to 2 percent at a given RH. Conversely, a 10°C reduction in temperature will increase seed moisture up to 2 percent. Thus the levels of absorption or loss of moisture usually vary from 0.6 to 1.6 percent of moisture content in the relative humidity range of 10 to 75 percent (Roberts, 1972).

Since the humidity of the air and the moisture content of the seed have an equilibrium relationship, one loses moisture and the other gains moisture until they reach equilibrium. In a warehouse where a free exchange of air occurs with the outside air, seed will reach equilibrium with the RH of the outside air because the amount of air is many, many times the amount of seed. On the other hand, if seed is kept in a sealed container, the RH of the air within the container will come into equilibrium with the moisture content of the seed because the amount of moisture in the air is minute compared with the amount of moisture in the seed.

Climate in relation to storage needs

The climate of the seed storage location is important. The main data required are the average monthly relative humidity and temperature. Some locations provide satisfactory seed storage conditions naturally; others necessitate special stores.

The nature of the storage conditions and the climate at the time of harvest will determine the need for seed drying and whether or not the seed store must have dehumidification and refrigeration. For bulk short-term storage of certified seed, adequate protection can be provided by the use of insulation materials, vapourproof walls, and judicious ventilation. Obviously consideration should be given to these factors in selecting seed-production areas and in locating seed stores. The choice of packaging may also be affected by these factors.

Pest and disease control

Storage pests

The pests of stored seed include birds, rodents, insects, and moulds (fungi). A good store should have no windows, have only one door, which can be locked, and be of solid construction. Birds can be a constant source of seed loss if even small openings exist at the eaves or between the roof tiles. All openings should be sealed or be screened if needed for ventilation.

Rats and other rodents are a more serious problem. Specific recommendations for the control of rats in seed stores include (*a*) building the store so the floor is 90 cm above ground level at the entrance, (*b*) having a 15-cm lip all around the building at the 90-cm level of the floor, and (*c*) providing a removable dock at the entrance for use only when seed is being loaded or unloaded.

Sanitation

Proper sanitation in the store is essential, not only for rat control, but also for insect control. Immediately clean up all spilled seed and repair or replace torn sacks containing seed. If rodents are present in the store, use poison rodent baits, taking proper precautions to avoid poisoning other animals and humans. If proper housekeeping practices are followed, rodents should never or rarely be a problem in a seed store.

Insects are much more difficult to control. They frequently infest the seed in the field and are brought into the store with the seed. They can harbour in cracks and enter the store through small openings. Used bags may contain insects and reinfest a clean store when brought into it.

The practice of good housekeeping in the seed store can do much to prevent infestation of seed that is free of insects when it is placed in storage. Every store should be cleaned thoroughly each season. All cracks in the walls and floor should be sealed. The floor and walls should be sprayed with a residual insecticide. Recommended materials and rates are (Parkin, 1963):

DDT (50% W.P.) ½–1 lb/gal per 1 000 ft^2 (1–2 g/m^2)

Malathion (25% W.P.) 1 lb/gal per 1 000 ft^2 (1.25 g/m^2)

(The latter material should not be used on such surfaces as brick, cement, and concrete.)

Seed treatment

Malathion and DDT can be used separately or combined with a fungicide that may be applied as a protectant. DDT has the advantage of long duration, but it should be used only when there is no likelihood that the seed will be consumed by animals or man. Malathion is effective for no more than one season, but it is generally acceptable on food grain. Recommended dosages are:

For Malathion used alone prior to processing, 8 g per 100 kg of seed being treated.

For DDT combined with a fungicide at the time of processing, 100 g of DDT (50% W.P.) per 1 g of the fungicide. It should be mixed well with the fungicide. The rate of application of the fungicide should be the dosage recommended by the supplier.

Fumigation

If all other precautions fail, fumigation can be used as a last resort. But fumigation of seed is always somewhat harmful, because a fumigant which is toxic to insects is also, to some degree, toxic to seeds. Damage to seed is not great if seed moisture content is below 14 percent and storage temperature below 30°C. Repeated fumigation is cumulative in its injury to seed. Keeping seed at a moisture content below 9 percent, so that most species of insects cannot multiply, is a much safer method of keeping seed insect-free than repeatedly fumigating seed with a higher moisture content. It does no good to destroy insects if the germination of seed is also destroyed.

Fumigation is effective only in gas-tight storage. While ridding seed of insects, it does not remove sources of reinfestation from walls and neighbouring piles of seed and trash.

All fumigants are toxic to humans as well as to insects. Make sure that the storage is well ventilated after fumigation, to remove all toxic gases before workers enter.

For all fumigants there is a relatively small safety margin between the dose that is toxic to insects and a dose that will cause loss of germination or vigour of seed. Reasonably safe fumigants at temperatures below 30°C and seed moisture below 12 percent are the following (Parkin, 1963):

Dosage	*Exposure period*
Methyl bromide 16–32 oz per 1 000 ft^3 (16–32 mg per litre)	24 hours
Hydrogen cyanide 32–64 oz per 1 000 ft^3 (32–64 mg per litre)	24 hours
Hydrogen phosphide 5–10 tablets per metric ton of seed (phostoxin, phosphine)	3-7 days

Storage fungi

Seeds may be invaded by pathogens before harvest or in storage. Storage fungi invade damaged or cracked seed much more rapidly than they do good seed. The best way to prevent damage from storage fungi to cereal seeds is to keep the seed moisture below 13 percent.

Methods used to improve seed storage rooms

Moisture-vapourproofing

Obviously seed storage rooms must be waterproof; however, it is equally important that they be moisture-vapourproof. Water runs off concrete and stone walls, but water vapour, or moisture, readily penetrates concrete and stone. If seed is to be protected from the high relative humidity of the atmosphere, the storage room must be sealed against moisture vapour.

Materials commonly used to resist moisture-vapour penetration are (*a*) polyethylene film (also called polythene or alkathene), (*b*) asphalt or tar (also called bitumen), and (*c*) aluminium foil. Three-millimetre asphalt and 700-gauge or .025-mm polyethylene are considered the minimum thickness necessary for adequate moistureproofing of a seed store. Aluminium foil should be thick enough to prevent small pinholes from forming or be laminated to paper with polyethylene or bitumen so as to seal the holes and avoid vapour penetration.

If a seed store is to be moisture-vapourproofed, all surfaces must be included: floor, walls, ceilings, doors, and windows. The best place to moisture-vapourproof is under the concrete plinth, or slab. The moisture-vapourproofing must extend to the inside of the bearing wall. If insulation is used, it should be placed on the dry side of the wall over the moisture-vapourproof material. A similar procedure can be used for the ceiling, but it is important that the moistureproofing be continuous. Breaks in the moistureproofing material at the corners provide an opportunity for vapour to enter. Detailed instructions on applications are often provided by suppliers (Kharas and Chandra, 1967).

Seed storage rooms should normally have only one door, which must be moisture-vapourproofed and gasketed, so that moisture does not enter around or through the door (Fig. 31). Seed storage rooms without windows are more satisfactory; however, if windows exist, they should also be covered with the moisture-vapourproof material.

Insulation

Heat always flows from a warmer area to a cooler area. Insulating materials appreciably retard this heat flow. Since one of the objectives of good seed storage is to maintain as low a temperature as possible, insulating materials can be used effectively to lower the temperature in stores by combining insulation and judicious ventilation during the cool periods of the day. In this way, seed stores for short-term bulk storage of certified seed can be kept many degrees cooler than would be possible otherwise. If refrigeration is necessary, insulation of the seed store is vital in order to utilize the refrigeration system efficiently.

FIGURE 31. Moisture-vapourproof insulated door for temperature- and humidity-controlled storage.

Good insulating materials include glass-wool, corkboard, foam polystyrene, and fibreboard. The amount of insulating materials needed depends upon the outside temperature as compared with the temperature to be maintained in the seed storage room. Engineers can calculate this requirement on the basis of specific needs. Except in seed storage rooms that are to be kept at a temperature below 10°C, thicknesses of 2.5-5 cm are normally adequate. Details of installation are available from suppliers.

REFRIGERATION

Refrigeration is neither practical nor normally necessary for the storage of bulk seed held from one season to another. It does become important, however, for seed that is to be held over for more than one season, for special kinds of seeds, for basic seed, and for breeding materials. Refrigeration should not be considered unless the seed storage room is properly insulated. The basic objective, of course, is to remove the heat from the room and from the seed that is stored in it.

The actual installation of a refrigeration unit should be done by a competent company, which will recommend the necessary insulation, the moistureproofing method, and the size and kind of refrigeration unit required. Seed technologists, however, have to specify the temperature and relative humidity requirements of the seed. As engineers often have had little experience in constructing seed stores, guidance on specific technical requirements will be necessary. A special maintenance contract should be considered before a project is undertaken, so that the company making the installation will also ensure proper maintenance of the equipment over a period of years.

DEHUMIDIFICATION AND DESICCANTS

Once a room has been properly moisture-vapourproofed, it is possible to lower the relative humidity on the inside much below that on the outside. The importance of low relative humidity in a seed storage room cannot be overemphasized. For bulk storage of certified seed within a season, a moisture-vapourproof room may be adequate for maintaining seed viability; however, if long-term seed storage is needed or if the relative humidity within the room averages above 60 percent, special dehumidification will be required.

Two kinds of dehumidification are commonly used: chemical dehumidifiers and refrigeration. Chemical dehumidifiers use a desiccant, usually silica gel, as a means of removing water from the air. The air from the storage is blown through a silica gel bed, which removes a large part of the water vapour, and the dried air goes back into the store (Fig. 32).

A refrigeration plant will remove some moisture vapour from the air, but the extent to which this occurs is less at lower temperatures. For example, a room at 20°C could probably reach a minimum RH of 48 percent. At 14°C the minimum RH attainable would be 70 percent. As temperatures are reduced below this level, the RH is obviously higher than desirable for proper seed storage. Refrigeration dehumidifies by condensing water vapour on the cooling coils. The condensed water or melted ice is then removed from the storage through a small water pipe. Suppliers of dehumidification equipment are prepared to recommend appropriate sizes based upon the particular conditions.

Where small quantities of seed are to be preserved, silica gel alone can be used. A quantity of dry silica gel can be placed in a cloth bag and enclosed with seed samples in a container sealed against moisture vapour. This container can be a gasketed metal box, a plastic jar with a gasketed screw-on lid, or an 800-gauge polyethylene bag which is heat sealed.

The proper quantity of dry silica gel depends on the moisture content of the seed when placed in the container, the amount of seed, and the equilibrium dryness desired to preserve the seed. Table 8 can be used to determine how much silica gel is needed. At 30 percent RH, for example, wheat has an equilibrium moisture content of 8.5 percent. Thus for every 100 g of wheat seed with a 12 percent moisture content, 3.5 g of

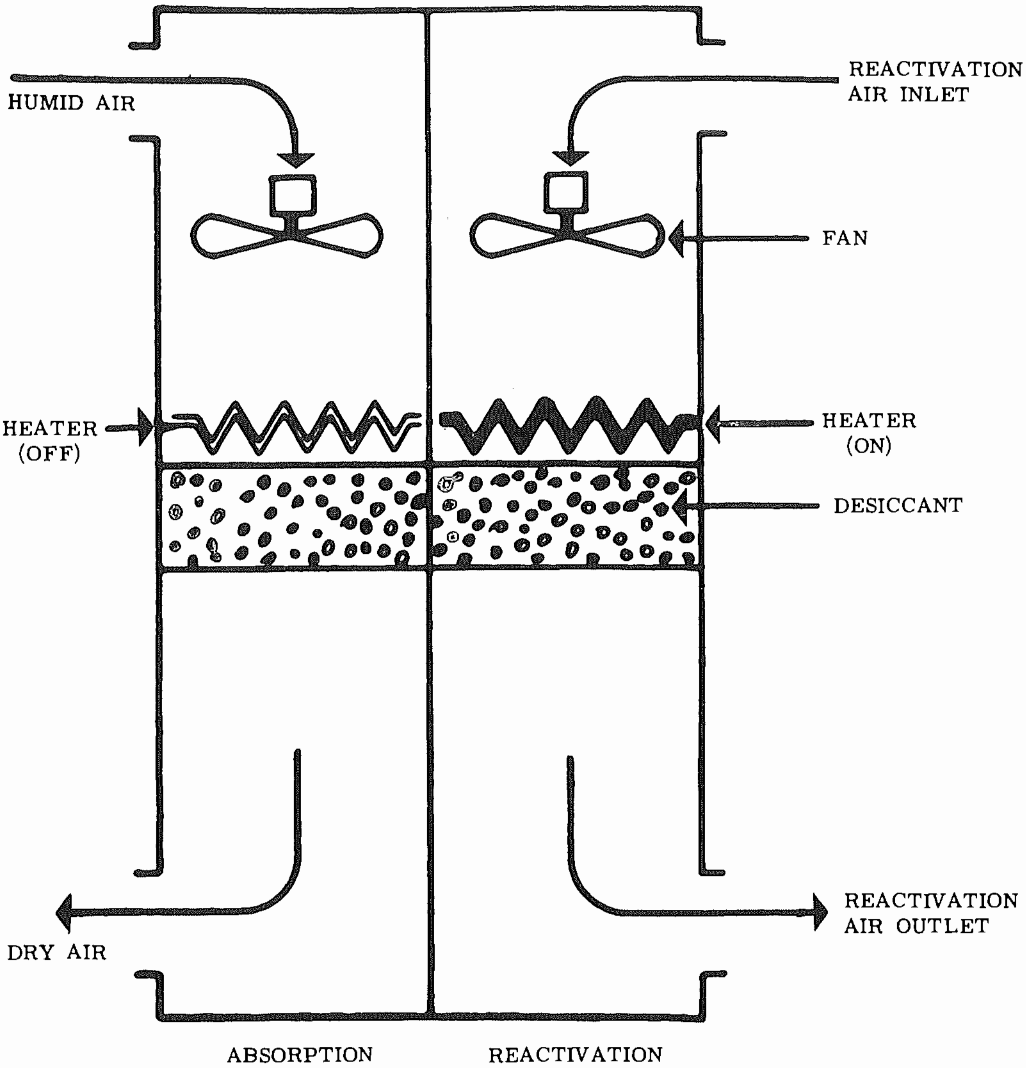


FIGURE 32. Schematic diagram showing the operation of an absorption chemical dehumidifier (Welch, 1967).

TABLE 8. — MOISTURE CONTENT OF SILICA GEL IN EQUILIBRIUM WITH SEVERAL RELATIVE HUMIDITIES

Relative humidity	20	25	30	35	40	45	50	55	60
	Percentage of total silica gel weight								
Water absorbed	10	12	15	18	22	26	29	31	33

moisture must be removed to reduce the content to 8.5 percent. At 30 percent RH, dry silica gel will absorb 15 percent of its weight in water. The amount of water that must be absorbed (3.5 g) is divided by the percent that silica gel will absorb (15 percent), giving 23.3 g of silica gel as the quantity to be included with the seed. To allow for any moisture-vapour leakage and other extraneous moisture vapour, 25 g should be used.

Silica gel is a white translucent material which gives no indication by appearance as to whether it is dry or saturated. It is possible, however, to obtain silica gel dyed with lithium chloride, which is blue when dry and pink when high in moisture, changing colour in the 40–50 percent RH range. If a small percentage of indicator silica gel (about 10 percent) is mixed with ordinary white silica gel, it is easy to determine by the change in colour when the silica gel is no longer active.

Before use and after becoming saturated the silica gel must be reactivated by driving off the moisture molecules which are adsorbed on the pore surfaces. This can be done by drying the silica gel in an oven at 120°C for 16 hours or at 175°C for 6 hours.

Application of storage principles

In view of the requirements for keeping seed as cool and dry as possible, open-air storage of seed is not normally suitable or possible in most parts of the world. Losses from rodents, insects, birds, and pests, plus reduction in germination due to dampness or high temperatures, necessitate other kinds of storage.

The selection of the kind of storage facility needed is influenced by

(*a*) the amount of seed to be stored;
(*b*) the temperature and relative humidity of the area;
(*c*) the kind of package or container to be used for the seed;
(*d*) the length of time the seed is to be held;
(*e*) economic factors relating to the cost of construction and the possible saving of seed viability through improved storage facilities.

It is estimated that about 75 percent of certified seed will be sold during the next planting season. Therefore the storage conditions for this seed can be less ideal than those needed for seed that may be held over. If it is anticipated that some seed may not be sold, this seed should go initially into better storage conditions so as to eliminate any doubt about its viability in the future.

A regular "in-season" certified seed store should be built with a foundation high enough to raise the floor about 90 cm off the ground. It will cost very little more to place a 3-mm bitumen or 700-gauge polyethylene moistureproof barrier between the foundation and the floor. The store should have only one entrance and no windows. The entrance should have a detachable ramp or stairs, which can be removed in order to minimize the risk of the entry of rats. The walls may be constructed of brick, stone, or concrete, whichever is the most satisfactory and economical in the area of construction, with sufficient thickness to provide adequate strength.

The roof should be sealed to the walls and be without cracks so as to prevent the entry of birds and insects. It is best to have a false ceiling with an air space between the seed store ceiling and the roof. This will keep the seed storage room cooler and reduce the need for insulation. The ventilation louvers should be screened, to keep birds and insects out of the air space. In high temperature areas, if a false ceiling cannot be provided, a 2.5–5-cm layer of insulation on the ceiling greatly helps to reduce heat in the seed storage room.

The inside of the walls and the floor should be smooth, with no cracks that might harbour insects or rodents. In areas of high humidity for prolonged periods the walls and ceiling as well as the floor should be sealed with bitumen or 700-gauge polyethylene. Walls need not be insulated, unless it becomes necessary to use refrigeration to maintain the seed in proper condition or unless the average temperatures are very high.

Ventilating fans should be installed at one or both ends, with tight coverings to minimize heat and moisture exchange when not in use and with insect-proof screens when in use. With the proper use of ventilation fans the seed may be both cooled and dried. The opening or door should be insect- and rodent-tight when closed and moisture-vapourproofed if the walls and ceiling have been sealed for this purpose.

The floor should be strong enough to support single stacks of 15–18 large bags of seed without cracking. All stacking should be done so as to leave at least a 45-cm space between the stacks and the walls, and the stacks should be on pallets, providing 7.5–10 cm of ventilation space between the floor and the stacks and 45–60 cm between the stacks and the ceiling (Fig. 33). There should also be space between stacks for ventilation and a wide space on one side of each stack, allowing easy access to the door for efficient piling and removing of the seed.

Seed storage in bins of metal or reinforced concrete is usually associated with installations handling larger quantities of seed. Normally, two types of storage bins are available: those for seed to be manipulated (e.g.,

FIGURE 33. Properly stacked bags on pallets and container storage.

in drying and processing) and silo bins with fittings for airtight seed storage. Bins are usually equipped with thermometers and humidity meters for remote reading.

CARRY-OVER AND BASIC SEED STORAGE

A well-run seed organization produces varieties of seed in quantities beyond the immediate seasonal requirements in order to meet emergencies, unexpected demand, and production fluctuations. This is called carry-over seed and must be stored so as to maintain high germination for two or three years.

Basic seed, which must be kept high in germination for several years, also needs better storage conditions. Basic seed should be reproduced as seldom as possible so as to minimize genetic drift and outcrossing; therefore it is better to produce enough at one time to last through four to six years than to produce small blocks of basic seed every year. Such long-term storage and infrequent production have special relevance for inbreds and single-cross parents used in hybrid-seed production programmes. More frequent multiplication of basic seed of such crops as wheat and rice is necessary.

Since relatively small quantities of carry-over and basic seed are stored, it is advisable to build a special room or divide off a part of the large storage to hold these seeds. The store should be well insulated against heat and, if possible, refrigerated to further cool the seeds. Storage conditions for this seed should be 20°C or less with relative humidity of 50 percent or less.

The seed to be stored should be dried to a 9–10 percent moisture content. By moisture-vapourproofing the floor, walls, and ceiling, as previously described, the seed can be maintained at this moisture level or a lower one by dehumidifying the storage. Packaging the seed in moistureproof containers is another alternative. The room should be completely sealed with no windows or ventilators, and the door should be well gasketed against the entry of moisture-vapour, as should any place where pipes or wires enter the room. A two-door entrance with an airlock in between is ideal.

If such a room is properly constructed with suitable doors, insulation, vapour barrier, and machinery, and if a system of maintenance is rigidly followed, carry-over and basic seed can be maintained at a high germination level for several years (Fig. 34).

Breeders' seed and germ plasm storage

Breeding programmes are sometimes hampered by the problems of maintaining breeders' seed and germ plasm. Many resources and much time are wasted on frequent resowings for the purpose of obtaining fresh seed because of viability losses in storage. With available technology and means of constructing improved seed-storage facilities, all breeding programmes should have long viability storage.

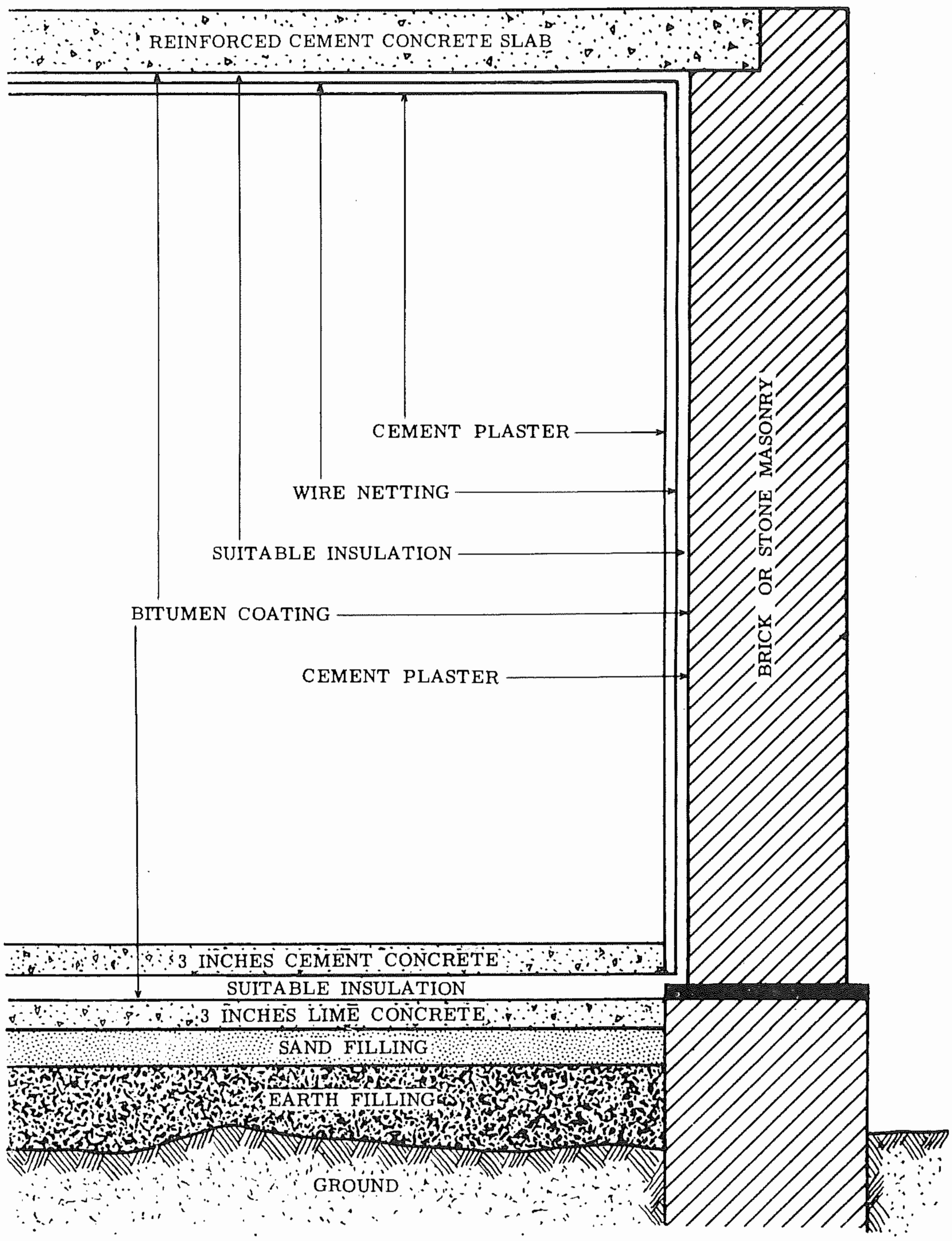
To achieve the long-term storage objectives of a breeding programme it is necessary in most areas to use all methods of obtaining adequate storage (moisture-vapourproofing, insulating, refrigerating, and dehumidifying). An alternative method for maintaining seed at a low moisture level is that of placing the breeding material in sealed containers with silica gel. If this is done, the primary concern in the storage facility is for insulation and refrigeration.

Seed packaging

Factors to consider

The seed package is in reality a small storage container. The kind of container needed is affected by several factors, including:

FIGURE 34. Cross section of a properly insulated and moisture-vapour-proof seed store (3 in = 7.5 cm).



(*a*) the quantity of seed desired in each package;
(*b*) the protection desired;
(*c*) the cost of the package;
(*d*) the value of the seed;
(*e*) the storage conditions into which the container is to be placed;
(*f*) the facilities for drying the seed.

As a matter of convenience to the farmer and in situations where land holdings are small, the package is often designed to hold seed to plant one acre or one hectare. For cereals this means that most containers are between 2 kg and 50 kg in size.

Packaging materials

Cereal seeds have commonly been packaged in cotton, jute, and paper bags. Cost and availability of materials have been the major considerations in determining what to use. Moisture vapour penetrates all these containers, and they offer no protection against high relative humidity. They require dry warehouses and storage conditions that will keep the seed from acquiring moisture levels above 12 percent until use. Where these requirements can be satisfied, as is often the case, the use of cotton, jute, and paper bags is probably the most satisfactory method of seed packaging.

In high-humidity locations with inadequate seed storage facilities, consideration should be given to methods of packaging which can protect the seed from moisture vapour. Such moistureproof containers include aluminium-polyethylene laminated pouches, polyethylene bags of over 700-gauge thickness, sealed tins, and gasketed rigid plastic containers. The cost of many of these materials has been considered too high for the packaging of cereal seeds. Nevertheless, the advantages of moistureproof packaging in terms of seed viability and less exacting storage requirements justify serious consideration of the various alternatives. Polyethylene bags have been regarded as the most attractive of these various possibilities because of their relatively low cost compared to other kinds of sealed containers. Heat-sealing devices must be available for easy sealing. Self-sealing bags, also in use, require special filling equipment and a bag industry that is prepared to manufacture them. Rigid plastic containers and sealed tins offer some possibility for hybrid seed if the quantity needed is not great.

Need for drying

An essential precaution in using moisture-vapourproof containers is the need for drying cereal seed to a moisture level of 9 percent or less. If cereal seed with a moisture content above 9 to 10 percent is packaged in sealed containers, deterioration will be rapid. In areas with a very low relative humidity at the time of seed maturity, some seed may reach this moisture content naturally, but experience indicates that special seed-drying facilities are usually needed. This limits the opportunity to adopt moistureproof packaging in many areas until such drying facilities are established.

Filling and weighing packages

Filling and weighing of seed packages require particular attention, although this is often ignored because these tasks appear to be so simple. In locations where manual labour is abundant, it is generally felt that these jobs can be done manually; however, where hundreds and thousands of bags are involved, a large seed cleaner may clean and grade seed faster than the bagging and weighing crews can handle the off-take. Hand-bagging of treated seeds causes discomfort and can be a hazard to health. Inaccuracies in weighing owing to human error may occur.

Various kinds of automatic or semiautomatic bagging and weighing devices are available for large-volume operations (Fig. 35).

Organization

Official facilities

Governments interested in improving their seed programmes have constructed special seed storage facilities to be utilized by government agencies or to be hired or leased to seed enterprises. Developing suitable seed storage facilities is a kind of subsidy to the seed industry, but it is a more permanent and effective use of funds than a direct subsidy on the price of seed. Government facilities of this kind have special relevance if buffer stocks are to be held against seasonal fluctuations. They also have special value where official agencies become primarily involved in the production of basic seed. Breeding programmes, which are usually government sponsored, also need good storage facilities. Wise investment in storage facilities for these three categories can be a major step forward in the development of a seed programme.

Seed enterprise needs

Figure 35. Automatic bagging and weighing device.

Seed enterprises, public or private, must consider their storage requirements. They should not undertake production programmes without a clear plan as to how and where the seed is to be stored within the current season and subsequently, if all the seed is not sold immediately. Investment in seed storage facilities by seed enterprises is a necessary part of the capital required to initiate a programme. Governments can assist seed enterprises by partially subsidizing the construction of facilities or by providing special financing.

Dealer and distributor needs

The storage space needed by dealers and distributors of seed is much less than that required by primary seed enterprises. Nevertheless, the storage facility of the seed dealer or distributor is important, as seed is just as liable to lose viability at this point as at other stages. Special moisture-vapourproof storage rooms and containers are needed by dealers and distributors.

Space required and costs

The amount of space needed for 100 kg of cereal seed is 0.15 m^3; however, since space is required for passageways, for entrances, and between bags approximately twice the actual storage space is required (i.e., 0.30 m^3).

The investment in seed storage facilities is relatively low compared to the value of the seed which may be lost if it is not stored properly. Therefore, governments, seed enterprises, and seed technologists should look upon the cost of constructing seed storage facilities as a necessary investment for the future rather than an extra current cost. Providing air-conditioned, dehumidified storage for all seed would however be an unwise use of funds in most situations. The extent and kind of seed storage facilities needed must be balanced against the pressures of the environment, the length of time the seed is to be stored, and the funds available.

6. SEED MARKETING

by K.P. Wagner (Coordinator), H.F. Creupelandt, and W.H. Verburgt

Marketing principles and objectives

The role of marketing

Seeds, fertilizers, pesticides, implements, and machinery have to be directly available to the farmer at the proper time in order to serve the requirements of his crops. They must also be of the correct quality and supplied at reasonable cost in relation to the particular needs of the farmer. It is the role of marketing agencies to organize the supply of these inputs and to arrange the related services required. This concept of "marketing" covers all business activities involved in the flow of goods from production to consumption — that is, for seed marketing, from the first multiplication stage of the basic material up to the distribution of the converted end product to farmers engaged in crop production.

A particular purpose of seed marketing is to provide the farmer with high-quality seed of the best varieties, so that he may fully exploit the results of research in plant breeding and crop cultivation.

For centuries farmers used their own seeds or obtained them from their neighbours. This simple system had the merit of immediate availability, involving no money transfer or, at most, a barter agreement with a trusted friend. Unfortunately, it tended toward stagnation in agricultural production, as it did not provide an opportunity for increasing yields by using seed of better quality and improved genetic potential.

Here, business operations with reproduction material of unknown origin and quality are excluded; this discussion refers, instead, to seed produced under systematic and officially recognized cultivation and control (certification) procedures which aim to improve production and productivity of agricultural and horticultural crops. In many countries with organized seed production, enterprises related to marketing are represented by seed trade associations. These are represented internationally by the International Seed Trade Federation (FIS: Secretariat, Leidsekade 88, Amsterdam, The Netherlands).

In a comprehensive marketing scheme the following business functions may be identified:

- Distribution or selling of basic seed to seed growers.
- Assembling, or collecting, the raw product from seed growers.
- Converting the raw product into a valuable crop-production input.
- Storing, which takes into account the seasonality of agricultural work and demand for farm inputs, as well as the perishable nature of seeds.
- Selling, including pricing.
- Making seed available to buyers in accordance with specific requirements (treating, packing, transportation).
- Servicing the farmer, mainly involving delivery to a convenient place at a suitable time and the providing of credit.
- Advising seed growers and farmers on production improvements.

Basic requirements

Marketing of seed requires special skill. Those who are in charge of operations need a broad knowledge of agriculture and commerce and should be tactful.

Implementation of a sound marketing system aiming at the eventual improvement of agricultural production and productivity will depend upon the following conditions:

- A clear-cut policy for developing the seed industry, defining the tasks and responsibilities of the official, semiofficial, and private economic sectors of the particular country.
- Availability of well identified and adapted varieties.
- Current official information on new varieties that have been recommended and released for crop production.
- Ensured variety maintenance and basic-seed supply for reproduction.
- Effective legally enforced control procedures to ensure uniform quality levels according to internationally recognized standards.
- Comprehensive marketing intelligence to indicate consumer requirements, appropriate production areas, location and size of market demand, and costs.
- Adequate production, storage, processing, and testing facilities for producing and maintaining seed quantities and qualities in accordance with the established standards.
- Intermediate storage and transportation facilities for the wholesale and retail sales sectors.

Reliable information systems to keep official and private institutions up to date on production and supply patterns.

These conditions indicate that the successful marketing of seed cannot be developed and fostered regardless of a country's general seed situation. It basically relates to the seed industry and is thus part of the country's economic development plans.

Relationship to general agricultural marketing

Although seed may be considered the key input for crop production, it is not the only one required to implement modern production techniques. Additional inputs must frequently be supplied, at the same time and under similar conditions, to the same farmer. Furthermore, marketing of the farmer's produce is influenced to a considerable extent by the kind and quality of seed used for crop production. It is therefore obvious that the marketing of seed should be closely linked to the overall agricultural marketing process. In practice, certain activities of the seed business may be handled successfully by a single enterprise as an integrated part of a comprehensive input-output marketing business.

As the functions and services to be performed are complementary, they can be provided more economically and with a substantial saving of personnel and facilities when combined. A typical case is the marketing of crop production through grain boards, cooperatives, or processing industries, all of which also handle the distribution of quality seed, as well as other inputs. As such, the building of a seed marketing system has to take into consideration the existing marketing pattern in each country and make maximum use of existing organizations and appropriate complementary services.

Demand assessment and promotion

In planning the marketing of seed the producer and seller (often the same entity) are initially faced with the question of the size of the market — that is, how many farmers will decide to buy how much seed. To be in a position to supply the farmer on request with the required quantities and types of seed, appraisals of the demand have to be made one or two years in advance of the sales period.

Calculation of *potential national demand* (total seed requirement) for government services or central marketing agencies is based on cultivated acreage, seed rates, impact of extension efforts on the introduction of improved production techniques, and future plans for promotion. Thus it is advisable to calculate not one forecast but an estimated minimum and maximum range within which the total requirement will probably fall.

Assessment of *effective seed demand* on the market based on total seed requirements is of limited value, since the demand for high-quality seed will normally exist only for the crop area which is under improved varieties. The requirements for the remaining crop area (of traditional agriculture) are covered by uncontrolled reproduction material obtained from previous crop production.

Furthermore, experience shows that the varietal purity and the yield potential of high-quality seed of self-pollinating varieties can be maintained by farmers during the reproduction process without significant deterioration for three or four generations. Therefore, since individual farmers only need to replace seed of self-pollinating varieties every third or fourth year, the demand for high-quality seed of cereals, for example, is normally not higher than 25 to 30 percent of the total requirement for areas under improved varieties.

Nation-wide figures do not show where seed has to be supplied. As the necessary details are not always found in official statistics, such information will have to be collected in a field survey of actual and potential consumption areas. This may be done by contacting distributors of other inputs, such as local cooperatives, processing industries, and selected official agencies. Estimates will usually be subject to considerable alteration due to the exchange of varieties, variations in the crop area, and unforeseen climatic and economic circumstances.

A rather different approach must be taken if the main objective is the marketing of hybrid seed, as new seed is needed by the farmers each season. Although the initial period may be rather difficult, future organization will be easier to plan, particularly after sales statistics are seen to point in a certain direction. Lacking such statistics, it is estimated that for hybrids the annual seed demand may vary between 80 and 100 percent and for synthetic varieties between 30 and 40 percent of the crop area.

In addition, the following general points require consideration when assessing the demand for improved seed.

Resistance to innovation

Use of improved seed, like that of any new input, has to be fully accepted by the farmer, who tends to be conservative, particularly if a change of techniques involves an expenditure of money as well as of extra effort. Field demonstrations or advisory extension programmes play an important part in overcoming such resistance to change. The new seed and related cropping techniques (cultivation, fertilizer application, and pest control) must be clearly demonstrated to farmers.

Variety changes

Successful introduction of new varieties and cultivation techniques generally calls for sustained and expensive demonstration and extension work on farms. Breeders are continuously searching for higher yielding varieties with an improved resistance to diseases or pests and of a quality better suited to market requirements. Future replacement of varieties must therefore be considered in assessing seed demand. To ensure systematic replacement, released varieties of proven higher standards must be selected for new demonstration programmes and included in marketing promotion. Recommendation of varieties that are unsuited to specific requirements may make farmers reluctant to buy any new seed at all.

Financing capacity

Small farmers who are close to subsistence level have hardly any financing possibilities, except perhaps during a short period just after their harvest has been sold. At planting time they are tempted to take seed from the preceding crops so as to avoid having to pay for good-quality seed. If credit is not provided, this practice can be a real obstacle to expanding the areas under improved varieties.

Economic incentives

An economist measures the attractiveness of a production alternative or improvement by the ratio between benefits and costs. Compared with other production inputs, this ratio as calculated for additional yields from improved seed is generally most attractive. It may be stated as follows:

$$\text{benefit/cost ratio} = \frac{\text{use of the input}}{\text{cost of the input to farmer}}$$

Because the total benefit of a "package" of appropriate inputs is normally greater than the sum of the benefits of the component inputs, the availability of additional inputs required should be considered when assessing seed demand.

The most progressive farmers are likely to benefit greatly from new high-yielding varieties, but they will have hardly any incentive to use them for other than their own food consumption unless the marketing of any surplus is organized properly.

In many countries the production of certain crops, especially staple foods, remains largely at subsistence level. Farmers have learned from experience that high yields and the consequent greater surplus for sale may cause a substantial fall in prices. This can make them extremely reluctant to continue crop production with improved seed of high-yielding varieties in the future. Hence, marketing of good-quality seed and any other farm production improvements lead to consideration of marketing arrangements for the produce and the possibilities of selling farm output at profitable prices.

This implies organization of market facilities within reach of the farms and corresponding communication facilities. Price information must be available to the farmers, and storage facilities in the market store and at the farm must be financed. Eventually, fixed price systems may be necessary for crops that are easy to handle and store (e.g., cereals).

Supply requirements

Timing of supply

The best time for sowing is normally limited to a few weeks in each growing season. Seed which has not reached the farm by sowing day will not be sold before the next season. To facilitate timely supply and to assess needs more accurately, traders encourage advance ordering; however, such advance commitments are not natural for farmers, who are already concerned about the uncertainty of their yields and the risks of bad weather or attacks by pests or diseases. Advance ordering may be induced either by strong discipline imposed by a central organization, such as a cooperative or government agency, or by pricing incentives, such as seasonal discounts.

Place of delivery

It is often not feasible for retailers to deliver to each farm the small quantities of seed needed for planting one or two hectares — perhaps only 100 or 200 kg; however, farmers can carry a few bags of seed home from the market or store by horsecart or on the back of a donkey. Delivery service for groups of farmers may be arranged for specific dates in market places, villages, or even fixed roadside locations. This arrangement can be organized through a group leader who agrees to take responsibility for the group order.

Packing

The packing of seeds requires careful attention. Unfortunately, this is often ignored in countries where seed is seen as just another agricultural product and the containers used are certainly not serving the purpose effectively. The aim must be to deliver seed packages undamaged to the farmer.

A package should be of sufficient strength, as the seed often has to be handled several times and carried by various means.

It should be the right weight for easy handling at retail and by farmers. Bags of 50 kg or 100 lb are widely used, but where head-carrying has to be considered, 25-kg bags are more appropriate. It is also possible to adjust packing to the average seed rate per unit crop area (acres or hectares). For small seeds, such as pulses and forages, for which the seeding rate is low, unit packs may hold only 5 or 10 kg.

FIGURE 36. Certified seed in attractive packages.

It should be adapted to the customers' requirements. A small standard unit will often suffice.

It should be attractive. An attractive package often does not cost much more than a dull one, and presenting one's products in attractive packaging is certainly an important part of marketing (Fig. 36).

Labelling

Selected and treated seed of particular varieties may easily be confused with ordinary farm seed. Sealed bags tied with an authentic label and an identification sign are essential for guaranteeing the quality and preventing the misuse of seed (see Chapter 8).

Advisory service

Promotion of the use of improved seed should normally be part of the responsibility of government extension services. However, the work of these services must be complemented by the salesmen of seed-supply agencies, organizations, or firms, who are in direct contact with individual farmers. This, of course, implies a sound technical background for sales employees of state, private, and cooperative enterprises.

Marketing organization

MARKETING STRUCTURE AND FUNCTIONS

The various channels through which seed can be marketed vary greatly from one country to another, and when more than one marketing organization operates in a country, it depends upon their management which channels are chosen. Seed production may be centered in one area of a country, usually for economic reasons, whereas the market is often more widespread. In any event, a system of distribution from central production plant to customer should be established; this will usually require some middlemen in order to achieve satisfactory distribution. Several outlets can be chosen, and which kind of structure is established often depends upon economic and political circumstances.

Seed production and assembling

Collection of supplies is normally undertaken by the firm, agency, or institution involved in the multiplication of different seed classes. Such an organization controls production through purchase or multiplication contracts with selected farmers and arranges processing, storage, packing, and so on. Enterprises at this level mostly specialize in the seed business and handle only a limited number of crops or varieties, for which they may have exclusive marketing rights.

FIGURE 37. Seed storage in a wholesale warehouse.

Wholesale distribution

This function covers storage in central and regional stores and supply to retailers, as well as to large-scale farmers (Fig. 37). It may be combined with production and assembling activities in specialized seed enterprises or it may be taken over by centralized marketing enterprises, such as market boards, centralized cooperative organizations or private wholesalers dealing with seed of various specialized enterprises or inputs other than seed.

Retail sale

The retailers receive the seed processed and packed for supply to farmers. They may either store seed for months or keep very limited stocks available and order from a central store only after they receive the farmers' orders.

At this level the integration of farm-input and farm-output marketing functions is requisite if for other reasons no specialized seed retail outlet is contemplated. Consequently, seed retailing is often taken up by primary marketing cooperatives, agents or marketing boards, agricultural banks, or private shopkeepers acting independently or on behalf of a seed company. This business may be combined with the selling of fertilizers, pesticides, and animal feeds, and with the purchasing of crops.

Farm machinery — tractors, ploughs, and other mechanized implements — is generally sold through specialized outlets because of the expensive and special maintenance and spare-parts supply services required.

Types of enterprises

Seed marketing may be performed by various types of organizations or enterprises.

Government services or agencies

This approach has its merits, particularly where no reliable and effective marketing system exists. Generally, however, a government distribution network on a countrywide basis to deal with seeds alone or several inputs entails excessive costs and often does not have enough flexibility to react quickly to changing marketing conditions. For this reason, direct intervention in the marketing of seeds by a government service or agency tends to be limited to the initial phase of promotion or to wholesale distribution after the seed has been produced on government-owned seed farms. Alternatively, the government's business activities may be restricted to distribution and marketing of basic seed produced by official breeding or research institutes.

Semiofficial organizations

In many countries marketing board for grains and major export commodities have been established, to secure better access to the market and price stability for agricultural production by adjusting supply and demand for the overall purpose of securing farmers' incomes. These agencies rely mostly upon a vast network of facilities that are necessary for marketing the products under their control and thus are often also used effectively as a suitable channel for the distribution of seeds and other inputs.

A grain marketing board, in particular, may be designated by a government to act as the agency responsible for the overall purchase and distribution of seeds, provided it has access to the necessary facilities (e.g., processing and storage) and experience in handling and transporting of seed. Distribution operations at the farmer level are conducted either through cooperatives and licensed private agents of the grain board or directly by the board's personnel through the operation of permanent or seasonal centres. In countries where, for economic and other reasons, grain marketing boards operate as monopolies, seed distribution for the crops concerned is handled entirely by such boards. In most developing countries, however, grain marketing boards operate in competition with private trade. In these countries the boards' buying networks, as well as the facilities for handling and storage, are rather restricted, and it may be difficult to organize a nation-wide distribution system of seed exclusively through their services and agents.

Due to the importance of improved seed for agricultural development, *national seed enterprises*, operating as autonomous bodies, have been established by the governments of several countries. While seed is produced mainly on a contractual basis under the supervision of these enterprises, seed processing, storage, and wholesale distribution are left entirely in their hands. Retail distribution is carried out in collaboration with authorized agencies, such as banks, extension departments, traders, and cooperatives.

Favourable conditions and credit facilities for these enterprises may, however, create a state monopoly in the seed market, hampering free competition and the development of private or cooperative seed industries.

Cooperatives

A centralized cooperative organization is usually under government supervision. Most programmes of cooperative development are associated with the official government services. Independent and properly managed cooperative societies in developing countries are not very numerous. For seed distribution and marketing of agricultural products in general, cooperative societies have the greatest impact when they act as agents of a central production and marketing authority. Under such conditions, part of the complex integrated marketing and distribution operations, as well as the market risk, is taken over by the central authority.

Private enterprises and dealers

Exclusively private distribution channels for marketing cereal grain and seed are virtually unknown in developing countries. More often, all kinds of combinations of private trade, cooperatives and government agencies are found, over which government control is applied through regulations on seed production, quality control (certification), and distribution. This system represents an economically dynamic approach and has been adopted in many developed and developing countries where registered dealers, seed growers, cooperatives, and official agencies are authorized to market seed of controlled quality. To support this development, government intervention may be gradually reduced primarily to promotion and control functions.

Marketing management

Structure

The structure of the market organization may vary. Marketing enterprises may be involved in seed supply in the widest sense, from the production and distribution of basic material for reproduction to the sale of the converted, high-quality end product; or they may be limited to the actual marketing process, such as the acquisition and selling processed and packed seed, including intermediate storage, delivery, and promotion.

The organizational chart of a comprehensive seed enterprise is illustrated in Figure 38, which shows details of the components required for the marketing process. When the enterprise is not involved in production and processing, the production unit may be replaced by an acquisition unit.

Planning

Provided that adequate quantities of seed have been produced to meet the assessed demand, delivery at the right time to the place specified by the farmers necessitates careful planning. Factors to be considered are availability of seed from the producer; time needed for processing and certification; special storage requirements against seed perishability; and special arrangements for packing and transportation. The financial implications must be studied, and every opportunity must be taken to reduce marketing costs.

A properly planned system includes storage located to avoid intermediate handling and unnecessary movement of seed. Transport planning should aim toward both full truckloads and return loads, which are more

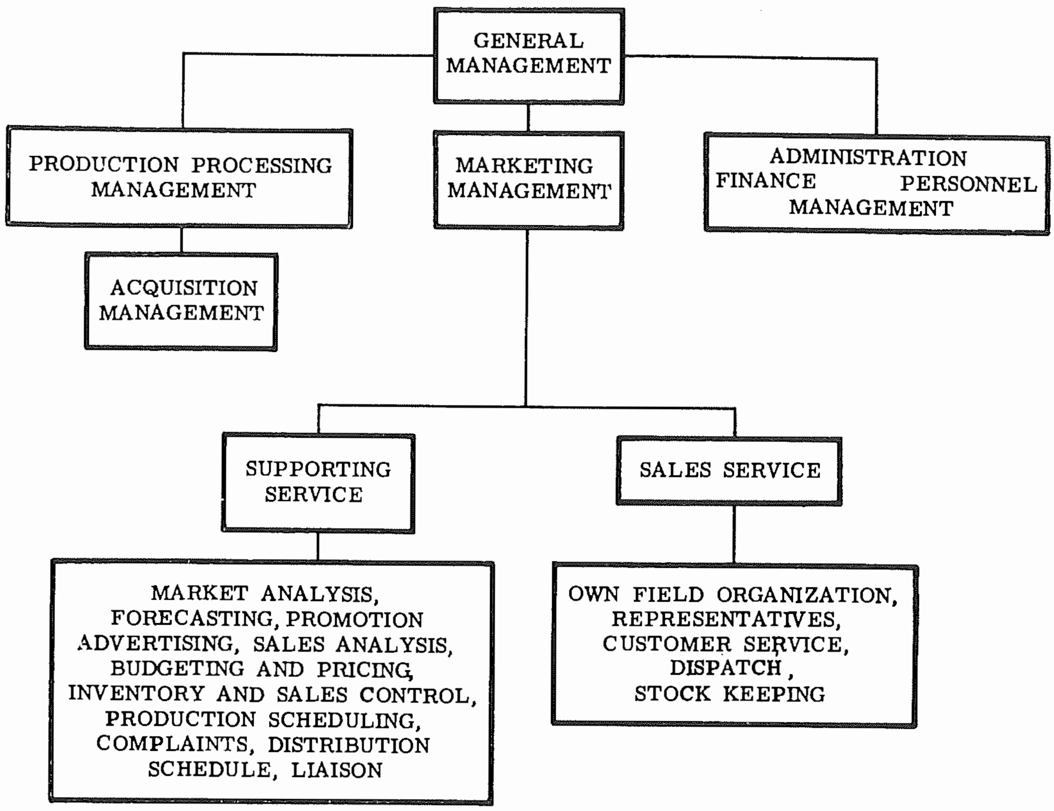


FIGURE 38. Organizational chart of a seed marketing enterprise.

possible if seed orders can be taken in advance. In areas where communications are likely to be cut during the rainy season or overloaded at certain other periods, holding stock at retail outlets is the key to an effective supply system.

Provision should be made to ensure a regular flow of information that will enable the marketing manager to make day-to-day decisions. The centralization of stock reports helps stock management to anticipate supply and demand and to prevent shortages. Because seed demand is influenced by many factors, adequate production planning and subsequent stock management may become one of the most difficult tasks in successful marketing. The aim is to satisfy all demands without keeping unprofitable carry-over stocks.

Obviously, accurate stock reports must be developed and checked against a report of sales. To ensure that reports can be properly completed by the storekeepers, the forms should be simple and clear, requiring as little writing as possible. A very simplified method of recording consists in removing the labels attached to the packages after sale, classifying them, and sending them to a central office for processing. Motivation of employees toward accurate stock reporting and planning is an important feature. Suitable training, salary incentives, and bonuses can be an important step in this direction.

Economic incentives are advisable for encouraging efficient service in a system which includes private enterprises or independent cooperatives and farmers' associations. These can be provided in the form of seasonal discounts, which have to be taken into consideration during the planning phase.

PRICING

Price control is the most effective and delicate management tool for regulating the flow of goods according to plans. This applies as much to seed as it does to any other commodity.

Components

An analysis of comprehensive marketing activities (see *The role of marketing* on page 108) will show the components of the final marketing price, which may be grouped as follows:

1. Acquisition, production, and distribution costs of basic seed when these are not fully recovered by selling basic seed to seed growers.
2. Production price for raw material to be paid to seed growers — which will be influenced by the impurities present, the moisture content, and the costs for special processing procedures, if necessary.
3. Processing costs for upgrading raw material to set minimum quality standards.
4. Costs of treatment for control of pests and diseases.
5. Storage costs for raw-material, end-product, and carry-over stocks.
6. Distribution costs, according to the organizational structure.
7. Costs of technical control and advisory and promotional services to seed growers and farmers.
8. Costs of quality control and certification.
9. Wholesale margin (if applicable).
10. Retail margin.
11. Sales promotion.
12. Losses.
13. Profit (if applicable).

Depending on the marketing scheme which has been chosen and the activities of individual marketing enterprises, these components may be concentrated in one enterprise or spread out over more than one enterprise involved in the production-supply chain.

Subsidies

In many developing countries, where there is still a clear need to create or improve the demand for farm inputs, it is believed that farmers cannot afford to pay the full price needed to support a high-quality seed production and distribution system; hence, a subsidy is proposed. It is often the case, however, that farmers would be prepared to pay the full price and recognize this to be worthwhile, but the obstacle is their lack of resources to pay in advance for the expected benefit.

Hence, investment in credit, market facilities, and extension programmes usually has a better long-term impact than a price subsidy, which normally should be limited to the initial phases of development and improvement programmes.

Pooling

It is often explicit government policy to give farmers in every area the same chances of improvement, with the help of uniform pricing of farm inputs and pooling of transportation costs. Pooling can be done by centralized organization, although this entails certain complications when independent private traders and cooperatives distribute seeds on their own account. But if pooling is improperly calculated and adjusted, it may become a charge on government revenue or add to the costs of the more profitable producers. Badly implemented pooling may maintain production in areas where it is not warranted.

Discounts and rebates

The purpose of marketing management should be to offer and sell seed at the lowest price, reducing insofar as possible intermediate storage and handling. To take advantage of low transportation rates in the off-season and minimum rent for retail warehouses, as well as seasonal discounts for storage and associated handling costs, some inducement may be given to encourage advance buying by retailers and farmers. To ensure that the marketing chain remains "alive" and efficient, inducement can be offered in the form of extra margins based on quantity; for example, a wholesaler or retailer is granted a higher margin as his turnover increases.

To facilitate the planning of production and wholesale marketing, term contracts of one year or longer with special rebates may be concluded by wholesalers and retailers. (Individual farmers will hardly commit themselves for a long term.) Transportation efficiency may be encouraged by discounts for full truckloads or an additional charge on small orders.

Credit

Credit to farmers

The simplest way of marketing seed is for *all* parties to pay cash, thus avoiding extra costs for investment and administration; but this, unfortunately, is rarely possible. In most circumstances, extending credit is the rule rather than the exception; but the utmost care must be taken as to the terms — and cost — of any credit which may be granted. Governments in many countries have therefore developed credit programmes through state and private banks, with the intervention of extension officers so as to ensure proper use of the produce and repayment of the credit.

The cost of providing institutional credit is high. In closely supervised credit schemes, it would be impossible to charge farmers the full cost (interest rate plus administrative and supervisory costs). An advantage of such supervised credit schemes, however, is the high repayment performance compared with what can be expected under traditional institutional credit systems — that is, over 95 percent versus 50–60 percent or even lower. A solution at lower cost may be an integrated credit-marketing scheme, offering favourable credit terms and more attractive prices for farmers' produce than those of private moneylenders and traditional village-traders. A cooperative credit-marketing scheme, if well administered, is an appropriate base for the extension of credit to the small-scale farming community. These schemes can be further strengthened when built into an overall marketing distribution system. This is particularly so where monopoly grain boards have overall responsibility for disposal of the grain crop and distribution of seed. A board may, for example, encourage the exchange of improved seed for part of the cereal crop purchased at buying stations.

Another method is that of supplying seed to wholesalers and retailers on a "sale or return" basis, which means the wholesaler or retailer is invoiced only for the seed he actually sells, while the leftover seed is returned to the principal when the season ends.

Credit to marketing enterprises

A seed marketing organization, because of the special seasonal nature of its sales, needs a considerable amount of money to finance its operations.

Depending upon the arrangements made, it is possible that an entire season's stock will have to be financed before cash comes in from the marketing channels. A proper cash budget must be made well in advance, to ensure that the necessary operational funds are available.

An obstacle to channelling credit to farmers is that the private retailers or independent cooperatives themselves are short of capital. Often they cannot raise the additional capital needed to deal with sales on a term-credit basis of six to nine months, the duration usually required by a farmer.

For traders, access to commercial bank credit through warrants and bills of exchange is a very easy and versatile procedure. The collateral is often mutual confidence based on records of previous repayment performance.

If public funds are made available, the emphasis on the economic viability of the organization may be somewhat less than if purely commercial funds are used, although taxpayers' money should be employed just as efficiently as that from any other financial source. If seed marketing comes under the direct jurisdiction of a government department, the big disadvantage is the inflexibility of government accounting systems. Seed marketing can hardly be carried out satisfactorily if the financial administration has to be within a government department. Consequently, if public money is used, the financial administration should be independent and apply commercial accounting practices.

Extension and advisory services

Seed demand depends to a considerable extent upon well-functioning government extension services for demonstration and introduction of new farm inputs, including seeds, with the related techniques. The failure of some seed programmes to reach their targets has shown that farmers not only have to be convinced of the benefits of using high-quality seeds; but, to achieve the best return, they must also be well informed on such matters as soil preparation, date and depth of planting, fertilizers, irrigation, and pesticides. Farmers also need market information on prices. Such information requires numerous contacts at different times of the year — a service which extension agents alone cannot adequately provide. Marketing agencies (private, cooperative, or marketing board) and their employees have an important role to play in completing the work of the extension agents and in helping to see that the farmer carries out the operations required to attain expected yields.

Promotion efforts can be implemented within the frame of a national drive to increase agricultural output, utilizing radio and other communications media.

Marketing cost margins

The margin, or difference between production cost and selling price, required by a business if it is to achieve long-term success should include the following:

1. Labour costs: handling, management, advisory services.
2. Investment costs: interest in capital employed and depreciation on buildings, plant, and equipment.
3. Operating costs: expendable material and equipment, organization, transportation, communications, interest on operational credits (warrants, bills of exchange, etc.), promotion, quality control, maintenance of equipment and buildings.
4. Losses: direct losses through damage on weight and quality; indirect losses through changes in market demand.
5. Profit and commissions (if applicable).

Profits are the earnings of a successful business after it has paid all its expenses. They may be considered a necessary "cost" for the purpose of attracting the interest of individuals and enterprises in a business activity. When the marketing of seed is fostered on a private, competitive basis, a reasonable profit has to be taken into consideration in the calculation of prices to seed buyers and eventual government intervention on pricing. Under competitive marketing conditions, profits generate expansion funds, since successful enterprises are able and willing to invest in new tools and equipment, adopt new methods, and hire better labour, all in order to maintain a favourable position in the business and obtain attractive profits in the future.

Costs should be constantly reviewed so as to detect possible reductions or improvements in services to the customer. Cost studies are based on direct costing — that is, on costs which can be assigned to operations relating to specific seed classes and varieties or to corresponding sales volumes in an integrated marketing system. To compare marketing systems operating at different annual sales levels under different conditions (as regards agroeconomic structure, type of enterprise, and the share represented by seed in the entity's total turnover), a comprehensive review (including detailed inquiries on labour, investment, and operating costs) is recommended.

On the basis of such a review it will be possible to improve existing marketing systems through a reduction of costs and the provision of more and efficient services. A semipublic agency can provide the government with such references, which may be difficult to obtain from the private sector.

Government policies and services

INTEGRATION OF DEVELOPMENT POLICIES

Government policies in connection with agricultural inputs in general and seed in particular can have a major impact on the success or otherwise of a seed marketing venture. Government policy should ensure that a seed marketing system evolves, as part of the seed industry, in relation to the overall agricultural development plans and the importance of related farm inputs (fertilizers, pesticides, and implements). It will be necessary to decide how the market is to be divided on a commodity (crop) basis. If farm-input marketing can be organized in connection with farm-output marketing, a reduction in costs is possible by making the best use of personnel, transport, and warehouse facilities.

In many countries, traders who buy or sell agricultural crops or other items are already involved in seed marketing. Because of the links they have established with the farmers, it may be necessary to define how these dealers may be incorporated into an improved and officially controlled marketing system. This equally applies to specialized seed firms dealing in specific crops.

GOVERNMENT SERVICES AND RESPONSIBILITIES

Promotion and coordination

When new farm inputs are first being introduced, particularly among small-scale farmers, the government generally has to take the initiative and promote the supply arrangement under its full authority. It may use a government service or department for the marketing of such inputs to the farmers.

The drawback is that a government department is likely to lack the required marketing management skill and businesslike approach. Moreover, there is the danger that the government resources in personnel and capital will not be able to cope with a rapid increase in demand. Thus, new channels, exclusive or competitive, must be created through cooperatives or private enterprises.

The primary role of the government services, then, is to provide market information, to set targets, and to regulate and control agencies and enterprises. Cooperatives and private enterprises must be encouraged to enter the business of marketing seed and other farm supplies and to improve their services to farmers.

Quality control

It is difficult for farmers to check the exact quality and potential of a seed lot at the time of purchase. A government or government-designated service has proved to be of the utmost importance for controlling of quality and for providing reliable, clear information on seed specifications.

In addition, in most countries with a sound private or semiofficial seed industry the governments have extended their control of the marketing and distribution of seed through appropriate laws and regulations that are closely related to quality-control legislation.

Under practical conditions, effective controls over seed quality and marketing procedures are relatively easy during central storage, processing, and distribution through wholesalers. But the safeguarding of seed in storage and protection against irregular practices at the village-shop level are more difficult and expensive, depending mainly upon a comprehensive and legally established scheme for seed production and marketing.

Price control

The economic return on the farmer's investment in high-quality seed is likely to be the highest among his purchased farm inputs if all other production factors are present. Therefore rigid price control is not essential to promoting the purchase of improved seed unless there is a shortage, which may induce traders to seek an excessive profit margin. It may thus be sufficient to set only a maximum price level. Regular price information will enable the farmers to check prices and to induce traders to keep margins within acceptable limits.

Another aspect of government intervention — perhaps not directly related to seed marketing, but nevertheless having a very important impact on its success — is the marketing and pricing policy for the products produced by the farmers. It is rather obvious, but often not fully recognized that if farmers are encouraged to use additional and more sophisticated inputs, they must have a ready outlet at reasonable prices for the increased surplus. Facilities should be created for dealing with the crops before deterioration starts to occur. Grading rules should be established in order that individual farmers may receive proper prices, according to quality, for their products. Grain prices that will be in force during the buying season should be announced in advance, so that farmers will know what they are to receive for their crops. Preferably these prices should not fluctuate too much, so as to more or less assure a stable income. Crop results are in any event dependent upon hazards of weather and growing conditions which cause yields to fluctuate, and if uncertain price patterns are added, the economic results of producing a grain crop become almost unbearably unpredictable.

Legislation

To protect both buyer and seller, a seed law which stipulates the various rights and obligations of everyone in the seed industry should be enforced.

Government services should keep a control on the quality of the seed, on planning for its distribution, and on sales practices. Qualities are defined by law or regulations, and legislation clearly has to be backed by effective sanctions against malpractices, which can only be a government responsibility. To have real impact, inspectors must be stationed throughout the country. They may be officers of the seed certification agency belonging to the extension staff or authorized officers of a government institution.

Clear identification of seed lots according to technical specifications and corresponding regulations is provided by labelling and by the form and colour of the packing. It is necessary, in connection with such arrangements, that the farmers be clearly informed by the extension agents of the technical specifications and the regulation code for labelling. These rules are as important as those applied to chemicals and are similar in application. Additional seed specifications are discussed under seed certification (Chapter 8).

Official statistics

To prevent either a shortage or an excess of stocks, it is advisable to publish periodically, on the basis of reliable information, the production and marketing movements for individual seed classes. Planning recommendations for enterprises other than public or semipublic agencies may be useful, and government intervention may have more impact when directed at price incentives.

Training programmes

Availability of personnel with adequate technical managerial skills for public and private agencies is one of the most important requisites for the implementation of realistic planning and pricing practices and for the providing of effective services to the farmer.

It is a government responsibility to organize the appropriate training, not only for officers of public agencies, but also for those of cooperatives, and to make assignments in the seed industry attractive to well-trained, top-level personnel.

Conclusions

Marketing is a vital part of any development programme for the seed industry. The availability of seed of improved varieties from multiplication fields is of no value if the seed does not reach farm gates before sowing time. Delivery conditions must be geared to the economic situation of the farmer, and the seed must be accompanied by other related farm inputs and technical information.

Governments may naturally decide to take entire and exclusive responsibility for seed marketing through the establishment of public or semipublic enterprises, especially in the initial stages of promotion where no marketing system for distribution exists. However, this should not limit other forms of marketing development or opportunities for new sources of financing, such as cooperative and private enterprises.

It is in a country's national economic interest that the government control at least quality and marketing procedures for improved seed. Furthermore, the integration of seed with the marketing of other inputs allows the government to play the role of promoter and adviser to traders and farmers through the development of sound policies and economic relationships.

The emphasis given to the role of the semipublic corporations in the production and supply of improved seed exemplifies a model for government intervention during the first stages of agricultural development and marketing in other sectors.

7. SEED TESTING

by L. Kåhre (Coordinator), O. Svensson, and A. Wold

Principles and objectives

Generations of farmers and gardeners have accumulated considerable skill in evaluating the quality of seed. By using their senses — looking, feeling, smelling, and even tasting — they have developed an ability to discard seed lots of low quality. However, many deficiencies cannot be detected by such simple methods, and consequently low-quality seed may be used, leading to thin fields, poverty, and starvation.

By using the services of seed testing laboratories it is possible to avoid the use of inferior seeds, thus removing one of the hazards of crop production. A good personal understanding of seed cannot replace detailed, unbiased, methodical analysis. Therefore seed testing has spread all over the globe and is today an important link between plant breeders, who create new cultivars, and those who distribute and make use of them.

STANDARD PROCEDURES

Seed scientists and seed technologists have established standard testing procedures for the evaluation of seeds, making it possible to obtain detailed information on all important quality characteristics that determine the value of seeds for sowing. The most important qualities are: purity (mechanical purity, purity of species, and purity of cultivar), weed-seed content, germination, and absence of diseases.

Farmers and the seed industry

Seed testing has been developed to aid farmers; however, although they can obtain the necessary information directly from the seed-testing station, it is usually the seed merchant who obtains the seed-test report. The seed industry — comprising production, storing, processing, and distribution — has a heavy responsibility in supplying the consumers with high-quality seed of the right cultivars. A constant check on the quality of the seed lots is necessary from the date the seed is harvested until the lot is marked with the required quality information for distribution to the growers.

Research and experiments

Seed testing laboratories and other research institutes, as well as the seed industry itself, carry out experiments and research in connection with the production of seed and its utilization for sowing. During such experiments it is necessary to monitor the effects of seed qualities. In this way a better understanding of the behaviour of seed under various conditions is obtained and new procedures for handling and testing seed are developed.

Organization

SEED TESTING AGENCIES

International

Organized seed testing started more than a hundred years ago. It was early realized that cooperation between seed testing stations was imperative to the establishment of common methods of testing that would secure uniformity in evaluation and test results. This led, in 1924, to the foundation of the International Seed Testing Association (ISTA: Secretariat, P.O. Box 68, N-1432, Ås-NLH, Norway).

The primary object of ISTA is to develop, adopt, and publish standard procedures for sampling and testing seeds and to promote uniform application of them for the evaluation of seeds moving in international trade. This organization also promotes research in all aspects of seed science and technology, including sampling, testing, storing, processing, and distribution; encourages cultivar certification; participates in conferences and training courses aimed at furthering these objectives; and establishes and maintains liaison with other organizations having common or related interests in seed.

At present, ISTA has 115 member laboratories in 52 countries. The technical and scientific work of the association is carried out by 15 special committees (e.g., on sampling and bulking, purity, germination, vigour, cultivars, seed moisture and storage). One of its foremost achievements was the adoption of the International Rules for Seed Testing. These prescribe testing techniques based on scientific evidence, which are accurate within stated statistical limits and practicable within the everyday operations of seed production, processing, and distribution.

The introduction of the International Seed Analysis Certificates, widely used in the international seed trade, is another important achievement, greatly facilitating the movement of seed lots across international frontiers.

Scientific and technical papers are published in the Association's journal, *Seed Science and Technology.*

National

In some countries laboratory testing of seed quality and cultivar purity are concentrated in one institute, whereas in others two institutes may be involved. It is advantageous to have these two services centred in one institute. The testing of varietal purity and trueness to cultivar is one of the more difficult tasks of a seed testing institute. Some information may be found by examining the seed or by growing plants in a growth chamber or greenhouse; however, for most cultivars it is necessary to grow mature plants in the field (plot test) for definite determination of varietal purity.

With the facilities for all these tests located in one centre, only one set of samples need be submitted and all the information on a seed lot can be given by one institute. This arrangement also improves the labour situation in the institute through a more even distribution of work over the year, at least in temperate-zone countries, as laboratory tests are a winter activity, whereas field plot tests have to be made during the growing season.

When organizing the seed testing facilities in a country, it is also important to ensure that institutes testing seeds for trading purposes are entirely free from any suspicion of financial interest in the seed trade. Even though the seed trade may be an official enterprise, seed testing should be the responsibility of separate, independent institutes.

Seed has an enormous impact on the world economy, because it strongly influences the value of the crops produced. In both developing and developed countries there is a widespread lack of knowledge among farmers concerning the importance of using high-quality seed of adapted, high-yielding, disease-free cultivars. Seed testing institutes, seed technologists, and scientists have an important role to play in bringing more knowledge and understanding to this field.

Seed testing institutes

To ensure good seed-testing work, the following conditions are essential:

1. A highly responsible staff, which must continue to work conscientiously when the person in charge is away.
2. Uniformity of equipment, procedures, and interpretations — in other words, consistently good facilities and skilled analysts.

3. Good service — that is, prompt analyses and a cooperative spirit among employees.
4. Leaders with a scientific background to give advice to all types of customer (including the farmer) and to furnish explanatory remarks in reports, when necessary, to those who submit samples.
5. Promotion of research, leading to improvement of the whole seed programme, especially of testing procedures, with practical questions being submitted to scientific analysis.

Staffing

The person in charge of a seed laboratory must have a good knowledge of science and should preferably be qualified in botany or agronomy. A seed laboratory needs both technical and administrative staff. For an average of 5 000 samples annually, the estimated staff numbers are eight trained analysts (four for purity tests and four for germination tests), one clerk, and a few analysts in training (ISTA, 1969*a*). To start a small laboratory, a minimum of three all-round staff members seems reasonable.

Of course, the distribution of staff numbers between technical and administrative will vary. A new laboratory needs less staff, especially administrative, during the period when it is starting up and staff is being trained. An established laboratory which is in full service and employed in a seed certification scheme may be faced with heavy administrative burdens, requiring an increase in office staff.

Seed laboratories should be organized in such a way that all samples can be put under analysis for germination within 24 hours after arrival at the laboratory. Nevertheless, regular overstaffing for encountering the peak season, normally preceding the planting season, should be avoided, as the slack season may be frustrating to trained and dedicated analysts. On the other hand, it has been noted that overtime work in seed analysis has an adverse effect on efficiency and accuracy; instead, temporary workers should be employed, if possible, to take care of various simple, routine tasks, such as unpacking samples, cleaning, sand and seedbed preparation, sample storage, and communications.

Laboratory attendants should preferably have some background in agriculture, to enable them to understand the importance and relation of their work to the whole crop production process.

Buildings

Besides providing proper space for technical and administrative work, the buildings should also be designed to counteract climatic conditions which may adversely affect comfort and working environment. Nowadays, air conditioning and other environment control devices in offices and laboratories are not an extravagance under tropical conditions; nor is room heating during the cool season in a temperate climate. Temperature and humidity control, protection from direct sun radiation and rainfall (also over sufficient areas surrounding the building), ventilation, and mud-free paths to and between buildings are all important in creating a neat and attractive atmosphere, rather than that of an unpleasant labour camp.

Building construction and choice of materials are engineering tasks. Professionals should always be consulted and engaged to supervise construction of an entirely new building or for the partial or complete remodelling of an old building. At present there are at least two comprehensive publications dealing with the laying out, equipping, and furnishing of seed laboratories — ISTA, *Equipment* (1969*a*), and Chalam *et al.*, *Seed testing manual* (1967). The latter indicates that a minimum space of 1 500 ft^2 is necessary for a laboratory analysing about 10 000 samples annually.

This space can be divided into separate rooms for office, sample reception, "dry room" (purity and moisture tests and related work), "wet room" (germination tests), and sample storage. It is also better if an additional room can be assigned for keeping germination tests in sand for the required time after planting and before evaluation. In addition to office and laboratory rooms, space is needed for storing materials, for tag printing, and for a small maintenance workshop.

Cultivar purity tests often require the growing of seedlings or mature plants. To provide optimum controlled conditions for these tests, a greenhouse or, at the least, a wire-mesh enclosure close to the laboratory is essential, particularly if land is not available for field plots. Even if the various operations cannot be separated in different rooms, it is still possible to organize seed testing, as administrative and technical work can be done in the same room. A diagram showing the various steps through which a submitted sample has to pass in the laboratory may serve as a rough guide for a logical layout, which can be varied according to local conditions (Fig. 39).

Very special attention should be paid to the supply of water and electricity and to the sewage system. It is unbearable to work in a well-equipped laboratory with insufficient electric power for light and powered equipment or a shortage of good water and a poor or broken-down sewage system. Once installed, piping and wiring are difficult and expensive to change. It is necessary to plan for not less than double the estimated need of electric power and water supply into the building (including cord and pipe cross-section areas) and 50 percent more that the estimated need of electric-power

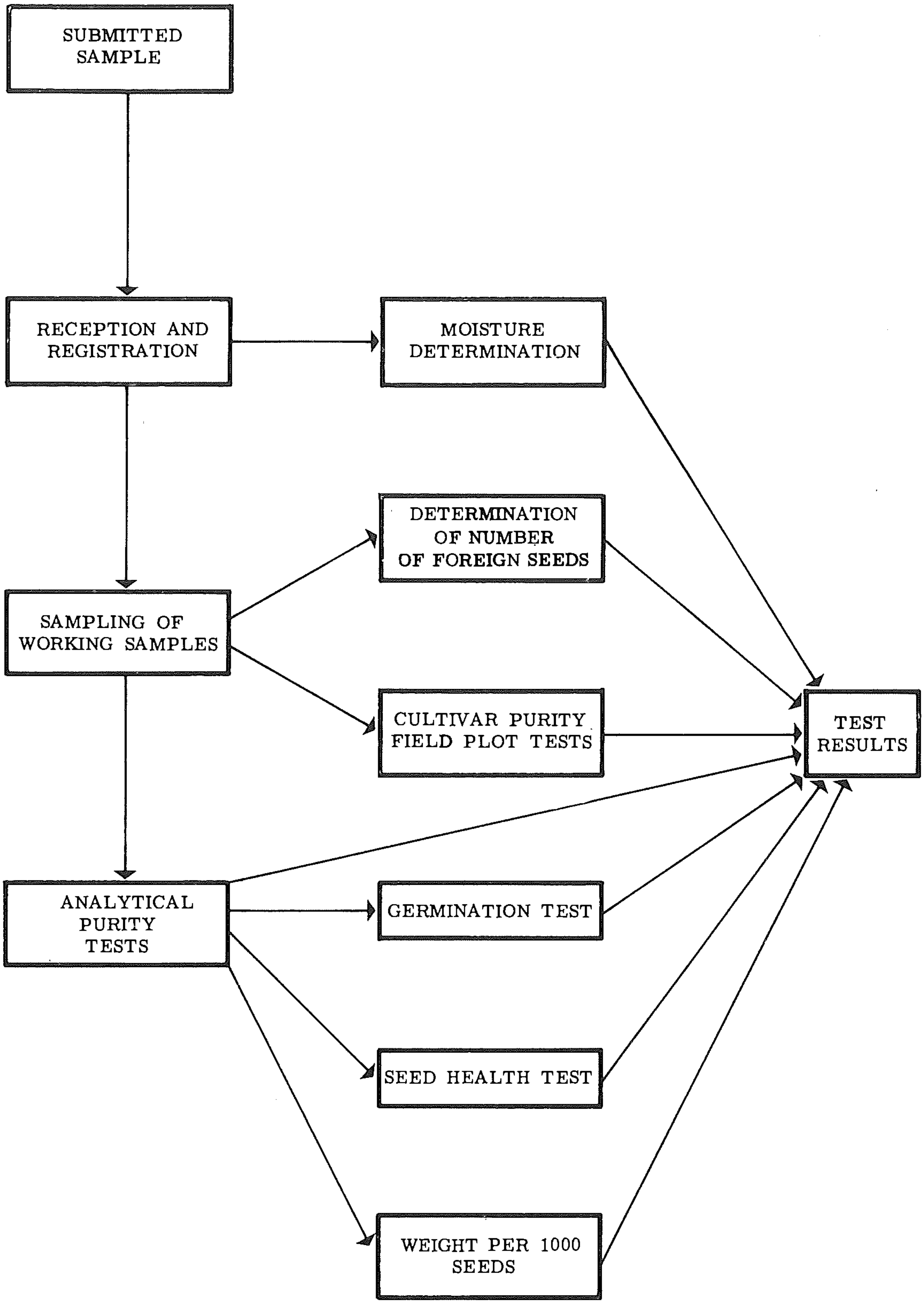


FIGURE 39. Steps in sample handling in the laboratory.

sockets, lamps, and switches and water taps. As later supplementation has too often proved difficult or impossible, it is advisable to request a budget including all investments from the very beginning.

A laboratory with normal basic equipment should have a supply of not less than 25–30 kilowatts of electric power and preferably operate on single-phase 220 volts or three-phase 380 volts A.C., 50 cycles. Other voltages can be used over adaptor transformers, but for safe operation of the various apparatus, a uniform voltage for both supply and consumption should be employed throughout the premises.

Irregularities in water supply and pressure may be counterbalanced by means of elevated stock tanks and tanks for collecting rain water from roof drainpipes.

Equipment and furniture

Seed testing is a strenuous task which needs to be eased by the provision of various aids and equipment. This should be borne in mind in planning and pointed out to architects and engineers with no experience of day-long routine analysis work.

In the execution of official tests for seed certification, seed-law enforcement, and the issuing of international certificates, the laboratory is required to follow prescriptions given in the International Rules for Seed Testing.

The rules prescribe tests and methods that require certain equipment, such as lenses, balances, germinators, and ovens. Of course, only the best equipment is good enough, and second-rate substitutes for the equipment ordered should be avoided. Biological variation will certainly cause the analysts enough problems without also having to bother with poor-quality apparatus. Consider quality first and price second, whether purchasing locally or importing, as efficiency and reliability are imperative.

No laboratory can operate at peak capacity from the first day. Staff must be trained, time is needed to implement a seed certification scheme, and the testing service must be publicized and "sold" to the public. Then there arises the question of whether to start out with a full-size laboratory or to begin by covering only the basic needs, which can subsequently be extended as the activities increase. As suggested in the above paragraphs on planning the building, it is usually well worthwhile to aim for a complete laboratory that is ready to meet a growing demand for its services. All too frequently the budget-approving authorities honour requests for investments only once — at the start of a programme. Overcapacity will be needed in the first year for staff training, experimenting with different methods, and calibrating equipment and generally getting the laboratory running smoothly. The number of sets or units and the capacity and design of equipment (including the material from which it is made), together with appropriate suppliers, must be considered on the basis of the individual laboratory requirements.

Frequently it is preferable to have the equipment and furniture made locally (e.g., office and laboratory tables, counting boards, and storage racks). It is a good idea to spend some days looking around for craftsmen and for stores selling appropriate hardware and household goods. Improvisation is often possible: a trolley can be made by putting wheels on a steel bookshelf, and suitable germination sand can be sieved out by using the right mesh size. Such items as a seed divider and the sampling equipment can also be made locally. The weighing unit is the most sensitive equipment in the whole laboratory. It is essential to allocate a quiet corner and a solid bench for the balances.

Organization of laboratory work

Delegation of responsibility

The person in charge of the laboratory has a general responsibility for seeing that the work is done at the right time and is of high quality. He is also in charge of liaison with seed certification and seed control programmes and should be in close contact at various levels with seed farms, producers, and dealers. He must see that budget provisions are made, that supplies are ordered in time, that equipment is maintained, and that samples and records are satisfactorily kept. Finally, and very important, he must recruit laboratory staff and organize its training. Besides being responsible for the technical work, the person in charge has in fact a heavy administrative burden and must make decisions on future policy. It is therefore necessary to delegate duties and responsibilities to assistants, which can easily be done in the technical field, where duties can be clearly defined and job descriptions established.

A working order should be set for the seed-testing officer and his staff. Descriptions of the different duties and responsibilities of each individual are most helpful, all the more so when someone is absent for illness, travel, or other reasons.

The work within the seed laboratory can logically be divided into two main sections: seed-germination and seed-purity analysis. If the laboratory is a unit of an extensive seed certification scheme, a third section for cultivar purity tests, both in the field (pre- and post-control) and in the laboratory, may be set up.

The following primary delegation of duties and responsibilities is suggested:

Position	*Duties and responsibilities*
Senior assistant in charge of purity analysis	Generally, to supervise work, equipment, and supplies in the purity section. To ensure that samples are promptly prepared for and placed under analysis. To ensure that samples for moisture determination are analysed immediately. To make sure that samples are stored properly and maintained in good condition. To maintain and develop a weed collection and crop-seed collection. To distribute the work among analysts. To check the analysis of official and certified seed samples. To decide when retesting is necessary, using the tolerance tables. To check analysis report forms before they are forwarded.
Senior assistant in charge of germination analysis	Generally, to supervise work, equipment, and supplies in the germination section. To ensure that samples promptly undergo the test procedure and that planting is arranged so that the day for counting the test seedlings will not coincide with weekends and holidays. To distribute the work among analysts. To ensure proper operation and functioning of equipment. To make sure that proper methods are applied. To make a final evaluation of germination tests. To decide when retesting is necessary, using the tolerance tables. To check analysis report forms before they are forwarded.

It is important to recognize the responsibilities of the individual seed analysts. To achieve maximum utilization of the laboratory workers and to promote a responsible attitude, coherent work sequences must be assigned to individual workers, who should also have to sign for it upon completion on the analysis form.

Seed testing is mainly teamwork, but the responsibility for the right evaluation of different purity and germination categories rests with laboratory staff members. This applies to all work, from dividing the working samples and preparation of germination beds to distinguishing between pure seed and inert matter or between normal and abnormal seedlings, as well as to such tasks as cleaning dividers and germination dishes.

Specialized or all-purpose analyst training

In general, all laboratory staff should be trained and able to carry out all kinds of analyses and to work in either section as the need arises. A sample should never be left idle because Mr./Mrs./Miss X is on leave. Likewise, when the officer in charge of seed testing has to be away for some reason, responsibility to sign certificates and to take over some of his other duties should be delegated to the most experienced and skilled assistant. Clear delegation of appropriate responsibilities should be laid down in a working schedule so as to ensure smooth functioning of the laboratory. The ability to delegate is essential in a small laboratory and is also of value in the larger seed laboratories.

As the laboratory grows and the staff is enlarged, the workers may specialize in certain areas of work according to ability and talent. This should be encouraged, of course, as it stimulates interest in the work. These general principles can be extended to recruit training policy, as every worker should be able to carry out all kinds of work. The main part of training is done in the slack season, but in the busy season the trainees can undertake any suitable duties. It takes from one to two years for a person to become familiar with most of the work with cereal seeds alone. A much longer training period is required for the testing of cultivar purity — a skill which some people are never able to acquire, although they may do better in other jobs.

Finally, it must be pointed out that seed testing is a matter of personal experience gained, through one's own work, although personal guidance from someone familiar with the subject is required. Textbooks can never replace personal experience, but can only provide rules and background understanding.

Procedures in sample handling

The aim should be "streamlined" service combined with the ability to give individual advice. The procedures inside the laboratory should be as direct as possible.

FIGURE 40. Registration of samples.

Record system

To serve the needs of seed certification, farmers, and other applicants, it is essential that records are immediately available for any sample tested during the current year, season, or time specified in regulations.

Upon registration the sample is assigned a test or analysis number; this is most simply done in serial order. The same test number is to be used for all working samples drawn from one submitted sample for the various tests in the different sections (Fig. 40).

It is suggested that two analysis forms with the analysis number be issued for each sample and accompany the sample in the laboratory. One form is for reporting analytical purity, numbers of weed and other crop seeds, moisture content, cultivar purity, and other requested tests (e.g., weight of 1 000 seeds). The other form is for germination, tetrazolium, and seed health tests, which are done in replication and thus require more space for recording the results. If cultivar purity is to be tested in field plots, a third form has to be used, on which the laboratory tests for cultivar purity will be recorded, instead of using the "purity form."

Upon registration a cover or master form is also issued for the files of the administrative office. On this form all information provided by the applicant and seed inspector is summarized, including species, cultivar, lot identification, weight of lot, number of units (bags, containers), analyses requested, origin of seed, certification class, and owner of lot and his address. The cover form is filed in order of test number, awaiting the return of the analysis forms from the laboratories upon completion of the tests.

An entry book or file should be started for the sample when it is registered. The records in this may be limited to test number, name and address of applicant, species and cultivar, lot identification, date of sample arrival, completion of tests, and report. The entry book or file thus serves as a diary.

With these minimum records it is always possible to identify samples easily and to obtain information on the test results and how far the analyses have advanced. Laboratories handling a great number of samples each testing season may, of course, develop more refined and sophisticated record systems. Layout and format of forms is a matter of preference. Uniformity within the laboratory and with cooperating agencies is desirable (ISTA, 1969*a*; Chalam *et al.*, 1967).

Methods

The International Rules for Seed Testing (ISTA, 1966) should be applied, so it is therefore necessary that this publication be available in the seed laboratories and, if possible, be translated into the local language. All laboratory workers should be familiar with the ISTA rules and in any analysis situation must be able to refer to them and to other publications (e.g., Wellington, 1969; Chalam *et al.*, 1967; U.S. Department of Agriculture, 1952; Association of Official Seed Analysts, 1970).

Sampling and uniformity

Before sampling the seed lot the seed inspector has to see that the lot is uniform by inspecting all package units. He may request that the lot be more thoroughly blended and mixed together or that part of it be withdrawn; he can also refuse to sample the lot.

The maximum weight of the seed lot is 20 000 kg. The required weight for the submitted sample is only 1 000 g, and the prescribed quantity for testing (working samples) is at the most 1 000 g. Thus the greatest care should be taken in sampling the seed lot and in subsequent subsampling to obtain working samples, which are presumed to represent the entire seed lot. The maximum weight ratio of sample to seed lot is only 1:20 000.

Seed in bulk or bins cannot be sampled by hand. Instruments must be

FIGURE 41. Seed sampling from containers.

used (Fig. 41), or the bins have to be emptied for access to the bottom layers. Similarly, deeper layers in bags weighing more than 25 kg are difficult to sample by hand, and when this is necessary, a sufficient number should be emptied, hand-sampled, and rebagged.

The most simple, sturdy, and easy-to-operate subsampling device for obtaining working samples is the soil divider. The submitted sample must be thoroughly mixed and uniform before halving starts; mixing can be done by running the sample through the divider two or three times (Fig. 42).

PURITY ANALYSIS

For purity analysis the required test quantities are 900 g for maize, 40 g for rice, and 120 g for wheat. For counting the numbers of foreign seeds the test quantities are 1 000 g for maize, 400 g for rice, and 1 000 g for wheat (Fig. 43).

For these species the "pure seed fraction" refers to all cultivars of the species under consideration as declared by the sender or found by laboratory test. It includes:

1. Mature, undamaged seeds of the species.
2. Undersized, shrivelled, immature, and germinated seeds, provided they can definitely be identified as the species.

FIGURE 42. Dividing the sample.

FIGURE 43. Purity analysis of maize seed.

3. Pieces of broken seeds that are more than half the original size. Seeds without evident damage to the testa are classed as pure seed irrespective of whether they are empty or full. If the seed has an opening in the testa, the analyst must decide whether the remaining portion is more than half the original size. If this determination cannot readily be made, the seed is classed as pure seed.
4. Diseased seeds, except those altered by fungi to form sclerotia or smut balls and by galls resulting from nematode infestation, which are regarded as inert matter.
5. Grass and cereal florets and one-flowered spikelets with an obvious endosperm.
6. Free caryopses of grasses and cereals removed from the glumes (bracts), paleae, and lemmas.

Items not included in the "pure seed fraction" include seeds of other crops and weeds. The latter include seeds, bulbets, or tubers of plants recognized as weeds by law or by general usage. All such structures, except certain undeveloped or badly injured weed seeds (defined under "inert matter" in the ISTA rules), are classified as weed seeds.

All other structures are classed as "inert matter," which consists mainly of the following:

1. Empty florets of both weed and crop species containing only anthers or undeveloped ovaries.
2. Broken pieces of pure seed and crop seed species that are one half or less their original size.
3. Pieces of straw, chaff, glumes, soil, and sand.
4. Empty fruits or seeds of weeds.
5. Smut balls, ergots, and nematode galls.

During analysis there is no consideration of what is "good" or "bad" seed, nor of whether the seed or seed fraction is likely to germinate, since this will be evaluated in the germination test.

To determine the numbers of foreign seeds, the working sample is separated into fractions of weed seeds, other crop seeds, and other material, including pure seed and inert matter which are not counted. The separated seeds are counted and must be identified.

GERMINATION, TETRAZOLIUM, AND X-RAY TESTS

Germination test

Strictly pure seed, as it is defined, must be used for germination and related tests.

The prescribed substrata are sand and paper (e.g., upright, rolled towels standing in open plastic bags). Of the two, germination in sand gives easier, less complicated seedling evaluation, but requires more laboratory (germinator) space. The "blotter" method is standard in seed-health testing, and the tests are conducted in the same kind of germination trays as utilized for tests in sand. The prescribed number of seeds for germination tests is 400, which can be divided into four batches of 100 seeds or eight batches of 50 seeds. With sand it is preferable and cheaper to use a constant temperature: 25°C for maize and rice, and 20°C for wheat (Fig. 44).

The seeds are spaced on the substratum so as to prevent the seedlings from coming into contact with one another before they are counted and removed. The substratum should be more moist for maize and rice tests than for wheat.

Intermediate counts are omitted when sand is the substratum. If seedling development is vigorous, the test should be completed, even though the ISTA rules specify a longer period. When seedlings are weak, the germination period may be prolonged. Dormancy in rice is overcome by presoaking for 24 to 48 hours in water at 40°C and in wheat by prechilling

FIGURE 44. Germination room. On the left, germination trays for tests in sand on mobile shelves.

(planted seeds) for up to 7 days at a temperature between 5°C and 10°C. Maize does not raise any such problems.

Fungicide treatment is not used in the normal germination test, nor is surface sterilization of seeds (e.g., in 1 percent sodium hypochlorite), although such treatments may be offered as a service or undertaken upon request.

When seedling evaluation is difficult or doubtful, and when testing samples which produce seedlings with phytotoxic symptoms in paper or sand, the test must be confirmed, using soil as the reference substratum. Any deviation from the ISTA rules and any pretreatment should be recorded on the analysis form and, for international use, reported on the certificate.

Standardized methods, experience in reading tests and seedling evaluation, and referee tests together provide the only way of achieving uniformity in germination tests. The excellent photographs and drawings of normal and abnormal seedlings in the publications previously cited are strongly recommended for reference study and for speeding up the training of analysts.

The best instrument for distinguishing dead from fresh ungerminated or dormant seeds is the forefinger. Press the seed moderately. If it is dead, the seed collapses and the creamy content is squeezed out; if it is dormant or fresh ungerminated, the seed is firm and resists the pressure. Dormant and fresh ungerminated seeds may also be dissected for final examination.

Rice. Development of fungi on seeds and seedlings may cause extreme variations in test results. More uniform results can be obtained if the seed is well spaced and grown in "flooded" sand or upright rolled towels. Wet conditions may also help to overcome dormancy.

Abnormal rice seedlings may show any one or several of the following conditions:

(*a*) no roots;
(*b*) a spindly primary root with very little or no branching or secondary development;
(*c*) no green leaves, but only the white sheath or coleoptile;
(*d*) a spindly and sometimes watery shoot, usually associated with decay of the rice grain;
(*e*) a short leaf extending no more than halfway up the coleoptile;
(*f*) shattered or longitudinally split plumules, with or without splitting of the coleoptile;
(*g*) decayed plumules, usually near the point of attachment to the grain, provided the decay is not caused by adverse test conditions.

Maize. Abnormal maize seedlings may show any one or several of the following conditions:

(*a*) no primary or secondary roots;
(*b*) no primary root, with small and weak secondary roots;
(*c*) no leaves, but only the coleoptile;
(*d*) short leaves extending less than halfway up the coleoptile;
(*e*) a short and thick plumule;
(*f*) a spindly, pale, or watery plumule, usually caused by mouldy seed;
(*g*) albino (white) seedlings;
(*h*) shattered or longitudinally split leaves, with or without splitting of the coleoptile;
(*i*) decayed plumules, usually near the point of attachment to the grain, and rotten scutella, provided the decay is not caused by adverse test conditions.

Wheat. Abnormal wheat seedlings may show any one or several of the following conditions:

(*a*) no seminal roots or only one seminal root;
(*b*) short and stunted seminal roots;
(*c*) seminal roots which are short and weak, spindly, or watery;
(*d*) a coleoptile without green leaves;
(*e*) short leaves extending less than halfway up the coleoptile;
(*f*) leaves which are shattered or split longitudinally, a coleoptile with a split that is easily visible to the naked eye, or abnormal coleoptile development due to damage, even though the leaves are normal;
(*g*) a spindly, pale, or watery plumule;
(*h*) a short and thick plumule, usually with short and stunted seminal roots;
(*i*) a decayed plumule, decay at the point of attachment between the seedling and the endosperm, or discoloration of the coleoptile which has penetrated to the leaves;
(*j*) decayed seminal roots;
(*k*) completely decayed seedling;
(*l*) weak and spindly or watery seedling;
(*m*) frost-damaged seedling, having a grainy coleoptile or a plumule which is weak and spirally twisted.

Tetrazolium test

The topographical tetrazolium test, or biochemical test for viability, is not a germination test. The test is very useful, however, for rapidly obtaining an indication of germination potential and viability of samples which show no signs of germinating at the end of the germination test, but may contain dormant or fresh ungerminated seeds. It should be remembered that the tetrazolium method, though quick, requires much more work, attention, and experience than the standard germination tests (ISTA, 1966, 1971*a*; Association of Official Seed Analysts, 1970).

X-ray test

The X-ray technique is well established as a nondestructive test for the assessment of insect damage and infestation, underdevelopment, mechanical damage, and polyembryony in seed. With the $BaCl_2$ contrast method, dead seeds can also be distinguished, and thus an indication of germination potential is obtained.

Superficial therapy X-ray sets can be used. The seeds are placed on top of a black paper cassette containing rapid X-ray film and exposed to radiation generated at 15 000 V, with a 2-mA current, for three seconds from a distance of 25 cm. If the contrast method is used, the seeds are first soaked in an aqueous solution of $BaCl_2$. (The X-ray test is not included in the International Rules for Seed Testing.)

MOISTURE DETERMINATION

The standard method for maize, rice, and wheat — drying in an air-oven at 130°C for one hour — is described in detail in the International Rules for Seed Testing (ISTA, 1966).

Samples should be analysed promptly on arrival, and only exceptionally may they be left over night. Sample containers should be air- and vapour-tight and completely filled with seed. If the sample is submitted to the laboratory in a type of container that does not conform to the description, this must be noted on the report form, which means the test cannot be regarded as official; for an official test a new sample, properly packed, must be submitted.

Quick or machine tests are valuable guides to the need for drying seed during processing and storage. A variety of brands and types of moisture testers are available on the market. For laboratory use, the units should be calibrated or checked against the standard air-oven method (Fig. 45).

CULTIVAR PURITY

Cultivar purity is tested in the laboratory, in the greenhouse, and in field plots. Morphological and physiological characteristics of seeds, seedlings, and plants are examined. For all types of tests, authentic samples of the cultivar should be available for comparison. The testing methods are described in the ISTA rules as well as in several manuals. Adaptations of these and additional methods must be worked out nationally or within regions, to take account of differences in climate, day length, and breeding background of the cultivar (Fig. 46).

Some tests are described here in order to indicate possible methods of examining the character of seeds, seedlings, and plants of maize, rice, and wheat.

General characters

I. MAIZE

Coleoptile	Colour
Plant	Average height and whether the plant form is compact or lax, weak or sturdy
Leaf	Length, width, colour, venation, margins, and whether erect or drooping, glabrous or pubescent, waxy or clear
Stem	Colour of various parts, thickness, internode length, hairiness
Tassel	Density, number of primary and secondary branches, pollen colour
Glume	Colour
Silk	Colour
Ear cover leaf	Number and whether tight or loose
Ear	Length, width, shape, regularity of rows, number per plant
Grain	Colour, shape, size, uniformity, and whether flint or dent
Cob	Colour

Number of days from planting to emergence of tassel and silk to maturity

Resistance to diseases and pests

FIGURE 45. Determination of water content with quick moisture tester.

FIGURE 46. Cultivar purity testing in field plots.

II. Rice

Coleoptile	Colour
Plant	Average height (dwarf, intermediate, tall), extent of tillering, and whether the plant habit is erect, prostrate, or intermediate
Leaves	Width, colour, margins, and whether glabrous or pubescent, erect, or drooping
Junction of leaf with sheath and auricle	Colour, hairiness
Stem	Colour, thickness, internode length, colour of nodes, strength
Panicle	Type (compact, open), length, colour of peduncle
Awns	Whether awnless, tip-awned, partly or fully awned, and colour if present
Grain (dehusked)	Size, shape, colour, ratio of breadth to length
Paddy (husked)	Hairiness, size, shape
Upland (dry) or paddy (wet) type	Whether sensitive to photoperiod

Number of days from planting to panicle emergence, flowering, and maturity

Amount of shattering

Resistance to diseases and pests

III. Wheat

Coleoptile	Colour
Plant	Average height, sturdiness and strength, extent of tillering
Leaves	Width, colour, margins, and whether glabrous or pubescent, waxy or clear, erect or drooping

Junction of leaf with sheath and auricle	Colour, hairiness
Stem	Colour, thickness, internode length, node colour and hairiness, cross section
Ear	Size, shape, awning, awn arrangement, compactness, degree of pubescence, internode hairiness
Glumes	Colour, length, width, shoulder shape, beak length, width and shape
Grain	Size, shape, colour, hair tuft, width and depth of crease, embryo shape

To be sown before or after winter

Number of days from planting to ear emergence, flowering, and maturity

Amount of shattering

Resistance to diseases and pests

Laboratory testing of seed and seedlings

Phenol test

Varieties differ in the extent to which their grain will colour when treated with a 1 percent phenol solution. Four batches of 100 seeds are soaked in distilled water for 24 hours and then exposed for 2–4 hours to phenol on filter paper moistened by the chemical. Seeds with palea and lemma are dehusked after soaking, but before exposure to phenol. The reaction is noted and compared with check tests on authentic samples of the cultivar. Cultivars can be divided into at least four or five reaction groups, ranging from unaffected seeds to dark-brown to black-coloured seeds. This test is applicable to wheat and possibly to rice.

Ultraviolet-light test

In black ultraviolet light (3 500 Ångström units) dry seeds of different cultivars may or may not show fluorescence. Other methods which may show differences between cultivars in fluorescence under ultraviolet light are the exudates on moist filter paper from roots of seedlings germinated on the paper or the exudates from dry seeds exposed for a couple of hours to filter paper moistened with 1-2 percent potassium hydroxide. Rice seeds can be examined for the characters of the paddy (husked seed with palea and lemma), the brown rice (dehusked seed, grain), and the polished rice grain (caryopsis).

The polished rice of glutinous cultivars is sticky and cakes when boiled, whereas nonglutinous cultivars remain "dry" and do not cake.

The dry brown rice of glutinous cultivars is opaque, whereas the nonglutinous cultivars are clear and shiny. When examined under magnification, the clear, nonglutinous grains show varying degrees of chalkiness — the chalky portion resembling a young embryo in an egg. Although chalkiness is related to the cultivar, it is also influenced by growing location. If the grain of brown rice is broken and treated with iodine solution, the glutinous cultivars produce a purple/brownish colour reaction, and the nonglutinous a blue colour.

Rice cultivars may also be grouped according to high, intermediate, or low gelatinization of the starch in individual grains after treatment with 1.7 percent potassium hydroxide for 2½ hours. A further test determines amylose content in a colorimeter after gelatinizing the starch in rice flour with sodium hydroxide and adding iodine solution; the strength of the colour reaction is a measure of the amylose content.

Chalkiness, starch gelatinization, and amylose content are all influenced to a certain extent by growing location, but the tests are nevertheless useful for grouping similar cultivars.

Sample storage

The sample storage room, though often neglected, is essential as soon as seed-law enforcement and seed certification are started. Bulk samples should be stored on racks or shelves arranged to utilize the space of the storage room in the best possible way. It may be necessary to remove the samples from their original package and repack them in uniform bags or containers for a neat and orderly arrangement of the samples. Bags or containers are put on the shelves in order of test number.

Samples submitted for moisture determination need not be stored. They are kept in the laboratory only until this particular test, including any necessary repeat test, is completed.

Samples of high value, such as breeders' seed, authentic samples, selections, research seed, and germ plasm collections, should be given special care. After being dried to a 7–8 percent moisture content, they may be stored in metal boxes kept in steel cabinets; the boxes should be supplied with silica gel and gasketed.

Storage must be ratproof, and pest control is essential. The samples on store should be revised continuously, and old samples must be removed when the prescribed storage period is ended.

Under tropical conditions the store should be air-conditioned and dehumidified. Storage temperature and relative humidity should not exceed 20°C and 40 percent, respectively; this is sufficient for one-year storage.

TOLERANCES

For many reasons analysts are often faced with variations in test results. Variation may occur between two replicates of the same sample, between results obtained by two analysts testing the same sample simultaneously, or between results from the same sample tested in two different laboratories. In testing two independently drawn samples from the same lot, variation will occur between results obtained by different analysts and laboratories. Acceptable variations, or tolerances, for various analyses have been calculated and listed by ISTA (1963*a*).

REPORTING

Test results calculated from the findings of analyses, as recorded on the analyses forms, should be reported on a certificate or report form. These certificates should preferably be preprinted, so that the reporting work is limited to completion of the form. A typewriter will eliminate misreading due to poor handwriting.

The certificate is submitted without delay to the applicant, owner, or legal possessor of the seed lot. Nobody else is entitled to the information, except when the tests are made for the purpose of seed certification or seed control, in which case the requirements should be backed by law or regulation. One copy of the certificate is also filed in the laboratory. Under certain circumstances additional copies may be issued upon legal request or agreement.

The result of a purity analysis is calculated as percentage by weight, given to one decimal point, and the percentages of all components must total 100. Components of less than 0.05 percent are reported as "traces." If the result for a component is nil, this must be shown as 0.0.

In reports for domestic use it is sufficient to identify pure and foreign seeds in the local language. It is also customary to report the nature of inert matter (e.g., soil, stones, chaff, glumes), as this provides information for possible recleaning. Determination of the number of foreign seeds is usually reported as numbers of specified foreign seeds in the unit weight examined.

Germination test results are reported as percentage by number, computed to the nearest whole number. In addition to the percentage of normal seedlings, the percentages of abnormal seedlings, dead seeds, and fresh, ungerminated seeds are also reported. If the result is nil for any category, it is reported as 0. As additional advice the percentage of pure germinated seeds (germination percentage multiplied by purity percentage) may be reported. This latter result and the weight of 1 000 seeds provide the basis for calculation of seed rate, so as to obtain a desired population density in the field, or for adjustment of the recommended seed rate.

Tetrazolium test results are reported as percentage by number, computed to the nearest whole number.

When 400 to 2 000 seeds are examined for cultivar purity, the number of extraneous seeds or seedlings is reported as percentage by number, computed to the nearest whole number; when between 2 000 and 4 000 seeds are examined, the percentage is computed to one decimal place; and when more seeds are examined, to two decimal places. If no extraneous seeds or seedlings are found, the report may state "no remarks."

The results of field plot tests are reported as percentage by number of the estimated number of plants examined, computed to a number of decimal places that is consistent with the number of plants in the examined population.

The moisture content is reported to the nearest 0.1 percent by weight.

Test results for international use must be reported as set forth in the ISTA rules, in which there are sections on "expressing and reporting results" in the respective chapters and a further chapter on certificates, reports, and tolerances.

Conclusions

A seed laboratory is an essential and indispensable institution in seed certification and seed control schemes. Its test results may cause rejection of seed lots for distribution or further multiplication and may serve as evidence against sellers of faulty seed in a court of law. However, the main objective of seed testing is to serve the producer, the consumer, and the seed industry and to provide as much information as possible on seed quality in general and on individual seed lots.

Seed laboratories will automatically gain knowledge and experience in matters related to seed quality, such as harvest technique; drying, cleaning, and grading; pest and disease treatment; storage, packing, handling, and marketing; and cultivar performance under various conditions. This knowledge should be readily available to all parties, both as experimental or research results and as advice. If information or an answer to a question is not immediately available, it must be obtained from other sources or through the undertaking of experiments. A customer should never be left with an indifferent answer to his problem or with a feeling that it is not worthy of interest. A frank and simple "no" can also be a positive answer.

The ultimate goal of benefiting the whole country can only be achieved through close cooperation with all parties directly or indirectly concerned, whether in the government or among the farmers.

The existence of the seed laboratory and the services it can provide must be known to the public. It is necessary to publicize the importance and value of seed testing as a means of estimating the quality of seed and providing criteria for selecting the best seed — which is, in any case, the cheapest input in crop production. In many countries most of the seed used is the farmers' own seed, saved from the previous harvest, which has not been subjected to seed certification and is of unknown quality. This is one of the hazards in crop production that can be eliminated through extended and general use of seed testing.

SEED HEALTH TESTING

by P. Neergaard*

Principles and objectives

Many devastating seed-borne pathogens, such as smuts in cereals, have long been known, but others which are parasites of major food crops, such as many species of *Drechslera*, *Fusarium*, and *Septoria*, have been ignored. Mere traces of downy mildews, such as tobacco blue mould (*Peronospora tabacina*), on seed may bring about explosive epidemics. Bacterial pathogens are transmitted by seed and cause serious diseases. Viruses are frequently seed-transmitted in legumes and substantially reduce one of the world's vital sources of proteins.

The inoculum of parasites in seed is dynamic, leading to chain reactions of increasing destruction. It may cause such consistent reduction in yields, year after year, that it is unnoticed by the farmer. Seed may be the vehicle for conveying serious pathogens to new areas. If seed of excellent germination and purity is loaded with serious pathogens, usually undetectable by the naked eye, the crop grown from it, and perhaps also the neighbouring crops, may be destroyed. Soil may become contaminated from infected seed, and subsequent crops will suffer from the disease thus established.

The best approach to controlling disease is to prevent it. In principle, the simplest procedure is to check the health condition of the seed before it is sown, and to *reject* infected seed or *treat* it if no healthy seed is available; for propagation, *select* seed of the highest standard.

Many routine procedures for testing seed health have been developed, which can give quick information to the seed owner, farmer, gardener, or seed company. The tests provide a basis for improving seed stocks, as an essential part of seed certification schemes, by selecting the most healthy seed lots for propagation. Using these methods, surveys of the distribution of pathogens can be made and the best areas for seed production found. Seed lots can be screened for sowing value, to find out whether seed treatment is needed, whether they are suitable for storing, and, last but not least, to comply with quarantine regulations. Seed health testing in itself provides research problems; furthermore, research into

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other aspects of seeds requires that their health condition be known, so that suitable experimental material is selected.

Organization

International cooperation in the development and standardization of procedure is organized by the Plant Disease Committee of the International Seed Testing Association. The Committee organizes international comparative seed-health-testing schemes and holds international workshops on seed pathology, in which the results of these and the principles of testing are discussed. These activities enable the Committee to make recommendations on standardization.

In recent years the activities of the Danish Institute of Seed Pathology for Developing Countries has given a lead in initiating seed health testing in developing countries. Students and research fellows at the Institute receive training in seed pathology at postgraduate level for about a year.

Seed-health-testing laboratories are in operation in some European countries and in an increasing number of developing countries. Some are affiliated with seed testing stations, and others with plant protection services working on quarantine inspection of seed lots. In seed testing stations, health tests are made on an advisory basis to comply with national seed legislation and seed certification schemes. The International Seed Testing Association provides a certificate for the physical quality of seed, while the International Plant Protection Convention requires member countries to use the International Phytosanitary Certificate (the "Rome Certificate").

Methods

Examination of the dry seed

According to the International Rules for Seed Testing, plant debris, sclerotia, galls, insects, smut balls, and the like are classified as "inert" matter. A considerable part of this material is certainly not inert, inasmuch as it consists of living pathogenic inoculum. Some pathogens can be detected by using a low-power stereoscopic microscope, with magnification up to fifty or sixty times under good light conditions. Examples of pathogens which can be detected in this way are sclerotia (e.g., ergot, *Claviceps purpurea*); fruiting bodies on seed and debris (e.g., *Septoria linicola* in flax), galls of nematodes (e.g., ear cockles in wheat), bunt or smut balls in cereals and grasses, seeds showing symptoms of infection (e.g., anthracnose and bacterial blights in beans), and pycnidia of *Septoria apiicola* in celery.

Observations of pycnidia, acervuli, sporodochia, and the like can be facilitated by placing the seeds in water or lactophenol. This procedure may very well be applied in seed testing stations during purity tests. Indeed, the test cannot be properly completed unless sclerotia and other such "inert" matter are correctly identified and classified; however, only a very limited range of seed-borne pathogens can be detected in this way.

Examination of suspensions from washing seed

A suspension is obtained by shaking the seed for a fixed period of time, preferably in an automatic shaker to facilitate and standardize the procedure. The suspension may be examined directly or after centrifuging and subsequent dilution in a known quantity of fluid. A haemacytometer may be used and several mounts made to improve the accuracy of the counts. This procedure is particularly suitable for detecting bunts of wheat, *Tilletia caries* and *Tilletia foetida*. The presence of short-lived spores, such as conidia of *Pyricularia oryzae*, may be taken as evidence that the fungus is probably present, but the inoculum is present mainly in the form of mycelium in the seed and can only be properly assessed after incubation. Conversely, the absence of conidia cannot be taken as evidence of freedom from infection.

Incubation tests

Many pathogens can be detected when conditions suitable for their development are provided for a period of time. The most important variations of this method are the blotter test, the agar test, and the seedling-symptom test. Particularly the blotter and agar tests have been fairly well standardized internationally.

The blotter test. The seeds are sown on absorbent paper (blotters), sufficiently moistened for the duration of the test. The blotters are placed in petri dishes, perspex containers, or other suitable recipients, and the seed is sown at a uniform spacing consistent with the size of the seed. The sown dishes are then incubated for a fixed period of time; for many kinds of seed, one week at 20° C±2°C, and for some tropical seeds, one week at 28°C±2°C. To stimulate sporulation of fungi, standard illumination of a near-ultraviolet light-darkness cycle of 12/12 hours has been adopted (ISTA, 1966). The seeds are examined under a low-power stereoscopic microscope, with magnification up to fifty or sixty times the numbers of infected seeds are recorded, and the results are given in percentages.

For certain kinds of seed that are often heavily contaminated with saprophytes, it may be necessary to pretreat the seed with 1 to 2 percent chlorine before sowing.

The blotter test is used for many kinds of seed, including those of cereals, vegetables, ornamentals, and forest trees. It is particularly useful for detecting fungi which readily produce conidia, including pathogens in the genera of *Alternaria*, *Ascochyta*, *Botrytis*, *Colletotrichum*, *Drechslera*, *Fusarium*, *Myrothecium*, and *Phoma*. The seedling symptoms or the characters of the mycelium can often be used to distinguish different species of fungi.

The agar test. The seeds are plated on agar, spaced according to the size of the seed. Malt-extract agar and potato-dextrose agar are commonly used. The seeds are incubated at a fixed temperature, normally 20°C±2°C, but for certain tropical seeds 28°C±2°C. The incubation period is usually five to seven days, using the standard illumination of near-ultraviolet light (12 hours of near-ultraviolet and 12 hours of darkness). The fungi which develop are recorded by microscopic examination, which enables recognition of the culture characteristics of the colonies. Both the obverse and the reverse of the plates are examined. The agar plate procedure is a quick test provided that the operator is skilled in identifying fungi rapidly by their growth characters alone. This is possible only if many seed samples are tested regularly on a standard medium; otherwise time-consuming checking by means of microscopic examination will be needed.

The seedling-symptom test. With this procedure an attempt is made to establish more natural growth conditions for seedlings and seedling pathogens. The seeds are sown in soil, gravel, sand, or similar material in order that infected seedlings may develop symptoms comparable to those encountered under field conditions. The classical *Hiltner method* was developed in Germany in 1917 to detect the symptoms of *Fusarium nivale* (snow mould) in rye, which are suppressed in the germination test. Sterile crushed brick, with a maximum grain size of 3–4 mm, is used as the medium, and it is moistened with enough sterile water to make later watering unnecessary. Often, low temperatures, such as 10–12°C, are used to enable the fungus to grow. A similar technique, but using higher temperatures, such as 20°C, will develop symptoms of *Septoria* and *Drechslera* spp. on cereals.

Another procedure is *the standard soil method.* A uniform soil mixture with fertilizers added is placed in multipots, and after watering, one seed is sown in each pot. A thin polythene bag is then pulled over the tray to keep the soil moist throughout incubation. Records are made after two to four weeks of incubation, depending on temperature and kind of seed. This technique can be used for testing cereals either before or after treatment with chemical fungicides.

Serological procedures

Serological procedures, which are widely used in human and veterinary pathology, have also been adopted for the identification of plant pathogens, particularly viruses and bacteria. Two such procedures are the *Ouchterlony agar double diffusion test* and the *latex flocculation (agglutination) test*, both of which seem to be very promising for testing seed health.

In the Ouchterlony diffusion test, a record of antigen-antiserum reaction is made by placing antiserum in a central circular well on an agar plate (for instance, of Difco Bacto agar) and the antigens in similar peripheral wells arranged clocklike around. Positive reaction can be observed in one or two days—for example, for barley stripe mosaic after two days of incubation (Hamilton, 1965), and for a tomato strain of tobacco mosaic virus after sixteen hours (Phatak, unpublished). Precipitation is visible as characteristic opaque white bands between the well containing antiserum and those containing extracts of infected seeds or seedlings.

In the latex flocculation test, large particles of the biologically inert polystyrene latex (0.81 μ diameter) are sensitized with the globulin fraction of virus antisera. Flocculation takes place when these particles are suspended in a solution containing a homologous antigen. Soybean mosaic virus may be extracted from the cotyledons and plumules of seedlings, developed in an ordinary blotter test, and incorporated in normal saline solution by maceration. A drop of this antigen is mixed with a drop of the sensitized latex suspension on a glass cavity slide, and the slide is incubated at room temperature in a moist chamber to avoid evaporation. After an hour a positive reaction can be seen by using a low-power stereoscopic microscope with reflected light and a black background. Also, by using extracts taken directly from seeds, a reaction is obtained after two hours (Phatak, unpublished).

Choice of method

For detecting fungi in laboratory tests, incubation is generally necessary. The blotter and agar tests allow identification to species level. The seedling-symptom test, on the other hand, places emphasis on detection of symptoms and seedling disease type, rather than on precise identification of the pathogen or pathogens involved — of which several may be present on one seed. The serological procedures enable precise identification of bacterial and virus pathogens, which are not so easily determined by incubation tests.

Growing-on tests and observations made in plots sown for testing cultivar purity may be used for detection of pathogens which do not attack seedlings, particularly downy mildews and wilts. It is often necessary, however, to observe these and other diseases in closed quarantine houses with special plant-growing units, where the escape of dangerous pathogens is prevented.

Identification of seed-borne pathogens

In the blotter method, which is the most frequently used routine procedure in laboratories, the identification of fungi is based on their structure as observed under stereoscopic binocular microscope at magnification of ten to sixty times. Growth characters such as the form, length, and arrangement of conidiophores, the arrangement of conidia on the conidiophores, the form, size, septation, and colour of the conidia, the appearance of spore masses, and the characters of the mycelium are all specific features that often make identification of species possible without the need for checking identification under the compound microscope.

The macroscopic growth characters of fungi which are used in the agar plate procedure are specific for many species; the fungi can therefore be quickly and readily identified by this procedure. However, other groups of fungi — for example, some dematiaceous hyphomycetes, including species of *Alternaria*, *Curvularia*, and *Drechslera* — may be extremely difficult to distinguish, and hence the procedure may be quite cumbersome for certain seeds in which these are predominant. Before this method is adopted for a certain category of seed, it is advisable to test several samples using both procedures.

Testing procedures and descriptions of individual pathogens, including symptoms are published in loose-leaf form as Series 3 of the ISTA *Handbook on seed health testing* (Noble, ed., 1965). Malone and Muskett (1964) have described 77 seed-borne species of fungi, mainly saprophytes. Recently, descriptions of the habit characters of some genera of fungi as they appear on seed have been published from the Danish Institute of Seed Pathology for Developing Countries, including *Curvularia* (Benoit and Mathur, 1970), *Fusarium* (Ram *et al.*, 1970), and

Drechslera (Chidambaram *et al.*) The Commonwealth Mycological Institute's series of descriptions of fungi and other organisms (1964) indicates which are seed-borne. Standard reference books for identifying fungi are indispensable. Special mention should be made of *Illustrated genera of imperfect fungi* (Barnett and Hunter, 1972), and the books by Booth (1971) on *Fusarium* and Ellis (1971) on Dematiaceous hyphomycetes.

TREATMENT OF SEED AGAINST SEED-BORNE DISEASES

Seeds are extensively treated with fungicides to control seed-borne fungi. It can be assumed that in most European countries more than 80 percent of cereal seeds are so treated, and according to Ordish and Mitchell (1967) about 80 percent of the world cotton area is sown with treated seed. About 25 percent of these fungicides are based on copper and 75 percent on organomercurial preparations. For cereals the usual dosage of organomercurials is 200 g per 100 kg of grain, but in Denmark a dosage of only 100 g per 100 kg has been used as a satisfactory standard for many years.

Seed testing for need of fungicide treatment

In Sweden for example, the use of organomercurials is restricted. There spring cereals are assessed for need of treatment by using the seedling-symptom method, with examination of the growth characters of the mycelium when necessary; seed lots are classified by visual inspection according to the severity of symptoms, and only those for which a licence is granted may lawfully be treated.

Disinfected seed lots may be tested by various methods for efficiency of the treatment. The seed may be evaluated for distribution of the dye (included in most treatments) by visual inspection, or small quantities of the fungicide can be ascertained by chemical methods (e.g., mercury by colour reaction with dithizon). The efficiency of the fungicide can often be assessed by noting its effect on ubiquitous saprophytes such as *Epicoccum purpurascens* and *Alternaria tenuis* in seeds from localities where these are common on untreated seeds, as they are in Scandinavia, New York State (U.S.A.), and many other areas. If these fungi are active, the seeds have not been adequately treated against pathogenic fungi.

EQUIPMENT FOR SEED HEALTH TESTING

The following items are the most important:

1. A good hand lens is indispensable, and a very helpful aid is the type of magnifier used by watchmakers.
2. Stereoscopic binocular microscopes are most commonly used. They should magnify up to sixty times, with a stepwise increase, rather than the zoom system. Experience has shown the advantage of knowing the precise magnification. The microscope should be fitted with two lamps, providing cool light from two sides so as to avoid shadows on the seeds.

3. Good binocular compound microscopes for higher magnification are needed for detailed studies of microorganisms They should have a fitting for a camera, and a drawing apparatus should also be available.
4. Incubation chambers can be either compact standard units, which are purchasable from several firms, or preferably walk-in chambers with thermostatic controls for cooling and heating. Standardized incubation temperatures are needed — usually 20°C, but 25–28°C for many tropical crops.
5. Light is needed to stimulate sporulation. The incubation chambers should be fitted with near-ultraviolet light tubes (Philips Black Light Lamps: TL 40W/08). The international standard is two horizontally hanging tubes placed 20 cm apart at a distance of 40 cm above the petri dishes. If black light lamps are not available, cool white fluorescent daylight tubes (e.g., Philips TLF 40W/34 De Luxe) have proved quite efficient. Light periods can be controlled by an automatic time switch. A 12-hour light exposure each day is the present international standard, but this may well be modified as research proceeds (Leach, 1967).
6. Containers of most kinds can be used for incubating seeds, but petri dishes are in general use. If the incubation room is fitted with near-ultraviolet lamps, plastic or pyrex petri dishes and containers should be used, as only they allow near-ultraviolet light to pass.
7. A glasshouse or controlled-environment growth room may be required to test for the presence of certain organisms that are not detected on seedlings. Various pathogens on imported seed material, including obligate parasites and viruses, may be detected under these conditions.
8. Clean blotters (absorbent paper or paper towelling), preferably produced and packed under sterile conditions, are needed, as well as potato-dextrose agar media and malt for the agar plate method.
9. A centrifuge operating at about 3 000 rev/min and a mechanical shaker should be available for the washing test, as well as an autoclave for preparing sterile media.
10. Small sundry items include glass slides, cover slips, beakers, flasks, petri dishes, culture tubes, forceps, and pencils for marking on glass and wet paper.

List of seed-borne diseases

An annotated list of seed-borne diseases, referring to about 400 different host plants, has been published by Noble and Richardson (1968). Economically important diseases are singled out in this publication, which also shows their distribution and control where known. The appendix of the EPPO/ISTA [European and Mediterranean Plant Protection Organization/International Seed Testing Association] report of 1966 also includes a list of seed-borne diseases which are important in quarantine and indicates appropriate test methods.

8. SEED CERTIFICATION

by O. Svensson (Coordinator), H. Al-Jibouri, and E.J. Fuentes

New crop varieties, superior in some quantitive and qualitative characteristics to existing ones, are continuously being developed through plant breeding. Seed of these should be made available in appreciable quantity to farmers in areas for which they are most suitable. Those who purchase seed should be sure they are obtaining good seed of specific varieties, properly identified for easy recognition. To provide a reasonable guarantee of the genetic quality of seed prior to sowing, seed quality control systems have been developed with the aim of thorough supervision of the entire production of the seed. This involves keeping records of the multiplication of varieties and inspecting the seed-production fields and the seed when it is ready for market. Regulations are needed for checking the production, harvesting, and cleaning of each lot of seed.

Seed certification is a legally sanctioned system for quality control of seed multiplication and production (FAO, 1969; Delouche and Potts, 1971) which consists of the following control measures: (*a*) field and bin inspection; (*b*) pre- and post-control tests; (*c*) seed quality tests.

The purpose of seed certification is to maintain and make available to the public high-quality seeds and propagating materials of superior crop plant varieties, so grown and distributed as to ensure genetic identity and genetic purity (International Crop Improvement Association, 1968). In addition to varietal purity and identity, other factors such as weeds, diseases, viability, mechanical purity, and grading are also important. Seed certification is therefore designed to maintain not only the genetic purity of superior crop varieties, but also reasonable standards of seed quality.

In several countries with well-functioning quality control schemes, seed certification has accomplished three primary objectives (Douglas, 1971):

1. The systematic increase of superior varieties.
2. The identification of new varieties and their rapid increase under appropriate and generally accepted names.

3. The provision of a continuing supply of comparable material by careful maintenance.

Delouche and Potts (1971) point out that seed certification has caused much confusion and many disappointments in developing countries. Therefore they reiterate the following points:

1. Seed certification is *not* the seed programme. It is only one supporting element.
2. Seed certification is *not* seed multiplication and production. It is a system for accomplishing these tasks.
3. Seed certification is *not* seed control legislation and seed marketing regulation, although it is legally sanctioned.
4. Seed certification is *not* government production of seed. Certification is concerned not with who produces seed so much as *how* it is produced.
5. Seed certification is *not* seed labelling, although certified seed *should* carry a distinguishing label.
6. Seed certification is *not* seed marketing and distribution.
7. Seed certification is *not* a panacea for all the ills that beset the development of a seed programme, although it can be most helpful in eliminating or preventing some of them.

Organization

Published regulations and procedures are necessary for seed certification so as to ensure that the established minimum standards are maintained, regardless of who is producing the seed (Delouche and Potts, 1971).

In most countries seed certification has developed gradually from modest beginnings, often without knowledge of what was being done in other countries; hence, the great differences between national certification schemes. These differences are also due to the fact that during development the schemes had to be adapted to local conditions, such as the general agricultural pattern and the existing system of organization and administration.

For climatic or other reasons a national seed supply may have to be met through the importation of seed. Also, a time may come when an efficient domestic seed industry has to find export markets for its surplus production. Thus there is an international aspect of certification which should be foreseen when developing a national certification scheme. Exporting and importing seed will be considerably facilitated if provisions are made for reciprocal recognition of classes of certified seed and applied control measures. To promote uniformity in certification and facilitate international trade in seed for the benefit of agricultural production, various certification schemes have been developed, such as those of the Organisation for Economic Co-operation and Development (OECD).

Certification agency

A competent authority or agency should be made responsible for the implementation of the seed certification programme. The organization and nature of this institution may vary from country to country, depending upon how plant breeding and seed multiplication are organized. A seed certification agency can be formed as an independent authority with representation from the ministry of agriculture and the colleges of agriculture, or it can be established as a separate agency within the ministry of agriculture.

In most European countries, seed certification is a function of federal or state governments. In the United States, it is a legal function of state governments through state agencies, while the Federal Seeds Act provides for minimum genetic standards on a national basis. In Australia, seed certification is a voluntary service conducted by the state departments of agriculture and coordinated nationally by a committee of state department officials (Cowan, 1972).

In the establishment of a seed certification agency, the following points relating to efficient operation should be considered:

1. Maintenance of an adequate staff trained for seed certification.
2. Provision of adequate facilities for ensuring timely and thorough inspection.
3. Clearly defined relationships with other related institutions (e.g., research, seed production, processing, storage, extension).
4. Application of uniform seed certification standards.
5. Servicing the interest of seed producers and seed buyers.

The activities of a seed certification agency may include (*a*) establishment of minimum certification standards, (*b*) registration of varieties for seed certification, (*c*) registration of seed growers, (*d*) registration of processing plants for certified seed, (*e*) registration of seed fields, (*f*) field and bin inspection, (*g*) seed sampling, and (*h*) international agreements for seed certification.

Manpower requirements

To ensure that certification operations are in the public interest, they should be under the guidance of a group of persons (board of directors) elected or appointed from various related institutions (e.g., research, seed production, extension). This group might be assigned to specific committees.

The basic technical staff of a seed certification programme may include:

1. A director, who is responsible for its overall functioning and should also be chairman of the various committees (variety registration, certification standards, etc.).
2. A supervisor for each group of related species under certification (cereal seeds, herbage seeds, vegetable seeds, etc.), who should be in charge of supervising the field inspectors' work and ensuring that regulations are observed and minimum standards are met. He should also train seed inspectors and other personnel in seed inspection techniques.
3. Seed certification inspectors.

Seed certification inspectors constitute the technical base of the seed certification system. Inspectors can operate in two ways: they may accept or reject fields "on the spot" and inform the central office; or they may only report the facts to the central office, leaving the decision to a supervisor. The way in which the inspectors operate is fundamental to the seed certification programme.

Many seed programme executives think that inspectors should have full authority to make any decision about the seed field, particularly if the central office is too far away, communications are too difficult, or decisions are urgent. Furthermore, they hold that inspectors' decisions should not be subject to appeal by the grower, thus avoiding the possibility that the inspectors' authority might be diminished if decisions are revoked by a superior authority.

On the other hand, some programme executives point out that field inspection work in seed certification has a public relations aspect and provides an opportunity for educating the seed grower, in addition to systematic control, since the inspector is the principal contact between grower and certification agency. For these reasons they believe that inspectors should never be in conflict with growers and should therefore only report the facts, leaving decisions to the central office.

Douglas (1971) summarizes the duties and responsibilities of seed certification officers as follows:

1. To arrange for suitable application, inspection, and report forms.
2. To identify sources of authentic breeder's seed that can be used as the basis for further multiplication.
3. To ensure that all basic and certified seed production has originated from acceptable sources of breeder's seed.

4. To ensure through field inspection that the prescribed minimum standards for isolation, planting ratio, roguing, and other requirements as specified in the seed certification standards are met.
5. To assist seed growers and producers in obtaining suitable planting seed and in planting their seed properly. This is especially true in the case of hybrid seed production.
6. To assist the seed producer at the time of harvesting, drying, and processing, to ensure that these are done correctly. This is particularly true for new producers who are just gaining experience; it should not be necessary to supervise every step of the operation after the seedsmen have had adequate experience in the programme.
7. To sample and inspect seed lots and submit such samples to the seed-testing laboratory, in order to ensure that the prescribed seed standards are met.
8. To issue appropriate seed certification tags for seed lots which pass inspection. Ultimately, more responsibility of this kind should be borne by the seedsman himself.
9. To carry out educational programmes designed to promote the use of certified seed and encourage seedsmen to develop their own promotional programmes.
10. To maintain adequate records, so that the eligibility of specific lots can be determined in subsequent years.
11. To operate in such a way as to ensure a close working relationship between certified-seed growers, dealers, research personnel, government officials, and others with an interest in certified seed.
12. To investigate vigorously any violation of prescribed standards or complaints from users of certified seed, and subsequently to take appropriate corrective action.

Organizing seed certification programmes

Organizing a seed certification programme requires careful planning and selective development components. Government, research, and other institutions concerned with seed development should cooperate in order to ensure that an appropriate programme is planned and developed. The main elements which contribute to a sound seed certification programme are discussed in the following paragraphs.

Crop varieties eligible for seed certification

The smallest necessary number of species and varieties should be accepted at the beginning of a seed certification programme, so as not to overload the system and to minimize the risk of failure, which could affect the prestige of the system. Only those varieties which are officially released and accepted in the register of varieties for seed certification should be certified.

Designation of classes of seed

A certification scheme should provide for different classes of certified seed. The more a variety is multiplied, the greater the possibilities of contamination, crossing, and variability. Therefore the number of classes and generations must be limited.

In several countries, four classes of seed are recognized. In the United States, for example, the Association of Official Seed Certifying Agencies (1971) distinguishes between (*a*) breeder's seed, (*b*) foundation seed, (*c*) registered seed, and (*d*) certified seed. (For definitions, see page 190.)

The OECD certification schemes (1970) recognize two categories: (*a*) basic seed and (*b*) certified seed of the first and successive generations. In the OECD schemes the number of generations from parental material before basic seed must be strictly limited. Discussions are now taking place in OECD to decide whether or not "pre-basic" seed should be defined; if this is done, a special label may have to be provided. Technical conditions, such as self-pollinating or cross-pollinating crops, have to be considered jointly by the breeder and the certification authority when deciding whether more than one generation of certified seed after basic seed should be permitted, and if so, the maximum number that should be accepted.

Cowan (1972) reports that in the United States, with the introduction of the generations system (by 1968), a very satisfactory commercial build-up is often achieved without using three generations beyond the breeders' seed. The purpose of deleting one of the classes is to provide seeds for commercial use which are fewer generations removed from breeders' seed, thus assuring greater genetic stability, particularly in varieties of cross-pollinated species. The limited-generations system for self-pollinated crops has been adopted primarily to overcome contamination due to admixtures.

Minimum certification standards

Certification programmes usually set minimum standards for each class, with which the individual seed lot must comply before it can be approved. These are usually established by the responsible agency and published officially. They vary from country to country, as well as for different crops (Feistritzer, 1966; Association of Official Seed Certifying Agencies, 1971), and should be designed to maintain a proper seed supply. They may be subject to amendment under exceptional circumstances. The standards normally include the following (FAO, 1969):

Activity	*Standard*
Field inspection	Varietal purity, isolation, seed-borne diseases, weeds
Pre- and post-control tests	Varietal purity, seed-borne diseases
Seed quality tests in the laboratory	Varietal purity (insofar as possible), analytical purity (particularly taking into account weed and other crop seeds), seed health, germination, and moisture content

As a general principle, though standards for basic and certified seed must necessarily be strict, it must be emphasized that at any given time they should be set at a level that most producers of quality seed can attain. This means that a country just starting or about to start seed certification may initially have to set somewhat low standards, and these can be raised from time to time as seed producers gain experience and acquire better equipment. Thus certification standards may vary, depending upon the species (self- or cross-pollinating), the method of multiplication, and the level desired. For guidance, the genetic seed standards published by the Association of Official Seed Certifying Agencies — which may have to be modified to fit local conditions — are given in the appendix to this chapter (see pages 186-202).

International agreements

The national seed certification programme should not be developed in isolation from other countries or international institutions. In Latin America, for example, the Pan-American Seed Seminars (periodic meetings of specialists) discuss technical problems and make technical recommendations to the governments of the region for better development of their seed programmes.

For international trade in certified seed, reciprocal agreements are necessary. These are more easily reached when governments follow international schemes, such as those of OECD, for seed certification. Although these are not difficult, a certain amount of experience in seed certification on a national level is necessary before a country is able to participate fully in the schemes.

At present, three schemes for varietal certification are established and operative among member countries of OECD* and the United Nations; these schemes pertain to cereal seed, herbage seed, and sugar beet and fodder beet seed moving in international trade. The provisions and regulations of the schemes are basically uniform, as established by the OECD Council Decisions of 11 February 1970 (OECD, 1970).

The schemes are open to all members of OECD, as well as to member countries of the United Nations and its specialized agencies. If a country participates in any of the schemes, it is obliged to ensure that the rules are strictly observed, for which purpose a national authority responsible under the national government has to be designated.

The schemes authorize the use of labels and certificates for seed produced and processed for international trade in accordance with certain agreed principles.

Briefly, the schemes provide for the following:

1. Acceptance of cultivars (varieties). Only those cultivars which are officially tested (including comparative field tests) and recognized as being distinct, uniform, and stable and as having an acceptable value in at least one country are included in the official list of cultivars eligible for certification. An accurate cultivar description must be available; the name and address of the breeder of each cultivar must be listed.
2. Designation of categories of seed. The scheme recognizes (*a*) basic seed produced under the responsibility of the breeder, with a strictly limited number of generations from parental material to the basic seed; and (*b*) certified seed of first and further generations — the number depending upon crop and cultivar — directly descended from either basic or certified seed.
3. Control of the production of basic and certified seed. The following requirements are taken into consideration:
   - Previous cropping
   - Isolation
   - Seed-borne diseases
   - Weeds
   - Field inspection
   - Pre- and post-control
   - Minimum standards for varietal purity
   - Sampling and sealing
   - Official laboratory seed tests for analytical purity and germination

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* OECD Secretariat: Section for Agricultural Seeds and Machinery, Directorate of Agriculture and Food, Château de la Muette, 2 Rue André-Pascal, Paris 16^{e}.

4. Certificates and labelling.
5. Relabelling and resealing in another country.
6. Coordination between the national designated authorities.

In addition to the rules and directions as they appear in OECD Council Decision C(70)5 (final) for Cereal Seed (OECD, 1970) — and similarly for the other schemes — the Organisation has also published a guide to methods used in plot tests and to methods of field inspection of cereal seed crops (OECD, 1969). This guidance for the national designated authorities is intended to improve the methods used and ensure their uniform application in countries participating in the scheme.

Methods

In many countries the national plan indicates the total seed requirements and the percentage that should be certified. These plans show the total quantity of seed of each species required for sowing the planned number of hectares and the estimated use of each variety. Normally not more than a certain percentage of the total need for each species should be certified seed. This percentage should permit enough seed of improved varieties with acceptable varietal purity to be used by all interested farmers. To determine the percentage of certified seed for each variety, the calculations should assume that yields from certified seed are lower than yields from crop production fields, since certified seeds have to be cleaned and the requirements are stricter.

Seed inspection

Seed crops are controlled by various inspections, which may be confined to the standing seed crop or may also extend to drying, cleaning, and storage facilities and procedures.

Often varieties of the same species cannot be distinguished from one another in laboratory examination of the seeds. Examination of the growing plants in pre- and post-control field plots and field inspection may be the only means of checking on the maintenance of varietal purity during multiplication.

In general, the objectives of field inspection are to check the following:

(*a*) seed origin and identity of variety
(*b*) cropping history of the seed field
(*c*) crop and cultivation condition
(*d*) isolation
(*e*) freedom from impurities (other crop and weed plants)

(*f*) freedom from other cultivars and off-types
(*g*) freedom from seed-borne diseases

Examples of standards are given in the appendix on pages 186–190.

All field inspections must be made by well-trained and qualified personnel. The procedures and techniques to be used should be clearly established by the authorized agency. This will help to avoid decisions based on personal opinion and ensure the use of uniform criteria among field inspectors working in different zones.

The inspector has to know the prerequisites and standards for seed growing and has to be familiar with the character of the varieties to be inspected. By his thorough knowledge, good conduct, and manners, he will gain the seed growers' confidence and cooperation, which is the foundation for smooth operation of a certification scheme. In every respect the inspector has to achieve full cooperation from the seed growers, even in the case of rejection of a field. The seed grower or his representative should thus be present at the time of field inspection and, if possible, acknowledge suggested correction and advice by a signature on the inspection report.

It is sometimes maintained that field inspection should be made without prior notice so that less careful seed growers cannot make preparations for the visit. This has the disadvantage, however, of making it difficult to obtain and exchange necessary information. Moreover, a poor field cannot be improved on a few days' notice, whereas minor deficiencies may be corrected before rather than after the inspection, thereby avoiding the need for reinspection. Advance notice of inspection thus has its advantages.

Upon arrival at the seed farm the inspector checks all information about species, variety, seed origin, cultivated area, class of certification, name and address of seed grower and contractor (where applicable), cropping history of the field to be inspected, and known adjacent fields of the same species, which may be dangerous from an isolation point of view.

Each field and its boundaries are pointed out by the seed grower. All parts and rows should be covered and crossed by the inspector on foot. Sensitive areas are the vicinity of farm buildings, threshing places, and roads into or through the field, where seeds of various species and origin may have been dropped in waste or in transport. Figure 47 shows a highly schematic pattern for moving through a field and looking over the maximum area. The inspector should also move out of the field, when necessary, to check isolation.

During the walk in the field the inspector must make estimates of other varieties and impurities, diseased plants, general condition of the crop,

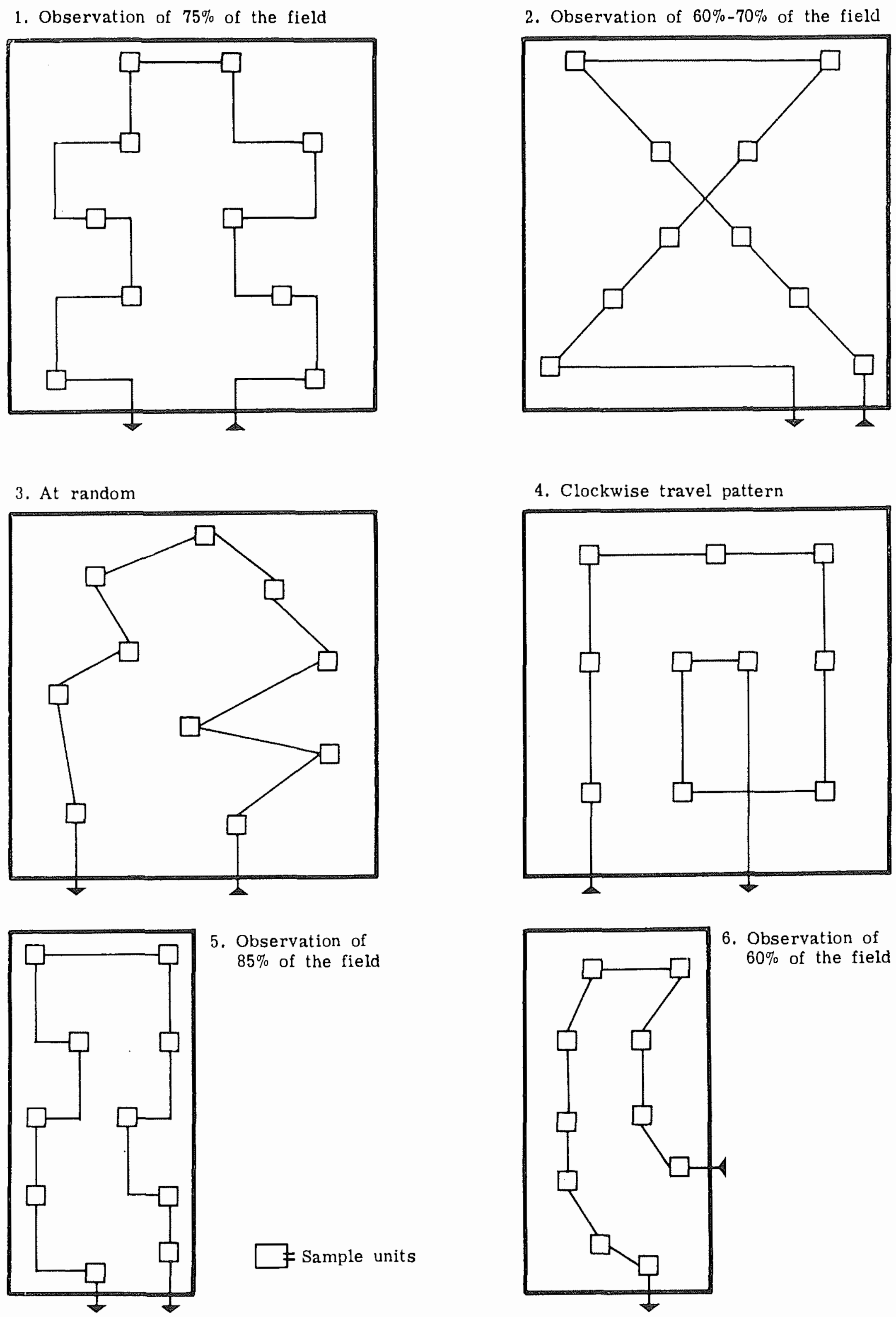

FIGURE 47. Suggested travel patterns for field inspection.

applied farm practices, and possible yield. Estimates of impurities (other crop plants, weed plants, other varieties and off-type plants) and diseased plants are made through counts. Five counts should be made for the first 2 ha, and one count for each additional 2 ha or part thereof; thus seven counts are made in a 4½-ha field. It is suggested that estimates be calculated as percentages of 100 plants per count for maize and of 2 000 plants per count for rice and wheat.

The procedure for maize may be as follows:

1. Inspect 10 plants in one row of seed parent or pollinator.
2. Shift over to another row of seed parent or pollinator, as the case may be, and inspect 10 plants in that row.
3. Repeat the process until 100 plants in ten different rows have been inspected.

The procedure for rice and wheat may be as follows:

1. Determine the average number of heads or plants in one step in five different locations.
2. Calculate the number of steps required to inspect 2 000 heads or plants. If one step contains 50 heads on the average, then forty steps will be needed to cover 2 000 heads in one row.
3. Take the required number of steps to inspect 2 000 heads or plants.

Moving across the rows, one can determine the average number of plants or heads in one metre of a row and the number of rows in one step, and thus calculate how many steps will be needed to inspect 2 000 plants or heads.

The counts should be taken at random when moving over the field. Rice (paddy) fields may be inspected by walking into the field from bunds that cross the area, and the counts can be taken at predetermined distances (steps) into the field from the corners and from the edges.

When taking the counts, it is suggested that extraneous plants or relevant parts of such plants (heads, tassels, etc.) be pulled out and kept until one count is finished. They are then counted and recorded before the next count starts, and the procedure is repeated.

Inspecting hybrid maize fields is different from inspecting rice and wheat fields, as hybrid maize seed is produced in detasselled female rows pollinated from tassels in the male rows. The planting ratio is often two male rows to six female rows, and the grower has to mark the ends of the male rows with a label on the first plant or with a peg placed between the rows.

When inspecting maize fields, very special attention should be paid to the following steps:

(*a*) checking isolation;
(*b*) spotting off-types and volunteer plants, and ensuring that both male and female rows are true to type;
(*c*) checking the percentage of shedders or shedding tassels.

An inspector must satisfy himself that the seed field meets the minimum isolation requirements laid down in the field standards. If the field does not meet these standards at the first inspection, a second inspection may be made later. He should record the details to be checked during the subsequent inspection, including the distance to the contaminant and the type and stage of growth of the contaminant. The inspector should suggest to the seed grower the following corrections for lack of isolation, poor detasselling, and roguing:

(*a*) destroying the contaminant before pollen is shed or silks become receptive;
(*b*) removing off-type and volunteer plants before they cause contamination;
(*c*) destroying the contaminated portion of the seed field and not harvesting it for seed.

Volunteer and off-type plants both within and outside the field must be spotted. All plants that are out of place, such as those in between the rows and male plants in female rows or vice versa, should be removed before they shed pollen. It must be remembered that off-types do much more harm in male rows, where their pollen is spread to a large number of silks, than they do in female rows, where they will be detasselled. Counts should be taken, and the number of pollen shedders, shedding tassels, receptive silks, rogues or off-types, and diseased plants should be recorded.

Locating the field

Normally, an application has been submitted before the planting season to the certifying agency for inspection of fields to be sown with a seed crop for certification. The application should give detailed information regarding the location of the seed grower and his field, the species and variety to be planted, the origin of the seed and supplier (preferably verified by enclosing the certification tag or other documentation), the intended certification class and generation, the cropping history of the field, and the amount of seed and the area to be planted. It will be useful to call upon the local extension staff, so that they will know inspections are being made in their area. A district extension agent may be of help in locating the seed grower.

It is desirable to see the seed grower before going to his field. He may want to accompany the inspector to the field, and should be encouraged to do so from an educational and training point of view. In any event, he can definitely confirm which field has to be inspected.

Time of inspection

Rice and wheat fields are inspected from the time of flowering up to the mature stage (Fig. 48). If a reinspection is required after the seed grower has corrected deficiencies, an appointment should be made so as to ensure that the field is ready for final inspection.

Maize fields are inspected three or four times. The first inspection, prior to detasselling, is made 30–40 days after planting and before flowering. The objectives are to discover any isolation deficiencies, to point them out to the seed grower, and to suggest corrections. The second and subsequent inspections are made to check the quality of detasselling and to ensure that it is done regularly. These inspections are made as soon as the percentage of receptive silks is 5 percent or more. Tillers should also be

FIGURE 48. Rice seed crop ready for field inspection.

detasselled. The final inspection can be made when the field has less than 5 percent receptive silks or has been 99 percent detasselled.

Number of inspections

In general, as many inspections are made as are necessary to satisfy the inspector before approval or rejection of the field. Of course, if no corrections are possible — for example, when the field carried a "wrong" crop the previous season — there is no need for inspection or reinspection. On the other hand, to save a seed field, isolation deficiencies or moderate excess of impurities can be corrected by the grower through roguing, detasselling, cutting off contaminating fields, and other means. All such corrections should be checked by the inspector during reinspections and never be left to the seed grower at his own discretion. Reinspections have a high educational value that must be taken into account.

Rice and wheat fields which meet field standards on first inspection do not need further inspections. Maize fields, in which the crop is cross-pollinated and seeds are produced from selected male and female parents, should be inspected three or four times, as recommended for the reasons given above.

Reporting results

The results of field inspections must be reported to the certification agency and filed there until the harvested seed crop has been processed, sampled, and laboratory tested and is found to meet all quality requirements (seed standards) for certification. The certifying agency should then inform the seed grower or his representative of the inspection results.

The field inspection report should contain the following information:

Maize

1. Name of seed grower (and contractor, where applicable)
2. Complete address
3. Location of farm
4. Area
5. Date of planting
6. Date of inspection
7. Inspection report number, and indication of whether it is a pre-tasselling or final inspection
8. Expected date of harvest (at least in the final report)
9. Hybrid designation (check tags of planted seed)

10. Female and male parents
11. Planting rate (female/male rate)
12. Previous crop
13. Method of marking male rows (at one end or both ends)
14. Isolation, including details, distances, contaminant, stage of growth of the contaminant, border rows, contaminated and rejected portions of the field (draw a map overleaf of the report)
15. Field count of pollen shedders, shedding tassels, rogues, diseased plants, as well as counts in male rows
16. Crop condition and stand, and yield estimate
17. Remarks (suggestions to the producer, corrections to be made, etc.)
18. Signature of inspector
19. Also useful, the signature of the producer, acknowledging requests and suggestions

Rice and wheat

1. Name of seed grower (and contractor, where applicable)
2. Complete address
3. Location of farm
4. Area
5. Species and cultivar
6. Quantity of seeds planted (plant density in paddy)
7. Date of planting
8. Date of inspection
9. Inspection report number, and indication of whether it is a reinspection or final inspection
10. Expected date of harvest (in final report)
11. Previous crop
12. Isolation, with reference to lodging, flooding, shattering, roads — all of which may cause isolation and contamination problems
13. Field count of other cultivars and off-types
14. Field counts of other crop plants
15. Field counts of diseased plants
16. List of most frequent harmful plants which at harvest will be bearing seed that is inseparable from the crop seed
17. Crop condition and stand, and yield estimate
18. Remarks, such as suggestions to the producer, corrections to be made, necessary reinspection
19. Signature of the inspector
20. Also useful, the signature of the producer, acknowledging requests and suggestions

Post-harvest inspection

In a developing certification scheme it is a necessity to inspect the seed producers' or contractors' premises, particularly such features as the threshing place, seed storage, drying and processing equipment, bags, and arrangements for sampling. This inspection can also be of great educational value.

Inadequate facilities and poor management in post-harvest handling of seeds should disqualify the seed lot from certification, as would be the case with any mismanagement of the fields.

Seed sampling, labelling, sealing, and lot identification

A detailed description of sampling is provided in Chapter 2 of the International Rules for Seed Testing (ISTA, 1966). Excerpts from this publication should be made available to seed and field inspectors and included in field-inspection manuals.

Sampling of each seed lot to be certified is normally done by the seed certification inspector. The bags should be stored or piled in such a way that the inspector can reach any bag to get a representative sample of the lot. The inspector must be very well trained in seed sampling; his sampling ability will determine whether the sample truly represents the seed lot.

Before sampling for germination and purity tests, the inspector should check to make sure that the moisture of the seed lot is not notably higher than the maximum standards and that the lot is acceptably uniform. If these conditions are not met, the inspector should not take the sample.

To sample a seed lot, a certain quantity of seed is taken out of each selected bag with an appropriate trier, and these quantities are put together to make the composite sample. This composite sample is usually too big to be sent to the laboratory; therefore it has to be divided by the inspector in the warehouse in accordance with ISTA procedures. It might be advisable to include a portable seed divider (soil type) with the inspector's equipment.

To prevent a change in identity and composition of the lot after sampling and before certification, all parts must be sealed in such a manner that seals which have been interfered with are destroyed beyond reuse. The act of sealing is not a manifestation of suspicion toward the owner, but an assurance to the user of the seed.

The sample, properly identified and packed, should be transferred to the seed testing laboratory without delay. It must be sealed if mailed or handled by nonauthorized persons.

A sampling report giving the following information should be submitted with the sample.

1. Owner of the seed lot and address
2. Seed producer and location
3. Species and cultivar
4. Lot number or marking
5. Weight of lot
6. Number and kind of units
7. Seed origin
8. Certification class and number of certification tags requested
9. Date of sampling
10. Signature of inspector

SEED TESTING

Through field inspections and checks on seed origin the production of seed is controlled by the certification agency, thus ensuring that genetical purity is maintained at a high level. The value of seed for planting, however, is composed of several other factors, such as mechanical (analytical) purity, germinative capacity, and moisture content. These qualities must be tested before certification to maintain an overall high quality level for seed made available to farmers for further seed and crop production.

Seed quality standards list minimum requirements for analytical purity and germination, as well as maximum limits for content of other crop or weed seeds and moisture. Where genetic purity and seed health tests are included in the seed testing programme, the seed standards may contain requirements for these properties as well. Certification standards should be strictly adhered to. Decisions must be taken objectively, so that disputes can be uniformly settled.

The following seed standards (Central Seed Committee, 1971) for maize, rice, and wheat in India are quoted as examples:

Maize	*Inbred lines*	
	Single crosses	*Hybrids*
Pure seed (min.)	98%	98%
Inert matter (max.)	2%	2%
Other crop seeds, including other cultivars (max.)	0.2%	0.2%
Weed seeds (max.)	None	None
Germination (min.)	80%	90%
Moisture (max.)	12%	12%
For vapourproof containers (max.)	8%	8%

Rice and wheat	*Certification class*	
	Foundation	*Certified*
Pure seed (min.)	98%	98%
Inert matter (max.)	2%	2%
Other crop seeds (max.)	10/kg	0.1%
Total weed seeds (max.)	10/kg	0.1%
Objectionable weed seeds (max.)*	2/kg	5/kg
Germination (min.): wheat	85%	85%
rice	80%	80%
Moisture (max.)	12%	12%
For vapourproof containers (max.)	8%	8%

* In rice, wild or red rice (*Oryza sativa* var. *fatua*); in wheat, field bindweed (*Convolvulus arvensis*).

Occasionally there may be a need to lower the standards — for example, after a crop failure caused by adverse weather conditions during harvest or other disasters that threaten the national supply of seed. Seed programmes should aim high, however, and frequently varying standards should be avoided.

Samples are usually tested for analytical purity, germination, and moisture content. Other tests, though not included in the routine testing programme for certification, may be performed upon request. Such tests are rapid "viability" tests, weight of 1 000 seeds, entomological examinations, and seed health tests.

Seed testing laboratories should not be expected to state the genetic purity of seed lots. The genetic purity of many types of seed cannot be determined by looking at the seed, since there are no morphological characters present which differentiate one variety from another. In a seed certification scheme, genetic purity is safeguarded through knowledge of the origin and history of the seed lot from field inspections made to evaluate the varietal purity of the seed crop. In general, a seed testing laboratory can only interpret information about the seed lot in making a statement about genetic purity, although there are some special variety tests, which can be conducted in the laboratory, to supplement normal visual examination and field tests and inspections.

The procedures for laboratory tests are elaborated in Chapter 7 of this publication and in the International Rules for Seed Testing (ISTA, 1966).

A certification programme may include, in addition to field inspection, investigation of growing material, to determine the cultivar, the purity of the cultivar, and the occurrence of certain seed-borne diseases. This is normally done by growing field plots (Fig. 49) and can be undertaken by seed testing laboratories in a slack season.

If results from field plot tests are presumed to be as decisive for certification as, for instance, germination test results, then the staff evaluating the field plots must be very well trained, experienced, and familiar with the characteristics of the varieties being tested.

Field tests may serve as pre-control, post-control, or both in a certification scheme.

Pre-control

A sample of a seed lot intended for production of certified seed is planted in two or three field plots (replications), arranged and designed for convenient examination of the rows and comparison with plots planted with authentic samples of the cultivar. Chapter 8.7 of the International Rules for Seed Testing (ISTA, 1966) and the OECD guide (1969) both indicate general techniques for this type of field plot.

The plots are examined continuously during the growing season, when the seed lot in question has been used to sow a crop growing simultaneously in the seed producers' fields. Results of the detailed examination and counts of other varieties, off-types, and diseased plants in the field plots are thus available, together with the results of field inspections, when the seed crop is harvested. Seed lots which have been multiplied but are shown to be inferior can thus be eliminated from further multiplication at an early stage and prior to further processing.

Post-control

A sample of a certified seed lot planted and examined in field plots during the next growing season serves to check the accuracy and efficiency of the work in the previous season, such as seed origin control and field inspections; however, the result of the post-control is not available until the seed lot from which the sample is drawn has been certified, distributed, and replanted.

For post-control purposes only it may not be necessary to grow samples from all certified lots. It may be sufficient to plant samples chosen at random — for example, every tenth, fifteenth, or twenty-fifth sample.

FIGURE 49. Field plots for pre- and post-control tests, with glasshouses and laboratory buildings in the background.

Pre- and post-control

A most rigid system for control and maintenance of varietal purity may be created by combining field plot tests with pre- and post-control. Samples from all certified lots are planted in field plots and examined for cultivar purity and seed-borne diseases. Post-control of the certified lots will thus serve as pre-control for the next generation of seed. With such a system it is possible to keep pedigree records of the parental and subsequent certified generations of any particular seed lot.

Lots which are not intended for further multiplication, as when the number of generations is restricted, are not subjected to post-control other than the random sampling indicated in the last paragraph under the discussion of post-control above.

Figure 50 illustrates the reciprocal relation between pre- and post-control and how they fit into a certification scheme.

ISSUING OF CERTIFICATE, LABELLING, AND SEALING

Upon completion of all control measures required for certification, the result — certification approved or denied — should be formally

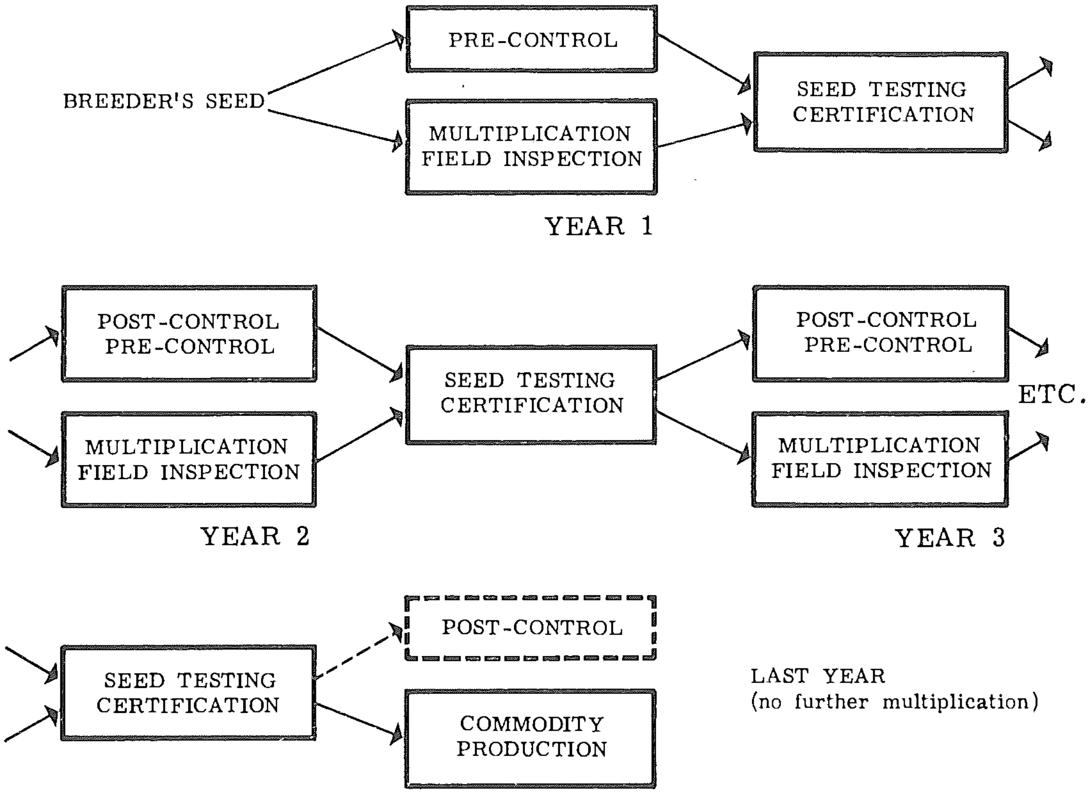

FIGURE 50. Relation of pre- and post-harvest control in a certification scheme.

stated in a certificate submitted to the parties concerned. A copy of this certificate should be used by the certification agency for future reference and documentation of eligibility for further multiplication as certified seed.

The certificate should provide the following information:

1. Name and address of producer and/or applicant
2. Species, type, cultivar
3. Lot identification and test number
4. Weight of lot, number of bags or containers
5. Seed origin
6. Approved certification class
7. Date of certificate

In addition the certificate may give results of field inspections and plot tests, laboratory seed tests, and other tests. This is usually the case when the administration of field and laboratory activities for certification is centralized and handled by one and the same office.

Seed lots approved for certification will usually be distributed to many buyers. Each bag, package, or container must therefore be labelled, to prove that it is part of a certified lot. Tagging or labelling the bags is the concrete act of certification and provides the tangible document of certification to each buyer.

Only as many tags are printed as are needed for the distribution units. The tags are handed over by an inspector and under his supervision are affixed by lead sealing, adhesive tape, or other means to each bag or container of the certified lot.

Commercial or advertising slogans are not relevant to seed quality and should not be allowed on certification tags, which are entirely official documents, serving the public interest. Information and statements on the certification tags may be of an official and technical nature:

Official

1. Name and address of certifying agency
2. Species, type, variety
3. Certification, class, generation
4. Lot identification and test number
5. Date of expiry

Technical

Certification tags may also provide information on the seed quality as evaluated in laboratory tests. Usually purity, germination, and moisture-content percentages are printed on the tags. In addition the number of other crop and weed seeds per unit of weight may be reported.

Though such technical information is not necessary from the point of view of certification, farmers often demand it; it also increases confidence in certificates and has an educational value.

GENETIC SEED CERTIFICATION STANDARDS FOR THE ASSOCIATION OF OFFICIAL SEED CERTIFYING AGENCIES

I. GENERAL

The following standards are the minimum standards required for the certification of seed for genetic purity and identity by member agencies of the Association of Official Seed Certifying Agencies hereinafter to be referred to as AOSCA. This seed certification programme shall cover planting stocks of varieties * (hereinafter to be considered synonymous with cultivar) produced, processed, sampled, and labelled in accordance with the seed certification standards of the AOSCA.

II. ELIGIBILITY REQUIREMENTS FOR VARIETIES

A variety shall be eligible for certification by member agencies of AOSCA only if it has been approved as meriting certification by at least one member agency or by an appropriate national variety review board. The secretary of AOSCA will maintain a current listing of all varieties eligible for certification. Member agencies must advise the secretary when a variety is declared eligible for certification.

The following must be made available by the originator, developer, owner, or agent when eligibility for certification is requested:

A. The name of the variety. This name must be the established name if the variety has previously been marketed.

B. A statement concerning the variety's origin and the breeding procedure used in its development.

C. A detailed description of the morphological, physiological, and other characteristics of the plants and seed that distinguish it from other varieties.

* In some cases certification will be as to kind, on an interim basis: for example, where varieties have not been developed.

D. Evidence of performance of the variety, such as comparative yield data, insect and disease resistance, or other factors supporting the identity of the variety.

E. A statement delineating the geographic area or areas of adaptation of the variety.

F. A statement on the plans and procedures for the maintenance of stock seed classes including the number of generations through which the variety may be multiplied.

G. A description of the manner in which the variety is constituted when a particular cycle of reproduction or multiplication is specified.

H. Any additional restrictions on the variety, specified by the breeder, with respect to geographic area of seed production, age of stand or other factors affecting genetic purity.

I. A sample of seed representative of the variety as marketed. The sample size shall be that required for a submitted sample in the current issue of the Rules of Testing Seeds for the Association of Official Seed Analysts.

III. Designation of classes of seed

Classes of seed are defined in Appendix I [see page 190] and are recognized as follows in the United States and Canada:

United States:	(*a*)	Breeder
	(*b*)	Foundation
	(*c*)	Registered
	(*d*)	Certified

Canada:	(*a*)	Breeder
	(*b*)	Select
	(*c*)	Foundation
	(*d*)	Registered
	(*e*)	Certified

IV. Limitations of generations

The number of generations through which a variety may be multiplied shall be limited to that specified by the originating breeder or owner of the variety and shall not exceed two generations beyond the Foundation seed class with the following exceptions:

A. Recertification of the Certified class may be permitted for older varieties where Foundation seed is not being maintained.

B. The production of an additional generation of the Certified class only may be permitted on a one-year basis, when an emergency is declared prior to the planting season by the certifying agency stating that the Foundation and Registered seed supplies are not adequate to plant the needed Certified acreage of the variety. The permission of the originating or sponsoring plant breeder, institution, firm or owner of the variety, if existent, must be obtained. The additional generation of Certified seed to meet the emergency need is ineligible for recertification.

V. Establishing the source of seed

The certifying agency shall be supplied with satisfactory evidence of the class and source of seed used to plant each crop being considered for certification.

VI. Production of seed

A. Genetic Purity and Identity
Each certifying agency must make every effort to determine that genetic purity and identity are maintained at all stages of certification includingseeding, harvesting, processing, and labelling of the seed.

B. Unit of Certification
The unit of certification shall be a clearly defined area which may be divided subject to special regulations for specific crops.

C. Field Inspection
One or more field inspections shall be made each time a seed crop of any Certified class is to be harvested and when genetic purity and identity or any other factor affecting seed certification can best be determined. The field shall be in such condition to permit an adequate inspection to determine genetic purity and identity.

D. Inspection of seed
Harvested lots of seed from inspected fields may be inspected at any time by representatives of the certifying agency. A certification sample shall be drawn in a manner approved by the certifying agency from each cleaned lot eligible for certification. Evidence that any lot of seed has not been protected from contamination which affects genetic purity, or is not properly identified, shall be cause for rejection of certification.

VII. Processing of seed

A. Processors requiring certification services shall apply to the certifying agency having jurisdiction where the services are to be performed. In approving the processor to process seed of Certified classes, each certifying agency shall stipulate that the following requirements be met:

1. Facilities shall be available to perform processing without introducing admixtures.
2. Identity of the seed must be maintained at all times.
3. Records of all operations relating to certification shall be complete and adequate to account for all incoming seed and final disposition of seed.
4. Processors shall permit inspection by the certifying agency of all records pertaining to Certified seed.
5. Processors approved to process seed for certification shall designate an individual who shall be responsible to the certifying agency for performing such duties as may be required.
6. Approval of processors shall be on an annual basis.

B. Seed lots of the same variety and seed class may be blended and the seed class retained. If lots of different classes are blended, the lowest class shall be applied to the resultant blend. Such blending can only be done as authorized by the certifying agency.

VIII. Labelling

A. Seed of all Certified classes when offered for sale shall have an official certification label properly affixed to each container clearly identifying the certifying agency, the reference number, the variety name, and the kind and class of seed. In the case of seed sold in bulk, the invoice or accompanying document shall identify the certifying agency, the crop kind, variety, class of seed, and the identifying number.

1. All official seed certification labels must meet color and other specifications approved by AOSCA. Copies of approved official certification label specifications, colours, and label format shall be maintained by the office of the secretary of AOSCA.
2. Each agency shall file with the secretary of AOSCA a sample of each official certification label used by that agency.
3. The official certification label may be printed directly on the container when control of such containers is maintained by the certifying agency.

B. Labelling requirements will vary with the crop and methods of handling; but in all instances labels shall be attached to containers in a manner that prevents removal and reattachment.

IX. Interagency certification

Interagency certification is the participation of two or more official certifying agencies in performing the services required to certify the same lot or lots of seed. The methods and standards employed in each step of the interagency certification process are those used when certification is completed by a single agency, with the following exceptions:

A. The agency issuing the labels shall require the seed to meet standards at least equal to the minimum standards of AOSCA for the seed in question.

B. Seed to be recognized for interagency certification must be received in containers carrying official certification labels or evidence of its eligibility from another official certifying agency together with the following information:

   1. Variety and kind
   2. Quantity of seed (pounds or bushels)
   3. Class of seed
   4. Inspection or lot number traceable to the previous certifying agency's records

C. In addition to compliance with the requirements specified in Section VIII, each label used in interagency certification shall be serially numbered or carry the certification identity number and clearly identify the certifying agencies involved, the variety, kind and class of seed. Although detailed arrangements may be made between two agencies for the interagency certification of a specific lot, it is not necessary to obtain prior approval from the other agency.
The agency last having jurisdiction of the seed must keep on file complete information indicating the quantity of seed finally certified, nature of service rendered (reclaiming, rebagging, or relabelling) and the certification and lot numbers of the seed involved.

I. Definition of terms used in the AOSCA certification programme

1. VARIETY

The term variety (cultivar) denotes an assemblage of cultivated individuals which are distinguished by any characters (morphological, physiological, cytological, chemical, or others) significant for the purposes of agriculture, forestry, or horticulture and which, when reproduced (sexually or asexually) or reconstituted, retain their distinguishing features.

2. CLASSES OF SEED RECOGNIZED IN SEED CERTIFICATION

a. Breeder

Breeder seed is seed directly controlled by the originating or sponsoring plant breeding institution, firm, or individual, and is the source for the production of seed of the certified classes.

b. Select

Select seed is unique to the Canadian certification system. It is the approved progeny of Breeder or Select seed produced in a manner to ensure its specific genetic identity and purity by those growers authorized by the certifying agency for the production of this class. Select seed is not a seed of commerce.

c. Foundation

Foundation seed shall be the progeny of Breeder, Select, or Foundation seed handled to maintain specific genetic purity and identity. Production must be acceptable to the certifying agency.

d. Registered

Registered seed shall be the progeny of Breeder, Select, or Foundation seed handled under procedures acceptable to the certifying agency to maintain satisfactory genetic purity and identity.

e. Certified

Certified seed shall be the progeny of Breeder, Select, Foundation, or Registered seed so handled as to maintain satisfactory genetic purity and identity, and which has been acceptable to the certifying agency (see section IV).

3. PLANT BREEDER

Person or organization actively engaged in the breeding and maintenance of varieties of plants.

4. OFF-TYPES

Plants or seeds which do not conform to the characteristics of a variety as described by the breeder.

5. INBRED LINE

An inbred line is a relatively true breeding strain resulting from at least five successive generations of controlled self-fertilization or of back-crossing to a recurrent parent with selection or its equivalent.

6. SINGLE CROSS

A single cross is the first generation hybrid between two specified inbred lines.

7. Foundation single cross

A Foundation single cross is a single cross used in the production of double, three-way, or top crosses.

8. Double cross

A double cross is the first generation hybrid between two single crosses.

9. Top cross

A top cross is the first generation hybrid of a cross between an inbred line and an open-pollinated variety or the first generation hybrid between a single cross and an open-pollinated variety.

10. Three-way cross

A three-way cross is a first generation hybrid between a single cross and an inbred line.

11. Open-pollination

Open-pollinated seed is seed produced as a result of natural pollination as opposed to hybrid seed produced as a result of controlled pollination.

II. Specific requirements for the certification of plant materials under the AOSCA system

A. Land, isolation, field, and seed standards

Crop	Foundation				Registered				Certified			
	* Land	** Isolation	*** Field	**** Seed	* Land	** Isolation	*** Field	**** Seed	* Land	** Isolation	*** Field	**** Seed
Alfalfa	4[1]	600[4,5]	1 000	0.1	3[1]	300[3,4,5]	400	0.25	1[1,2]	165[3,4]	100	1.0
Barley	1[7]	0[23]	3 000	0.05	1[7]	0[23]	2 000	0.1	1[7]	0[23]	1 000	0.2
Hybrid	1[30]	660[21,32]	3 000	0.05	1[30]	660[21,32]	2 000	0.1	1[30]	330[21,32]	1 000	0.2
Bird's-foot trefoil	5[1]	600[4,5]	1 000	0.1	3[1]	300[4,5]	400	0.25	2[1]	165[4,6]	100	1.0
Clover (all kinds)	5[1,9]	600[4,5,18]	1 000	0.1	3[1,9]	300[4,5,18]	400	0.25	2[1,9]	165[4,18]	100	1.0
Maize (corn)												
Inbred lines	0	660[10,11]	1 000[13]	0.1[15]	–	–	–	–	–	–	–	–
Foundation single cross	0	660[10,11]	1 000[13]	0.1[15]	–	–	–	–	–	–	–	–
Hybrid	–	–	–	–	–	–	–	–	0	660[11,12]	–	0.5
Open-pollinated	–	–	–	–	–	–	–	–	0	660[11,12]	200	0.5
Sweet	–	–	–	–	–	–	–	–	0	660[11,14]	–	0.5
Cotton	0	0[19]	0	0	0	0[19]	35 000	0.01	0	0[19]	7 000	0.1
Cowpeas	1[7]	10	1 000	0.1	1[7]	10	500	0.2	1[7]	10	200	0.5

See numbered footnotes on pages 198-200.

A. LAND, ISOLATION, FIELD, AND SEED STANDARDS (*continued*)

Crop	FOUNDATION				REGISTERED				CERTIFIED			
	* Land	** Isolation	*** Field	**** Seed	* Land	** Isolation	*** Field	**** Seed	* Land	** Isolation	*** Field	**** Seed
Crambe	1[8]	660	2 000	0.05	1[8]	660	1 000	0.1	1[8]	660	500	0.25
Crownvetch	5[1]	600[4, 5]	1 000	0.1	3[1]	300[4, 5]	400	0.25	2[1]	165[4, 6]	100	1.0
Field and garden beans	1[8]	0[23]	2 000	0.05	1[8]	0[23]	1 000	0.10	1[8]	0[23]	500	0.2
Field peas	1[7]	0[23]	1 000	0.1	1[7]	0[23]	500	0.2	1[7]	0[23]	200	0.5
Flax	1[7]	0[23]	5 000	0.05	1[7]	0[23]	2 000	0.1	1[7]	0[23]	1 000	0.2
Grasses, cross-pollinated	5	900[4,18,20]	1 000	0.1	1[8]	300[4,18,20]	100	1.0	1[8]	165[4,18,20]	50	2.0
Strains at least 80% apomictic and highly self-fertile species	5	60[4,18,20]	1 000	0.1	1[8]	30[4,18,20]	100	1.0	1[8]	15[4,18,20]	50	2.0[16]
Lespedeza	5[1]	10[4]	1 000	0.1	3[1]	10[4]	400	0.25	2[1]	10[4]	100	1.0

* Number of years that must elapse between destruction of a stand of a variety and establishment of a stand of a specific class of a variety of the same crop kind.
** Distance in feet from any contaminating sources.
*** Minimum number of plants or heads in which one plant or head of another variety or off-type is permitted.
**** Maximum percentage of seed of other varieties or off-types permitted.

See numbered footnotes on pages 198-200.

A. Land, isolation, field, and seed standards (*continued*)

Crop	Foundation				Registered				Certified			
	* Land	** Isolation	*** Field	**** Seed	* Land	** Isolation	*** Field	**** Seed	* Land	** Isolation	*** Field	**** Seed
Millet	1[8]	1 320	20 000[27]	0.005	1[8]	1 320	10 000[27]	0.01	1[8]	660	5 000[27]	0.02
Mung beans	1[7]	0[23]	1 000	0.1	1[7]	0[23]	500	0.2	1[7]	0[23]	200	0.5
Mustard	4	165	2 000	0.05	2	165[24]	1 000	0.1	2	165[24]	500	0.25
Oats	1[7]	0[23]	3 000	0.2	1[7]	0[23]	2 000	0.3	1[7]	0[23]	1 000	0.5
Okra	1[8]	1 320	0[27]	0	1[8]	1 320	2 500[27]	0.5	1[8]	825	1 250[27]	1.0
Onion	1[8]	5 280	200[22]	0	1[8]	2 640	200[22]	0.5[22]	1[8]	1 320	200[22]	1.0[22]
Peanuts	1[7]	0[23]	1 000	0.1	1[7]	0[23]	500	0.2	1[7]	0[23]	200	0.5
Pepper	1[8]	200[25]	0	0	1[8]	100[25]	300	0.5	1[8]	30[25]	150	1.0
Rapeseed	4	165	2 000	0.05	2	165[24]	1 000	0.1	2	165[24]	500	0.25
Rice	1[8]	10[40]	10 000	0.05	1[8]	10[40]	5 000	0.1	1[8]	10[40]	1 000	0.2
Rye	1[7]	660[18]	3 000	0.05	1[7]	660[18]	2 000	0.1	1[7]	660[18]	1 000	0.2
Sainfoin	5[1]	600[4, 5]	1 000	0.1	3[1]	300[4, 5]	400	0.25	2[1]	165[4, 6]	100	1.0
Sorghum Hybrid	1[8]	990	50 000[27]	0.005	1[8]	990	35 000[27]	0.01	1[8]	660[29]	20 000[27]	0.05

See numbered footnotes on pages 198-200.

A. Land, isolation, field, and seed standards (*concluded*)

Crop	Foundation				Registered				Certified			
	* Land	** Isolation	*** Field	**** Seed	* Land	** Isolation	*** Field	**** Seed	* Land	** Isolation	*** Field	**** Seed
Seedstock	1[8]	990	50 000[27]	0.005	–	–	–	–	–	–	–	–
Common hybrids	–	–	–	–	–	–	–	–	1[8]	660[21,29,31]	20 000[27]	0.1
Soybeans	1[33]	0[23]	1 000	0.1	1[33]	0[23]	500	0.2	1[33]	0[23]	200	0.5
Sunflower	1	2 640	200	0.02	1	2 640	200	0.02	1	2 640	200	0.1[34]
Hybrids	1	2 640	250[35]	0.02	–	–	–	–	1	2 640	250[35]	0.1[34]
Tomato	1[8]	200[25]	0	0	1[8]	100[25]	300	0.5	1[8]	30[25]	150	1.0
Tobacco	1[36]	150[37]	0[39]	0.01	1[36]	150[37]	0[39]	0.01	1[36]	150[37]	0[39]	0.01
Hybrids	–	–	–	–	–	–	–	–	0[36]	150[38]	0[39]	0.01
Triticale	1[7]	0[23]	3 000	0.05	1[7]	0[23]	2 000	0.1	1[7]	0[23]	1 000	0.20
Vetch	5[1,8]	10[4,17]	1 000	0.1	3[1,8]	10[4,17]	400	0.25	2[1,8]	10[4,17]	100	1.0
Watermelon	1[8]	2 640[26]	0[28]	0	1[8]	2 640[26]	0[28]	0.5	1[8]	1 320[26]	500[28]	1.0
Wheat	1[7]	0[23]	3 000	0.05	1[7]	0[23]	2 000	0.1	1[7]	0[23]	1 000	0.2
Hybrids	1[30]	660[21,32]	3 000	0.05	1[30]	660[21,32]	2 000	0.1	1[30]	330[21,32]	1 000	0.2

* Number of years that must elapse between destruction of a stand of a variety and establishment of a stand of a specific class of a variety of the same crop kind.
** Distance in feet from any contaminating sources.
*** Minimum number of plants or heads in which one plant or head of another variety or off-type is permitted.
**** Maximum percentage of seed of other varieties or off-types permitted.

See numbered footnotes on pages 198-200.

[1] The land must be free of volunteer plants of the crop kind during the year immediately prior to establishment; and no manure or other contaminating material shall be applied the year previous to seeding or during the establishment and productive life of the stand.

[2] Two years are required for the production of Certified seed of varieties adapted to the northern and central regions following varieties adapted to the southern region.

[3] Isolation distance for Certified seed production of varieties adapted to the northern and central regions shall be 500 feet from varieties adapted to the southern region.

[4] Isolation between classes of the same variety may be reduced to 25 percent of the distance otherwise required.

[5] This distance applies when fields are five acres or larger in area. For smaller fields, the distances are 900 and 450 feet for the Foundation and Registered classes.

[6] Fields of less than five acres require 330 feet.

[7] Requirement is waived if the previous crop was grown from Certified seed of the same variety.

[8] Requirement is waived if the previous crop was of the same variety and of a Certified class equal or superior to that of the crop seeded.

[9] Reseeding varieties of crimson clover may be allowed to volunteer back year after year on the same ground. Where a new variety is being planted where another variety once grew, the field history requirements pertain.

[10] No isolation is required for the production of hand-pollinated seed.

[11] When the contaminant is of the same colour and texture, the isolation distance may be modified by (1) adequate natural barriers or (2) differential maturity dates, provided there are no receptive silks in the seed parent at the time the contaminant is shedding pollen. In the case of inbred lines and Foundation single-crosses, these modifications may apply only for fertile seed production.

[12] Where the contaminating source is corn (maize) of the same colour and texture as that of the field inspected, the isolation distance is 410 feet and may be modified by the planting of pollen parent border rows according to the following table:

MINIMUM DISTANCE FROM CONTAMINANT	MINIMUM NUMBER OF BORDER ROWS REQUIRED	
	Field size up to 20 acres	Field size 20 acres or more
410	0	0
370	2	1
330	4	2
290	6	3
245	8	4
205	10	5
165	12	6
125	14	7
85	16	8
0	—	10

[13] Refers to off-type plants in the pollen parent that have shed pollen or to the off-type plants in the seed parent at the time of the last inspection.

[14] The required minimum isolation distance for sweet corn (maize) is 660 feet from the contaminating source, plus four border rows when the field to be inspected is ten acres or less in size. This distance may be decreased by 15 feet for each increment of four acres in the size of the field to a maximum of forty acres, and further decreased 40 feet for each additional border row to a maximum of sixteen rows. These border rows are for pollen-shedding purposes only

[15] Refers to definitely off-type ears. Ears with off-coloured kernels are limited to 0.2 percent.

[16] The variety of bluegrass, Merion, is allowed 3 percent.

[17] All cross-pollinating varieties must be 400 feet from any contaminating source.

[18] Isolation between diploids and tetraploids shall be at least 15 feet.

[19] Minimum isolation shall be 100 feet if the contaminating source differs widely from the field to be inspected. Isolation distance between upland and Egyptian types is 1 320, 1 320, and 660 feet for Foundation, Registered, and Certified, respectively.

[20] These distances apply when there is no border removal. Removal of a 9-foot border (after flowering) decreases the required distance to 600, 225, and 100 feet for cross-pollinated species, and to 30, 15, and 15 feet for apomictic and self-pollinated species. Removal of a 15-foot border allows a further decrease to 450, 150 and 75 feet for cross-pollinated species.

[21] Isolation distances may be modified if the sum of percentages of plants in bloom does not exceed 5 percent when more than 1 percent of the plants in either field are in bloom.

[22] Refers to bulbs.

[23] Distance adequate to prevent mechanical mixture is necessary.

[24] Required isolation between classes of the same variety is 10 feet.

[25] The minimum distance may be reduced to one half if different classes of the same variety are involved.

[26] The minimum distance may be reduced to one half if the field is adequately protected by natural or artificial barriers.

[27] These ratios are for definite other varieties. The ratios for doubtful other varieties are:

	FOUNDATION	REGISTERED	CERTIFIED
Millet	1/10 000	1/ 5 000	1/2 500
Sorghum	1/20 000	1/10 000	1/1 000
Hybrid sorghum	1/20 000	—	1/1 000
Okra	None	1/750	1/500

[28] White heart fruits may not exceed one per 100, 40, and 20 for Foundation, Registered, and Certified classes, respectively. Citron or hard rind is not permitted in Foundation or Registered classes and may not exceed one per 1 000 in the Certified class.

[29] This distance applies if the contaminating source is not genetically different in height to the pollinator parent or has a different chromosome number. If the contaminating source is genetically different and has the same chromosome number, the distance shall be 990 feet. The minimum isolation from grass sorghum or broom corn with the same chromosome number shall be 1 320 feet.

[30] Requirement is waived for the production of pollinator lines, if the previous crop was grown from Certified seed of the same variety. Sterile lines and crossing blocks must be on land free of contaminating plants.

[31] If the contaminating source is similar to the hybrid in all important characteristics, the isolation may be reduced by 66 feet for each pair of border rows of the pollinator parent down to a minimum of 330 feet. These rows must be located directly opposite or diagonally to the contaminating source. The pollinator border rows must be shedding pollen during the entire time 5 percent or more of the seed parent flowers are receptive.

[32] An unplanted strip at least 2 feet in width shall separate male steriles and pollinators in interplanted blocks.

[33] Unless the preceding soybean crop was planted with a class of Certified seed of the same variety or unless the variety planted is of a contrasting pubescence or hilum colour.

[34] May include not more than 0.04 percent purple or white seeds.

[35] Standards apply equally to seed and pollen parents which may include but not exceed 1:1 000 each of Wild-Type Branching, Purple Plants, or White seeded.

[36] A new plant bed must be used each year unless the bed is properly treated with a soil sterilant prior to seeding.

[37] This distance is applied between varieties of the same type and may be waived if 4 border rows of each variety are allowed to bloom and set seed between the two varieties but are not harvested for seed. Isolation between varieties of different types shall be 1 320 feet, except if protected by bagging or by topping all plants in the contaminating source before bloom.

[38] This distance is applied between plants of the same type, except that when male sterile and male fertile varieties are adjacent in a field, four border rows of male sterile shall be allowed to bloom and set seed. Seed set on these rows shall not be harvested for seed, except when the male fertile plants are used as the pollen parent. When plants are of different types, the distance shall be 1 320 feet, except if protected by bagging or topping all plants in the contaminant source before bloom.

[39] Plants affected with mosaic and or ring-spot disease are included and must be topped as soon as found.

[40] Isolation between varieties shall be 100 feet.

B. LENGTH OF STAND REQUIREMENTS

1. *Alfalfa*

Limitations on the age of stand and pedigree classes of seed through which a given variety may be multiplied for both inside and outside the region of adaptation shall be specified by the originator or his designee. Certified seed production outside the region of adaptation shall not exceed six years if not otherwise specified by the originator or his designee.

2. *Red Clover*

Only two seed crops permitted of all classes. Seed crops may be produced in the same or consecutive years.

3. *White and Alsike Clover*

Only two successive seed crops are permitted following year of establishment for Foundation and Registered classes, but two additional years are permitted if the field is reclassified to the next lower class. Four successive seed crops following seeding are permitted if the first and succeeding crops are of the Certified class providing the stand of perennial plants is maintained.

4. *Sainfoin*

All classes are eligible to produce five successive seed crops following seeding.

C. POLLEN CONTROL FOR HYBRIDS

1. *Wheat and Barley*

Shedders in the seed parent, at any one inspection, are limited to 1/200 for Foundation A Line and 1/100 for Registered A Line, except that when the A Line is increased outside the area of the anticipated A × R production in order to utilize self-fertility produced by environmental effects, only isolation and genetic purity standards will be in effect.

2. *Corn (maize)*

When 5 percent or more of the seed parent plants have receptive silks, tassels or portions of tassels which have 2 inches of the central stem, branches, or a combination of both shedding pollen are limited to 1 percent at any one inspection or a total of 2 percent for three inspections on different dates. This refers to tassels in the seed parent.

3. *Sorghum*

Shedders in the seed parent, at any one inspection, are limited to 1/3 000 for Foundation and 1/1 500 for Certified.

4. *Sunflowers*

Seed parents flowering and shedding before the male parents are shedding pollen must be removed. At least 50 percent of the male plants must be producing pollen when the seed parent is in full bloom.

9. SEED LEGISLATION

by H. Esbo (Coordinator), H.A. Al-Jibouri, J.C. Delouche, H. Potts, and J.R. Thomson

Since legislation is above all an expression of government policy, special legislation pertaining to seed is influenced by agricultural policy as a whole. This is compounded of economic aims and social aspirations, and the balance between them is reflected in the seed laws, which are designed to promote better cash returns per hectare and to protect the farmer against the risk of sowing seed of poor quality or of being otherwise exploited.

Another formative influence on the pattern of a nation's seed laws is the government's policy toward private enterprise. The seed industry may be wholly within either the private or the public sector of the economy, or it may be an amalgam of both. In the early stages of a developing seed industry the initiative comes from the government, but it is expected that with progress an increasing part will be played by private enterprise. This chapter assumes the free participation of private enterprise and discusses the restrictions that can be placed on it.

Why is a special seed law necessary?

Quality is much more difficult to judge in seed than in many other forms of merchandise. It is by no means certain that the seed in the bag is of the quality the farmer wants; weed seeds may not be visible and germinative capacity is impossible to assess by eye. Moreover, if a farmer sows seed of poor quality, he stands to lose not only the cost of the seed, but also the whole value of the expected crop and perhaps even a year's livelihood. The law therefore protects the farmer against fraud, negligence, or accident. It also provides some protection to the seller when failure cannot be attributed to the seed or to him. The reputable merchant is protected against unscrupulous competitors to the extent afforded by general law as well.

The seed laws with which we are concerned therefore impose certain restrictions on at least some of the various stages through which seed passes up to the point of sale to the farmer (production, processing, testing, packing, and trading). These restrictions are enforced by penal sanctions.

One of the most effective means of achieving increased production is for farmers to use high-quality seed. This is particularly true if seed of improved varieties is made available to them as quickly as possible. Without proper legislation, farmers risk purchasing seed of inferior quality. A system of controlled production and distribution will minimize this risk.

Certain seed qualities can be assessed by laboratory tests, which take up to a month to complete (for cereals, usually less than ten days). This means that a seed lot which is ready for sale can be sampled and tested; the quality thus established is expected to be maintained for a matter of months in good storage conditions and can be checked at any time by drawing and testing a control sample. Thus control of seed for these verifiable qualities is a relatively simple matter, and the necessary legislation can be quite straightforward.

In general, however, it is not possible to determine the cultivar to which a seed belongs by any laboratory test. Such tests for identifying cultivars by their seed may be developed in the future, and it will then be possible to determine cultivar purity equally as well as specific purity; but in the meantime much more complex measures of control are necessary. Cultivar purity has to be determined by reference to the mother plants from which the seed is to be harvested. This may be done by examination of a plot grown from a sample of the seed used to sow the seed crop and by inspection of the crop on the farm. In practice, crop inspection should be subject to confirmation by plot examination. After crop inspection the seed has to be harvested, stored, processed, and eventually bagged for sale to farmers. These operations are officially supervised to some extent, but for practical reasons never completely; there can be no guarantee that the seed has maintained its identity throughout or that cultivar purity is the same in the bagged seed as it was in the seed crop. Examination of cultivar authenticity therefore requires special procedures and should be the subject of special regulations.

The primary purpose of seed legislation should be to regulate various aspects of the industry — in particular, cultivar listing, seed production, processing, storage, testing, and marketing (including import and export) — with the ultimate aim of making high-quality seed available to farmers in sufficient quantities. Such seed should be:

- (*a*) of the most suitable cultivar;
- (*b*) of a satisfactory level of varietal purity;
- (*c*) of a high degree of analytical purity, particularly with reference to freedom from weed seeds;
- (*d*) of a high germinative capacity;
- (*e*) as free as possible from seed-borne diseases.

All seed in trade should come under the legislative provisions irrespective of origin, whether it is imported or, if home-produced, intended for sale on the internal market or for export. Seed exchange among farmers not normally trading in seed should be excluded from the provisions of seed laws.

The scope and magnitude of a nation's seed industry can only be decided within the country itself. The basic decision as to whether the industry should be developed either as a joint enterprise of the public and private sectors or exclusively by one sector is likely to be made according to social and political circumstances. In any case, in the "ground-breaking stage" the government will have to take the initiative of starting seed production, control, and distribution programmes. With overall agriculture development an independent seed industry should be encouraged to take over production and distribution of seed. Extension and education programmes may assist in convincing all concerned that good-quality seed is the most vital of all inputs for production.

Minimum standards and labelling requirements

It is generally agreed that seed should be tested when it is ready for sale, to control verifiable qualities, but there are two schools of thought as to how the information from the tests should be allowed to influence subsequent sale to farmers.

In some countries there is no legal ban on the sale of seed however poor the quality may be, but the results of the tests are made available to potential purchasers on labels or invoices or in catalogues. Quality may be expressed either as a percentage or by a grading system. Enforcement officers concentrate on checking the correctness of the information — a method usually referred to as "truth in labelling." It is suitable for countries where farmers are sophisticated enough to understand the information and to judge the quality of seed accordingly. Under these conditions high-quality seed is expected to drive poor-quality seed off the market by competition.

In other countries a minimum standard is set for each attribute, and a ban is enforced on the sale of seed that falls short of any minimum standard. The task of enforcement officers is to check on whether these standards are in fact being complied with. This system is suitable for less sophisticated farming communities; it concentrates on protecting farmers, but at the cost of allowing them no choice.

Modifications of these extremes are followed in certain countries: one sets minimum standards for sale, but the actual test figures are declared, thus enabling the farmer to exercise some choice; another sets fairly high standards, and seed that fails to reach the standards may be sold only if the actual test figures are declared. While this implies that seed above the standards is of high quality, the farmer is assumed to be sophisticated enough to judge the quality of seed below standards and to buy it if he wishes.

The seeds act

Legislation is enacted in two phases. First, the act, which lays down the general principles and gives the necessary powers to the minister of agriculture, is passed by the legislature. Subsequently, regulations which have the force of law are promulgated by the minister. These provide detailed procedures for enforcing the statute, and they are put into effect and amended as necessary, to keep pace with the development of the seed improvement programme in a way that does not take up valuable parliamentary time.

The seeds act declares the purpose of the legislation and lays down the general principles for achieving it — that is, by laboratory testing, seed certification, restrictions on sale, and either setting minimum standards or following the "truth in labelling" philosophy.

The responsibilities for control and enforcement have to be allocated and delegated very clearly. Under a "truth in labelling" system, sampling and laboratory testing before sale can be left to the merchant. Alternatively, sampling may be done by an official and the test carried out at an official seed-testing station. Between these extremes, sampling and sealing may be done by nonofficials who are specially trained for the purpose.

After sampling and sealing the regulations are enforced by inspectors who visit warehouses, processing plants, merchants' offices, and retail points. They examine records, scrutinize labels, and draw samples from seed lots for testing at an official laboratory. The powers of entry, sampling, and examining records have to be conferred on enforcement officers (Fig. 51).

Procedures have to be prescribed for stopping the sale of seed that is either substandard or wrongly described and for preparing evidence for prosecutions. In particular, it is necessary to state that tolerances on numerical values are admissible. Penalties for offences must also be prescribed. Most important of all, the minister of agriculture must be given powers to promulgate appropriate regulations covering a wide range of detail.

FIGURE 51. Examination of records of activities and operations related to seed.

General regulations

The main features of seed regulations are:

Definitions. Any technical terms used in the regulations (e.g., "fungicide" and "percentage purity") must be defined. In particular, a definition of "seed" is necessary in order to clarify whether the law applies to seed in the botanical sense only or whether it includes plants used for vegetative propagation (e.g., tubers).

Crops. The species to which the act applies must be listed. Minor crops and ornamental plants may be excluded.

Weeds. The species to be regarded as weeds must be specified. A special category of weeds, known as "noxious" weeds, may be established, and a ban placed on the sale of seed containing such weeds. A weed should not be regarded as noxious for this purpose unless there is strong factual evidence of these three attributes: (*a*) that it is absent from large areas of land; (*b*) that it is normally spread as an impurity in seeds; (*c*) that it is difficult to eradicate once it is established on a farm.

Arrangements for testing. One or more seed testing stations have to be designated as official stations. In addition, nonofficial stations may be authorized to carry out tests under certain specified conditions. To ensure uniformity of test results, it is necessary for all stations in the country to follow the same testing methods. Normally the International Rules for Seed Testing are adopted, sometimes with minor variations to suit local conditions. It should not be necessary, however, to prescribe testing methods in the regulations, because nonofficial laboratories will adopt the methods of the official station in order to avoid discrepancies.

Registration. Sellers of seed and, to some extent, producers, processors, and middlemen will have to be registered and required to keep records, which will be available for inspection. Between countries there are wide differences in the legal requirements in this respect. Regulations on registration are stricter for certified than for commercial seed, and those who register may be required to show their technical capacity and financial status before they are accepted.

Sampling. Reliable methods of sampling must be followed so as to ensure that the test sample is representative of the seed lot. The details specified in regulations should include maximum size of seed lot, size of sample, number of bags to be sampled, position of sampling probe in each bag, and instruments to be used. The methods prescribed in the International Rules for Seed Testing should be followed. The sample should be drawn by an officially designated sampler.

Attributes to be controlled. The verifiable attributes to be controlled comprise at least specific purity, germinative capacity, and weed seed content. Weed seed content may be expressed as percentage by weight or as number of seeds of a certain noxious weed in a specific weight of seed. The number or other crop seeds may also be required (e.g., the number of wheat grains in a kilogram of seed barley). Some countries require determination of moisture content.

The possibility of controlling seed-borne diseases requires careful consideration in the light of local circumstances. It may be worthwhile if a major disease of an economically important crop is in fact seed-borne and if the seed testing station can cope with a large number of disease tests during the busy season.

Labelling. Certain information about the seed has to be given to the buyer. This may be printed on labels attached to the bags or imparted in some other way (e.g., by a certificate). Some items of information are necessary for administration of the control system. Other items give the farmer who buys the seed the technical information he requires. The minimum information required is:

1. Names and addresses of the seller and the person responsible for the information supplied. If the lot was officially sampled, sealed, and labelled, the label should bear the name of the control authority.
2. Reference number of the seed lot.
3. Name of the crop species.
4. Country of origin of the seed.
5. An indication of the quality of the seed. If minimum standards are set, all that is necessary is a statement that the seed has been tested and complies with the standards for purity, germination capacity, weed content, and possibly health and moisture content. If there are no standards, the actual figures obtained in the tests have to be declared.
6. Date and place of tests. A maximum period of validity for tests should be set — say, six or nine months.
7. Chemical treatment, if any, including treatment with fungicides.

Tolerance. Except for minimum standards, tolerance figures for each verifiable quality have to be prescribed.

Imports. Control of imports may be desirable to protect the home seed industry or for quarantine purposes. Otherwise, it is necessary only to ensure that imported seed complies with the law applied to home-produced seed. If already packed for sale to farmers, it must be appropriately sealed and labelled; otherwise, it should be covered by an orange or a green International Analysis Certificate. Quarantine restrictions may refer to seed-borne diseases and pests or to weed seeds. When imposed recklessly, they hinder and distort the legitimate international trade in seed by excluding seed that is adequate for practical purposes. Quarantine may thus inflate the prices of essential seed imports. No country is completely self-supporting in seed. Quarantine should therefore be designed to exclude a very short list of pests, pathogens, and weeds.

Implementation and enforcement

After a seeds act has become law, certain authorities should be designated by and made responsible to the government for implementing the seed law; they should also be given the necessary powers for this purpose. Facilities, including trained staff, office space, laboratories, and trial fields, should be provided for the designated authorities. The authorities should fix the fees to be charged for the implementation of the law, and these should be announced from time to time in an official gazette. In developing countries, however, where the seed industry is just starting, the charging of fees for activities such as variety listing, field inspection, and laboratory examination of seed may be considered to discourage the implementation of seed production and distribution activities by seed growers and seed dealers.

A limited number of seed inspectors (seed quality control officers) should be appointed to enforce the seed law. A seed inspector must have adequate experience and training to be effective and must be a man of integrity, an educator, an organizer, and one who strives to make better seed available to farmers.

Although seed inspectors should be given a minimum of office space, they must be mobile, since as law enforcement officers they can only be useful to the extent that they are actually contacting sellers of seeds. Other requirements of equipment and supplies for seed inspectors are not great, but they are essential and must be available if the inspector is to be effective. The following is a suggested list of equipment:

1. An identification card or letter of introduction
2. Copies for distribution of the seeds act and rules, as well as other explanatory material about the act
3. Useful references, such as manuals on seed testing, production, certification, and processing
4. A list of the species and varieties covered by the act
5. Printed forms as required under the act
6. Large and small sampling triers
7. Sample pans
8. Sample bags or suitable containers
9. Sealing devices and seals
10. Sample tags

Education is essential to proper enforcement of a seed law. Emphasis should be placed on the development of an effective educational programme directed at the seed inspector, the seed seller, the cultivator, and the extension personnel.

Seed inspectors must be familiar with all aspects and details of the act and the regulations. They should be able to make an inspection and draw samples. They should know the procedures for handling cases of noncompliance with the seeds act and be able to examine complaints.

Seed inspectors should also be familiar with the operation of the certification agency and the working of the testing laboratory.

Seed inspectors, certification agency personnel, and extension specialists are responsible for educating seedsmen and cultivators on all aspects of the seed law and the seed industry.

Seedsmen should know what is required to produce, process, store, and market good-quality seed, how to apply to have seed certified, where and how to have seed tested, and how to test their own seed and decide whether seed is fit for sowing purposes. Seedsmen should also know how to interpret laboratory results and how to transfer such infornation to the label. They should be able to provide specific information on the provisions of the seed law and know what is to be done with seed lots that are unfit for sowing. Special discussion meetings, visits by seed inspectors, and tours and field days are some of the ways in which training and education of seedsmen are accomplished. Publications are also important for this purpose.

Cultivators should know why tested and high-quality seed will be profitable for them, where they can buy certified seed, where they may have their seed tested, and what additional assurances are provided with certified seed. If there is a provision in the seed law for labelling, cultivators should be able to understand what the label means. Special discussion meetings, training programmes, and field days should be organized for cultivators. Newspapers, radio, and television are useful media for disseminating general information on the quality of certified seed. The results of seed surveys are helpful in showing cultivators how their seed can be improved.

Special regulations for the control of cultivars

After legal control of the verifiable attributes of seed has been established and an effective system of seed multiplication has been developed on a voluntary basis, it becomes possible to promulgate regulations for the control of cultivars of the more important crop species. Additional definitions will be necessary (e.g., for "cultivar" and "breeder"). If the general regulations set standards for verifiable qualities, stricter standards may be set for certified seed, such as a higher purity percentage or a lower weed seed count. Labelling requirements will be different; the name of the cultivar and an indication of the stage reached in the multiplication cycle will be required. The control of cultivars may involve (*a*) cultivar listing and release procedures and (*b*) certification schemes. Cultivar listing defines and identifies the cultivar as distinct, as uniform and stable, and sometimes also as suitable for crop production. Certification authenticates individual lots of seed as having been produced in such a way as to keep the seed true to the cultivar name on the label.

Distinctness implies that a new cultivar is distinguishable from any other cultivar on the list, usually by methods suitable for use in a seed certification scheme. Uniformity is necessary for description and identification, but the standard to be expected depends on the mode of reproduction; cultivars are more uniform in a self-pollinated crop such as wheat than in a cross-pollinated crop such as maize. Stability is necessary for ensuring that the cultivar will remain unchanged from year to year.

The name of the cultivar should comply with the International Code of Nomenclature for Cultivated Plants, and a description of the cultivar should be filed at the time of registration. Determination of eligibility requires meticulous examination of botanical characters, both gross and minute; the tests extend over a period of two to three years, using seed supplied by the breeder.

While a cultivar is undergoing distinctness tests, it should be subjected to performance trials on a nationwide scale. The object of these trials is to assess agricultural value, and the results are used to promote acceptance of the best cultivars coming forward by the farming community. One method is to publish the results of the trials and to let the extension service select the best for recommendation. Another method is to add to the list only those that show superiority over the cultivars already on the list; in this case a cultivar should be removed from the list after a prescribed period (say ten years), unless there is evidence that it is still being used to a significant extent.

A cultivar list can be established as either a recommended list or a restrictive list. The former includes cultivars that are suitable for the country and has a purely recommendatory character, meaning that also cultivars not included may be eligible for seed certification and be marketed and grown. In some countries a restrictive list limits seed certification to cultivars included in the list; in others even the sale of unlisted cultivars is forbidden.

Seed regulations may establish a seed certification authority and give it power to operate a seed certification scheme. The authority may be the ministry of agriculture or an agency especially established for the purpose, with a properly established constitution. The governing board may include representatives from the seed and farming industries, but some provision should be made to ensure ultimate government control.

10. EXTENSION PROGRAMME FOR THE PROMOTION OF QUALITY SEED

by W.D. Maalouf (Coordinator), A. Singh, and T.Y. Sung

Scientific research has been remarkably successful in increasing quantity and quality of agricultural production in a given area of land through the use of good-quality seed. However, national agricultural production in developing countries, with few exceptions, does not reflect these potential increases. Important aspects of this situation are the extent to which farmers in general are in fact adopting good-quality seed and the extent to which they are applying the improved production methods that should accompany its use.

Seed promotion is considered to be a deliberate, planned, and sustained effort to establish mutual understanding between consumers (farmers) and agencies for promoting seed sales and uses. Seed consumers have to be willing to use the seed and follow the instructions given by the seedsmen. Seed promotion agencies must present the consumers with facts based on thorough and accurate studies of the technical, social, and economic problems of the local agricultural community. They need a thorough knowledge of crop and varietal adaptability and of the psychological and ethical issues likely to be raised by rural people in relation to the seed promotion programmes which the agencies are advocating.

Private programmes are usually aimed at the promotion of sales of seed of particular kinds and varieties. Many government agricultural agencies are engaging in seed promotion, which is normally aimed at educating farmers in a wide sense. It is most important that an extension programme for the promotion of improved seed follow the results obtained by research in experimental stations. The aim of such an extension programme is to spread the proper use of improved seed to all farmers in the country who might profit from it.

Objectives

In general terms the objective of a seed extension programme is to advise farmers on the use of controlled quality (certified) seed of improved varieties. This should lead to increased production and bring more returns to the farmers and better welfare to the entire rural community through a well-planned, coordinated and properly executed seed programme.

To accomplish this, a seed extension programme must be designed to reach the specific objectives discussed below.

To inform farmers of the existence and advantages of certified seed. Making farmers aware of the existence, availability, and advantages of quality seed is the first major objective in the process of seed promotion. Farmers, who are accustomed to sowing local varieties and applying production techniques used for several generations, need to understand the reasons why they should change to quality seed of new varieties and possibly new techniques. They have to be informed that science and research have produced new varieties which are not only more productive, homogeneous, and responsive to modern techniques, such as fertilization, irrigation, and the use of farm machinery, but also probably have more nutritive value. The economic advantages of the improved varieties have to be explained to farmers in terms of higher yields and prices, leading to an appreciable increase in farm income and, ultimately, to improved living conditions for the agricultural population (Fig. 52).

To convince farmers to use certified seed on a large scale. An extension programme will have achieved its objectives when the majority of farmers accept the change and adopt the use of certified seeds along with the related recommended techniques. Those who are responsible for the extension programme need to use all possible methods and facilities to convince farmers that they should participate. Information must be followed by intensive promotion work if the improved methods are to be used extensively in the field. What really counts at the end is the farmers' knowledge and actions in the field. Methods for convincing farmers of the need to use improved seed will be discussed in detail later.

To inform farmers of ways and means for the requisition of certified seed and related government policies. Each country may have different arrangements for the distribution of quality seed to farmers. Seed may be produced on government seed farms or private properties rented to the government, or official seed production may be contracted to private firms. In all these situations the commercialization of certified seed is under the management of the government. Under another system, private seed companies produce certified seed for sale directly to farmers; this could involve specific arrangements with the government, including subsidies, financing, and distribution facilities.

There are different ways in which farmers may obtain certified seed, and extension workers must be aware of all the possibilities and advise farmers accordingly. The selection of arrangements suitable to each country will depend to a large extent on the prevailing social, political, and economic conditions.

To train farmers in recommended production methods for the cultivation of improved seed. Very often the introduction of seed of improved varieties necessitates the application of new production techniques, such as sowing methods, fertilizer application, irrigation, special pest treatments, harvesting, and, more particularly, the various measures which have to be taken to prevent the seed from being mixed with other varieties. Some of these methods require skills in the proper use and maintenance of farm machinery. The extension service should be in a position to follow up seed distribution with the technical advice required, both through appropriate training of field workers and by the use of subject-matter specialists.

To establish an effective liaison between farmers using improved seed, plant breeders, and seed production specialists. Although this liaison activity appears to be of minor importance in the extension programme for im-

FIGURE 52. Making farmers aware of the advantages of quality seed — a major objective in seed promotion.

proved-seed promotion, it does play an important role in providing seed scientists with information from the field which could be of great value to their research programme. Seed specialists may need to establish seed trial plots outside experimental stations, on private farm properties, to test the validity of their findings. This activity can be better accomplished if it is included in the extension programme.

Organization

The programme should be based on knowledge of the following:

1. Technical information about the advantages of recommended improved seed and related production techniques. Information on locally used seeds and practices is also useful for comparisons.
2. Information about government policies and the arrangements of private organizations and agencies related to seed reproduction, distribution, marketing, financing, and so on.
3. Information about training programmes for extension personnel and farmers in promotion activities for improved seed.

As stated earlier, the main objectives of a seed extension programme are to convince the majority of farmers to use certified seed and to train them in the best recommended techniques for its cultivation. Therefore the programme should be confined to a well-organized extension system that is capable of achieving these objectives. But it must be emphasized that the extension system cannot function effectively unless other activities related to the programme — including variety evaluation and related research, seed multiplication, quality control, and marketing — are well planned and efficiently executed. The establishment of organizations to undertake these functions is an essential prerequisite to a successful seed extension programme.

Likewise, the production of quality seed cannot go far if seed distribution to farmers is not encouraged, thus leaving local varieties in use on a large scale. For this reason, coordination between the seed extension programme and other agencies, which together constitute the functioning system of the comprehensive seed programme, is important.

The extension service

In most countries a government agency is in charge of advising farmers and providing them with technical information and services related to agricultural production. This agency is usually under the ministry of agriculture and is normally called the agricultural extension service. In some countries agricultural extension services are also created under other ministries, such as those of agrarian reform, land settlement, or community development. The name of the agency is of little importance, of course, as long as it functions effectively at all levels and provides a suitable organization for an efficient seed extension programme.

The programme

There is no standard formula for the organization of a seed extension programme which can be applied to all countries. In many developing countries, due to the shortage of trained personnel, insufficient communications, and scarcity of other necessary facilities, it is advisable to confine crop improvement projects to a few selected provinces during the initial stage. A concentrated effort of the combined forces of all the related agricultural and financing agencies can thus be utilized more efficiently. The aims should be reasonable, and the chances of success should be studied carefully. All available means which are essential to achieving the goal should be considered. There must be possibilities of fitting the programme into the existing system of extension in each country, provided the system includes the following basic requirements:

1. A strong organization at the top level, where decisions concerning agricultural development and the national economy are taken.
2. An effective organization at the field level, allowing field workers to reach farmers of all categories and work with them both individually and collectively.
3. Trained personnel of all categories in sufficient numbers to carry on the programme from planting stage to practical implementation in farmers' fields.
4. An effective machinery for staff training, both in-service training for existing personnel and initial training for new recruits.
5. A sufficient budget to cover all programme costs.
6. Close coordination and collaboration with all agencies in charge of agricultural research, certified seed production and control, marketing, and agricultural credit.

Coordination board

Sufficient coordination between the extension service and the various bodies involved in the seed programme can be ensured by the creation of a coordination board in which all government and private agencies concerned are represented; representatives of farmers and farmers' organizations should be included. One of the principal functions of the board is to establish the general course of seed production and extension programmes within the framework of national policies. The board has to make sure that

(*a*) the seed extension programme is considered an integral part of the overall agricultural extension programme and given high priority;
(*b*) the extension service is adequately organized and equipped with qualified staff and suitable facilities to undertake such an important task;
(*c*) seed production, certification, distribution, extension, and marketing of products function harmoniously, since a defect in any one of these functions will seriously affect the whole seed promotion programme.

PROVINCIAL AND DISTRICT LEVEL

It is suggested that similar coordination boards be created in each province. The main responsibility of a provincial board is to ensure joint efforts in the implementation of the seed programme. At the district level the extension service has to make sure that its personnel is adequate and suitably qualified and that all the necessary equipment and material for undertaking such a vital task are made available.

OTHER SUPPORTING PROCEDURES

Although the extension service is considered to be the most suitable agency for encouraging and training farmers in the use of certified seed, other procedures may be used to support the efforts of this agency; for example, direct contact may be established between the agency for seed multiplication and individual farmers or farmers' organizations (agricultural cooperatives, associations, etc.). This type of seed promotion activity, though possible, lacks the effective technical support that the extension service can provide to farmers right in the field. Possibly, seed production agencies can provide farmers and farmers' organizations with written technical information, but this is useful only in countries where the farmers' level of education is high enough to allow them to understand and apply written instructions and where farmers are sufficiently motivated toward change and adoption of new ideas. Unfortunately, this is not so in most developing countries where the promotion of improved seed is most needed; in such countries the seed extension programme is better carried out through the extension service under a plan of action that is well coordinated with relevant agencies (Fig. 53).

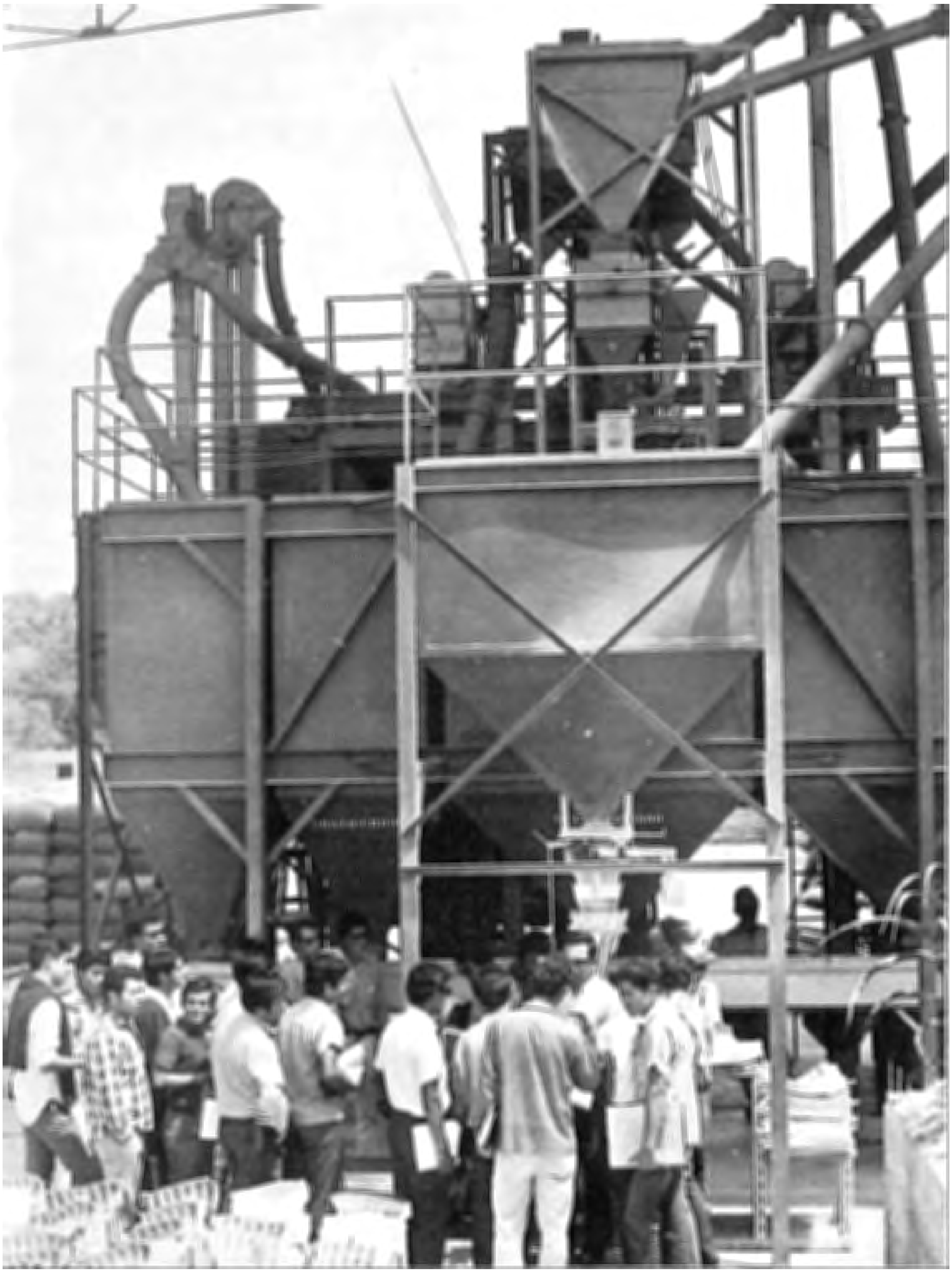

FIGURE 53. Visit to a processing centre for certified seed.

Main activities of the seed extension programme

The extension programme should include three main activities:

(*a*) training of extension personnel (field extension workers and supervisors) in specific subjects related to the programme;
(*b*) preparation of materials necessary for the execution of the programme;
(*c*) implementation of the seed extension programme at the farmer level.

Training of personnel

Training high-level officials

This group includes responsible officers in the areas of extension services, seed promotion, agricultural research, agricultural credit, and agricultural marketing, as well as a number of administrators whose work is related to the seed extension programme. The group usually has a strong influence in decision-making on general policies, programme planning, budget appropriation, recruitment, and the like. It is prerequisite that this group be thoroughly informed of the objectives and of all matters concerning the seed extension programme. The educational programme for this group is not a training activity in the true sense of the word; it is, rather, an effort to make the members of the group aware of the problem and gain their support.

The programme for informing officials and administrators may be accomplished in various ways. The following procedure may be useful in some countries:

1. Participation in meetings on the importance of the use of certified seed and the role of the extension service in getting farmers to adopt seed of recommended varieties and related production techniques. Holders of senior posts are asked to make personal contributions in presenting and discussing topics on the seed promotion programme.
2. Visits to areas where the extension service has succeeded in promoting recommended agricultural practices. This will help convince the group that a well-supported extension programme is able to promote the use of improved seed by the majority of farmers.
3. Selected members of the group may visit seed extension programmes in other countries. This gives them opportunities to observe and study well-established programmes and the methods and facilities used in undertaking similar activities.

Training of extension personnel

In implementing a seed extension programme through the extension service, it is assumed that the personnel of the service have already acquired basic training in extension education. It is also assumed that an in-service training programme will be undertaken, as a part of which the special training for seed extension work could be introduced. At any rate, an intensive training programme for extension personnel should be conducted, to provide them with all the necessary information and knowledge concerning seed promotion.

Methods. The following combination of activities is recommended for the training of extension personnel:

1. Short training sessions on the premises of seed production stations, where seed specialists will explain the characteristics and advantages of recommended varieties. Trainees will have the opportunity of learning new production techniques appropriate to these varieties. They observe in the field and discuss the impact of each technical practice on production and the possible increase of income which may result from it (Fig. 54).

FIGURE 54. Field training of extension personnel.

2. Special training sessions devoted to the explanation of policies and regulations established for the commercialization of certified seed and the marketing of the produce.
3. Visits to seed-multiplication fields — which may belong to government stations, selected farmers, or private contractors — to familiarize the trainee with methods used in this type of work.
4. Special sessions arranged for extension personnel, seed specialists, and staff of all related agencies in order that they may plan together the seed extension programme. This group planning procedure has two main objectives: first, it brings together the ideas of all parties concerned in the programme, meaning everybody will adopt it as his own responsibility; second, it gives extension personnel the opportunity to be trained in the concerting of policies, regulations, and technical recommendations into suitable action programmes for implementation at the farmer level.

Preparation of materials

Before launching the seed extension programme, trained personnel, together with seed specialists, should design and prepare at least models of the various kinds of advertising materials required for implementation of the programme. This will be followed by preparation of the actual materials needed for the motivation campaign, which should be the first step in the programme.

Materials should include films, slides, leaflets, posters, articles for publication in newspapers, newsletters, and equipment for field demonstrations. Manuals for training farmers should be prepared in advance and include main ideas on various subjects of the seed programme, at the same time leaving enough flexibility for adaptation to different farmers' groups and situations.

Implementation

The motivation campaign

All development efforts, since they induce changes in people's ways of life and methods of work and call for their participation, need to concentrate initially on motivating people to accept new ideas and on showing them the economic and social benefits that might be obtained. Experiences have given repeated proof of the failure of development programmes, especially in the agricultural sector, because motivation efforts have failed to prepare the ground among some of the various groups of people involved

FIGURE 55. An extension officer explaining the advantages of using quality seed.

in the programme. Therefore, it is highly recommended that a seed extension programme start with a well-organized motivation campaign reaching all categories of people concerned, from top government officials to small farmers (Fig. 55). The theme of the campaign should emphasize the economic and social advantages to be obtained from the adoption of certified seed — first, by farmers as the group directly concerned in such efforts and, second, by the entire nation. The information programme for senior officials and administrators suggested earlier should serve to motivate this group and gain their support for the seed extension programme. The following items should be included in the motivation campaign:

(*a*) information supported by exact data on the improved varieties which are available and their production requirements;
(*b*) characteristics of local varieties and their response to modern production techniques;
(*c*) advantages of the use of quality seed of recommended varieties because of their better response to modern techniques;
(*d*) feasibility of the adoption of new varieties within the limits of the farmers' facilities and financial circumstances;
(*e*) the government's intention regarding the programme and assistance available to farmers who cultivate recommended varieties.

Information used in the motivation campaign should be simple, factual, and backed by figures in order to make it acceptable and convincing.

Recommended channels

The following channels and methods suggested for use in the motivation campaign are not introduced here in any order of priority or importance, since it will be most effective to use more than one channel, depending on several human, physical and financial considerations.

Radio and television. Radio and television programmes are effective means for motivating people to use certified seed. It is suggested that farmers' leaders and government officials, particularly field officers known to farmers, take part in these programmes.

Meetings. Meetings at local government offices in which farmers' representatives participate provide useful opportunities for motivating people by explaining the objectives of the seed extension programme. Meetings may also be held with farmers on their farms or in villages where extension workers explain the advantages of recommended varieties. Films, slides, and other audiovisual facilities should be used at these meetings.

Visits. Organized visits to seed production centres, seed testing stations, and field demonstrations can be arranged for groups of farmers.

Mobile demonstrations. A mobile unit equipped with appropriate films and slides can do a very effective job if properly used in conjunction with meetings with farmers.

Newspapers. Publication of articles in local newspapers is suggested for drawing attention to the seed extension programme. This method is helpful to a motivation campaign in areas where a good percentage of farmers are literate and newspapers circulate in the rural communities.

News used in motivation campaigns should be informative. The economic aspects of quality seed of the new varieties should be emphasized, as farmers are interested in the net return of modern production practices, including new varieties and quality seed. Training aspects should be left to the second part of the programme, which trains farmers in the proper use of certified seed once they have made the decision to use it.

Training of farmers

All efforts made by research and seed specialists and by government officials in establishing policies and regulations for encouraging the use of improved seed culminate in the trained farmer. Such a farmer is convinced he should use quality seed of recommended varieties and is able to apply related modern production techniques. He is the main element in making the seed programme a profitable investment.

Farmer training in the context of the seed extension programme should include the following main topics:

(*a*) policies and regulations related to the national seed programme;
(*b*) technical information and practices related to the use of certified seed and specific production methods;
(*c*) economic aspects of the programme;
(*d*) social aspects of the programme.

Policies and regulations

Farmers need to know, in very simple terms, what kind of arrangements they have to make with the seed authority or dealers in order to obtain certified seed. If new seed is obtained by exchange for local seed, what are the terms of this agreement? What are the terms of the loan agreement if farmers need credits to acquire seed, fertilizers, or other production inputs? What kind of arrangements have been established for marketing the production? What would be the appropriate price? Is there any government guarantee of prices, to prevent a sudden drop which might ruin the entire seed programme?

The training programme should include frank and clear answers to these questions and to other relevant queries which may come to the farmer's mind before deciding whether to use improved seed.

Technical information

Before the introduction of certified seed of improved varieties, farmers are used to the cultivation of certain local varieties and to the application of certain production methods that they believe to be suitable to these. The change to new varieties may bring different production techniques and methods, which need to be well understood and correctly applied. The following are examples of new techniques that are recommended with the use of improved seed:

(*a*) seed treatment with chemical products to control certain diseases or to protect seeds from insect damage;
(*b*) the use of drills for sowing seeds, thus regulating the amount of seed sown in a given area according to the recommendations of seed specialists;
(*c*) the use of modern farm machinery for cultivation and harvesting;

(*d*) irrigation methods and techniques that are essential for the cultivation of new varieties;
(*e*) types and amounts of fertilizer and methods of application that are appropriate to individual varieties;
(*f*) cultural, harvesting, handling, and other practices as recommended by specialists.

The main responsibility of extension workers is to train farmers in these practices and to provide them with all technical assistance in the various production activities related to improved seed.

Economic aspects

It has already been pointed out that farmers are interested in the net return to be obtained by using improved seed and new methods. The increase in net profits is normally the main incentive for their interest in adopting new varieties and learning new techniques. It is suggested that the training programme should include simple cost-benefit calculations, to show farmers the profit to be expected if they sow quality seed of recommended varieties and adopt improved production techniques.

Social aspects

Another important incentive for raising farmers' interest in the seed extension programme is the improvement of their social status, which may come about as a result of the increase in their net income. This can be done through simple calculations and explanations of possible ways of using the additional income for enabling their children to have more education, for improved nutrition and housing conditions, for buying new furniture, and for more participation in social activities. Possible community improvements deriving from a better income for its members should also be a topic of discussion.

Methods of training

Most methods used in training farmers have been discussed in textbooks, extension teaching material, and various educational publications. But simply transmitting information is not enough. The main objectives are to ensure that farmers understand and apply recommended practices. Training must therefore be combined with promotional work supported by convincing demonstrations. It is of great importance to choose the combination of methods that is suitable for each particular situation, taking into account such factors as the level of education of the farmers, the availability of training facilities, the opportunities to demonstrate recommended practices, and the expenses involved.

Extension methods can be broadly classified as follows:

Individual approach	*Group approach*	*Mass contact*
Visits to individual farmers	Demonstrations	Radio talks
Personal letters to farmers	Training the leaders	Films
	Discussion meetings	Exhibitions Field days

Extension workers in the seed programme are more efficient if they work through existing farmers' organizations. Through leaders and skilled members of these organizations, they can reach and convince a large number of farmers in a relatively short time. The following suggestions might be considered as training methods for farmers.

Demonstration of results

Farmers need to see, observe, discuss, and evaluate results before they can be persuaded to adopt new recommendations. The method of demonstrating results is still the best one to start with, especially in situations where most farmers have only attained a low educational level. Farmers and their leaders should be associated with all stages, from setting up the demonstration in the field to the final stage of calculating the net profit. Farmers should participate in all activities involved in the demonstration. They should know, for example, the amount of seed sown in a given area and the depth of sowing; the amounts of fertilizers put in the soil at seeding time and applied as top-dressing later; the irrigation methods used, including the amount of water and the frequency of application; and the harvesting techniques. Although it is preferable to conduct result demonstrations in the field, where the farmers themselves work, research stations may also be used as demonstration sites.

Training sessions

Farmers may attend short courses of one to three days for training on specific problems of recommended varieties. The training site need not be a large, expensive centre; it can be a modest meeting room near a seed production station or a community gathering place, where twenty to thirty farmers can meet and discuss particular topics with a technical staff. Practical work may be carried out on the fields of seed stations, on community land, or on private property. The training programme may deal with such specific technical problems as sowing methods, fertilizer application, pest and disease control, and mechanical harvesting.

Field days

Extension workers should organize field days for groups of farmers, so that they may visit seed experiments, demonstrations of results, or properties of progressive farmers using quality seed of recommended varieties. A well-organized programme should be prepared far in advance of each occasion. Extension workers should provide farmers with opportunities for discussion among themselves and for asking all questions that they find important during the field day.

Mass media

Television and radio networks can be effective for training farmers, especially in areas where illiteracy is widespread among the farm population, if proper programmes are adequately prepared and well presented. Extension publications, such as leaflets, bulletins, and newletters, can be used effectively in areas with a reasonable percentage of literate farmers.

Intermediate agricultural schools and youth clubs

Since farmers' children may become successful farmers if they receive the proper education, it is recommended that (*a*) intermediate agricultural schools put strong emphasis on all aspects of improved seed in their programmes and (*b*) youth clubs for boys and girls initiate programmes using certified seed of improved varieties.

Obviously, no single method can be recommended for training farmers; rather, a combination of methods should be planned, harmonized, and effectively implemented. Of course, group methods are better for reaching a large number of farmers.

Manpower costs

Manpower is one of the most important factors in the implementation and execution of any development programme. In a seed extension and development programme the number of personnel required largely depends upon the area to be covered with high-yielding varieties within a specified period of time. In general, one agricultural extension officer who is responsible for seed development work will be required in a block of 50–100 villages, depending upon the population. The agricultural extension officer develops his programme among the villagers through a multipurpose village-level worker. Ten village-level workers will be required in each block of 100 villages (i.e., one village-level worker for 10 villages). With several blocks in one district the agricultural extension work will have to be organized and supervised by one district agricultural officer, assisted by a seed-development officer and an information specialist. This pattern can be used to work out the manpower requirements for a country.

The resources for the extension programme are drawn from the people and the government. For each block of 50 to 100 villages, development schemes will be conditioned by a qualifying scale of contributions of people in cash, kind, or labour. When state assistance is granted for project execution, expenses can be shared by the state and central governments; for recurring items each government may bear half the cost, while for nonrecurring items the state may bear three quarters and the central government one quarter of the cost. For productive work, like production and distribution of quality seed, the necessary funds can be advanced by the central government to the state or regional government in the form of loans. The central government may also bear half the expenditure for the personnel employed by the blocks.

In the state plan the block should be the basic unit of development and funds allocated accordingly. Each block should have a proper budget for local funds, which can then be supplemented by funds from the development department.

Conclusion

The use of improved seed is a crucial factor in improving agricultural production and farmers' income. It is important that recommended varieties be used by most of the farm population; therefore it is suggested that this task be confined to a well-established extension system which is capable of motivating farmers and training them in production techniques needed for the cultivation of the improved varieties. This system needs to work in very close collaboration with those agencies which establish policies and regulations for seed production, quality control, and marketing.

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