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QUALITY SEED PRODUCTION

A. J. G. van Gastel
J. Kerley
(editors)

International Center for Agricultural Research in the Dry Areas (ICARDA)

Quality Seed Production

Papers presented at the Seed Technology Course
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Editors:
A.J.G. van Gastel
J. Kerley

International Center for Agricultural Research in the Dry Areas
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Foreword

Constraints in many seed programs often stem from a lack of sufficiently trained seed-technology personnel. Training of seed technologists and analysts is, therefore, an important tool for strengthening national seed-production capabilities.

In 1985 an ICARDA special seed project, "Development of National Seed Production Organizations," was initiated. The project emphasized training and is funded by the governments of the Netherlands (DGIS) and the Federal Republic of Germany (GTZ).

Since the initiation of the project, several seed technology courses were organized. The genesis of this book was ICARDA's Seed Technology Course held in March 1986 in Egypt. The course was attended by seed technologists from the Nile Valley countries, Egypt, Ethiopia and Sudan. The course was supported financially by the Nile Valley Project, the Seed Production Project, ICARDA's core budget, and by the Central Administration for Seeds, Ministry of Agriculture and Food Security, Egypt.

On behalf of ICARDA, I would like to express my sincere appreciation to all contributors to the course; sponsors, lecturers and participants.

I hope that this publication will prove a valuable manual.

G. Jan Koopman
Deputy Director General
International Cooperation
ICARDA

Introduction

Improved varieties can help farmers increase yields, but only if seed is readily available. Yet in many parts of the ICARDA Region, seed production has not kept pace with the development of new varieties.

To remedy this situation, ICARDA is working hand-in-hand with national programs and seed companies to increase the quantity and quality of seed that is available to farmers. The center, in addition to its other seed-production activities, organizes training courses, produces reference books, and works to increase communication among seed specialists in the Region.

This book is part of that process. The papers in this manual were presented during the Seed Technology Course, held March 15-30, 1986 in Cairo, Egypt. The course dealt intensively with seed production in Egypt, Sudan and Ethiopia, and was intended primarily for scientists and technicians, such as seed analysts and seed inspectors, who are working with seed production on a practical level in these countries.

This volume, which includes only a selection of the papers presented during the course, is intended to meet specific needs. The first sections of the book deal with seed-production technology, and are intended to supplement another ICARDA publication, "Seed Production Technology," edited by J.P. Srivastava and L.T. Simarski. This volume covers topics that were not dealt with in that book. The two books, taken together, provide a general introduction to seed production.

The papers in the last sections of this book provide an overview of seed-production activities in Egypt, Sudan, and Ethiopia. The papers deal with seed production of specific crops and with the history of, progress of, and constraints to seed production in these countries.

We hope that both students and seed-production professionals will benefit from having this information easily available, and that the book will help spark a continuing exchange of ideas and expertise among seed-production workers in the ICARDA Region.

The editors would like to express their sincere appreciation for the excellent support of the Central

Administration for Seeds, Ministry of Agriculture and Food Security, Egypt. The efforts of Dr. A.S. Gomaa and his staff contributed considerably to the success of the course. The efforts of lecturers from the Agricultural Research Center and the Egyptian Seed Companies are also most gratefully acknowledged.

Dr. B. Bhardwaj and the staff of the ICARDA Cairo Office assisted in organization of the course. Without their support we would not have been able to conduct the course.

We also extend our appreciation to the consultants Dr. P.K. Agrawal (Head of Seed Science and Technology Division, New Delhi, India), Dr. Ahmed Abu El Gassim (Director of the National Seed Administration, Khartoum, Sudan) and Mr. Gugsa Endeshaw (Head of Seed Production, Ethiopian Seed Corporation, Addis Ababa, Ethiopia). Without their valuable contributions this book would not have been possible.

The Editors

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Wheat Breeding in Egypt

A.S. Gomaa
Under-Secretary for Seed Affairs
Ministry of Agriculture
Cairo, Egypt

and

O.H. Khalil
Director Wheat Research
Agricultural Research Center
Giza, Egypt

INTRODUCTION

Wheat, the main winter cereal crop in Egypt, is grown on 1.2 million feddans (approx. 500 000 ha). It is the staple food of urban areas and is blended with maize flour in rural areas. In addition, wheat straw is a source of fodder for animal feed, with the price of straw sometimes exceeding that of grain.

Wheat yields have increased from 0.8 t/feddan (1.9 t/ha) in 1950 to 1.6 t/feddan (3.8 t/ha) in 1985, an increase that is mainly due to the release of improved, high-yielding varieties. Accordingly, the total annual production has increased from 1.4 million tonnes in 1950 to approximately two million tonnes, despite the fact that the wheat growing area was reduced by at least 400 000 feddans (approx. 170 000 ha). However, Egypt faces a major challenge to feed its increasing population. Assuming present per capita consumption, Egypt will consume eight million tonnes of wheat each year. Thus, more than six million tonnes of wheat will need to be imported annually.

STRATEGY AND OBJECTIVES OF THE PROGRAM

The aim is to develop high-yielding varieties (HYV) that combine desirable agronomic attributes and good quality, and to define the cultural practices which will give farmers the best chance to realise the full potential of the newly released HYVs. A strong breeding program, a sound seed-multiplication program and vigorous extension work are all prerequisites for raising national yields.

In general, the program objectives are as follows.

- To develop high-yielding cultivars that are responsive to high doses of applied N and that use fertilizer efficiently. It is important that such cultivars should have the least possible interaction with N rates. That is, yield levels should not drop sharply with lower N rates, yet the cultivars should give high yields with increasing N rates.
- To produce stable varieties that have wide adaptability.
- To breed for disease and insect resistance.
- To improve stress tolerance to salinity, drought, and heat.
- To improve nutritive quality.
- To produce early maturing varieties that can be harvested in April. Such cultivars would make it possible to plant cotton after wheat or a short duration crop (soybeans or sunflowers) before maize, sorghum or rice. In this way the wheat area could be doubled and cropping intensity increased.
- To define optimal cultural operations for the newly released varieties.
- To produce basic seed at state farms.
- To upgrade applied and basic research capabilities.

WHEAT BREEDING: ITS HISTORY AND ACHIEVEMENTS

Wheat improvement started about 1920 when varieties such as Hindi D, Hindi 62, and Tosson were developed

from newly introduced Indian material. Some varieties, Baladi 116 (Triticum pyrimidale); Dakar 49 and Dakar 52 (T. durum), were selected from local material but their productivity was low and they were susceptible to diseases. They were never produced in large quantities.

By 1942 a program was developed to obtain stem rust resistant varieties by using material from Kenya. This resulted in Giza 139, which was resistant to stem rust, but unfortunately was attacked by leaf rust.

Since 1950 breeding has been based on greater genetic diversity rather than on large numbers of crosses of limited and related parents. As a result, the varieties Giza 144, Giza 145, Giza 146, Giza 147, Giza 148, and Giza 150 were evolved. These varieties are resistant to stem rust. Giza 144, resistant to both stem and leaf rust, was the most popular, but was attacked by stripe rust. Later, crossing work was intensified when new sources of rust resistance were introduced. As a result, Giza 155 was developed. This variety, resistant to stem and stripe rust, has a high tolerance to leaf rust, is early maturing, moderately resistant to lodging, and has about 20% more yield potential than Giza 144.

Giza 156 has better yield potential than Giza 155, but is also susceptible to stripe rust, and is therefore recommended for growing in middle Egypt.

In 1962 dwarf genes were introduced in the breeding program. By 1975 this had led to the development of several high-yielding varieties that were resistant to lodging and disease and were responsive to high N rates.

Development of Giza 155, released in 1968, and Giza 156, released in 1972, were major achievements. These two varieties alone raised the national average from 2.6 t/ha in 1968 to 3.1 t/ha in 1972.

In 1973 two short-statured, high-yielding and fertilizer-responsive varieties, Mexipak and Chenab 70, were recommended for cultivation, in addition to Giza 155 and Giza 156. As a result, the national average reached 3.3 t/ha in 1976. Mexipak was eliminated from cultivation in 1977, due to shattering and disease problems. The widespread cultivation of Chenab 70 during 1976-1977 changed the leaf rust race spectrum due to the rapid build up of the pathogen population on

this variety. Therefore, its acreage declined during 1978, and it is no longer among the recommended varieties.

In 1976 Giza 157 and Sakha 8 were released. Both showed good resistance to the three rusts and to shattering. The durum variety, Mexicali (= Stork 'S'), was recommended for middle and upper Egypt, and was sown on 530 000 feddans (approx. 220 000 ha) during 1979-1980.

In 1977 Sakha 61 and Sakha 69 were recommended for cultivation. Both varieties outyielded Giza 157 and Sakha 8 by about 10%, and both exhibit stability in performance over all tested sites. In 1982 Giza 160 was recommended for upper Egypt, due to its tolerance to high temperatures.

Our projection for the 1980s is that the newly released high-yielding varieties will raise the national wheat yield to approximately 5 t/ha as compared with 3.3 t/ha during 1977/78 season.

Varieties and the year of their release are shown in Table 1.

Table 1. Improved varieties and their years of release.

Variety	Year of release
Giza 139	1947
Giza 144	1958
Giza 145	1958
Giza 146	1958
Giza 147	1958
Giza 148	1959
Giza 150	1960
Giza 155	1968
Giza 156	1972
Giza 157	1976
Giza 158	1976
Sakha 8	1976
Sakha 61	1977
Sakha 69	1977
Giza 160	1982

MAJOR PROGRAM ACCOMPLISHMENTS

The major accomplishments of the wheat breeding program are listed below.

- Breeding work has been extended to Sids and Shandaweel Stations in addition to stations at Giza and Sakha. Each research/extension center now supports an independent breeding program aimed at specific problems.

Giza (headquarters)	Basic research, germplasm maintenance, rust testing, and coordination.
Sakha (northern delta)	Rusts, high salinity, and drought resistance in the north coast region.
Gemmeiza (southern delta)	Rusts and varieties that give high yields with low inputs.
Sids (middle Egypt)	Aphid tolerance and breeding for high yield; durum wheat research.
Shandaweel (upper Egypt)	Heat and aphid tolerance; durum wheat research.

  Nine sub-stations serve as yield-evaluation sites.
- At each station, about 70 feddans (approx. 30 ha) are used for the breeding program. Materials are screened and exotic germplasm is introduced to meet specific objectives. Promising material is identified and field trials are performed in a number of environments to ensure widespread adaptability.
- A national series of four trials was established in 1980 for bread wheat, durum wheat, and triticale. In each stage the number of entries is reduced and the number of testing locations is increased.
- Sakha 8, Sakha 61, Sakha 69, Giza 157, Giza 160 and Stork 'S' were developed. Between 1979/80 and 1984/85, the national average increased from 9 ardabs/feddan (3.2 t/ha) to 10.5 ardabs/feddan (3.7 t/ha), an increase of 17%. This was mainly due to the replacement of lower yielding tall varieties, (Giza 155, Giza 156 and locals) with

higher yielding ones (Giza 157, Sakha 8, Sakha 61, Sakha 69, Stork 'S' and Giza 160).

- Six new varieties of bread wheat and two new durum lines have been developed and show promise. These are undergoing large-scale field verification.
- Twelve types of agronomy trials have been conducted to determine the optimum cultural practices for the newly released varieties. Results indicate that the most cost-effective application of nitrogen is a rate of 60 kg N/feddan (approx. 140 kg/ha). No response to phosphorus and potassium was found. Five irrigations were superior to three irrigations, particularly in middle and upper Egypt. Chiselling at right angles is the best tillage method. Drilling is superior to broadcasting. Foliar spray of major or micro-elements is not recommended. Mid-to-late November is the best planting time. Corrugation-type furrows for irrigation increase grain yield by 19% over the small basins used by most farmers, and increase water use efficiency.
- About 4 000-5 000 feddans (approx. 1 700-2 100 ha) are allocated on state farm fields to breeder and foundation seed production.
- On-farm trials are conducted in the main wheat-producing governorates, where the recommended production packages are evaluated in farmers' fields. Yield increases of 4-6 ardabs/feddan (approx. 1.4-2.1 t/ha) (40-65%) were obtained as compared with local seed and traditional practices. About two ardabs (300 kg) were due to improved seed.
- A production demonstration program, conducted jointly with extension staff, started in 1980/81. Since then both the area and the number of farmers have expanded steadily, increasing from 5 844 feddans (approx. 2 500 ha) and 6 363 farmers in 1980/81 to 65 146 feddans (approx. 27 000 ha) and 55 911 farmers in 1984/85. The data from yield and agronomy testing programs indicate that the tested package increases wheat grain yields by about 50% and straw yields by 30% on small holdings.
- Support programs involving physiology, cytogenetics, entomology, plant pathology and cereal quality are established. Interdisciplinary cooperation has increased.

Breeding of Faba Beans

S.A. Khalil
Head Food Legumes Research Section
Field Crops Research Institute
Agricultural Research Center
Giza, Egypt

and

A. Nassib
Director Field Crops Research Institute
Agricultural Research Center
Giza, Egypt

INTRODUCTION

Faba bean (Vicia faba L.), the oldest pulse crop grown for seed in Egypt, has a high nutritive value and is useful as a break crop in the cereal-rotation system.

The average cultivated area ranged from 104 793 ha in 1979 to 119 576 ha in 1985 with an average yield of 2.3 tonnes/ha during the past seven years (Table 1).

The area is located in three ecological regions, i.e. north delta (31%), middle (45%), and upper Egypt (23%). The average seed yield in the north delta region was lower (2.0 t/ha) than in middle Egypt (2.3 t/ha) and upper Egypt (2.6 t/ha). This was mainly due to foliar diseases, chocolate spot (Botrytis fabae) and rust (Uromyces fabae). Mohamed (1981) reported that losses caused by foliar diseases ranged from 22.8% to 55.7% at Sakha Research Station. Ibrahim et al. (1979) pointed out that crop losses as high as 50% have been reported in the north delta region, but losses normally range from 5-20%. Williams (1978) found that in Australia severe early rust infestations

Table 1. Faba bean area, yield and production in the north delta, middle, and upper Egypt during 1979-1985.

Year	North delta*			Middle Egypt**			Upper Egypt***		
	Area 1000 ha	Yield 1000 t/ha	Prod. 1000 tonnes	Area 1000 ha	Yield 1000 t/ha	Prod. 1000 tonnes	Area 1000 ha	Yield 1000 t/ha	Prod. 1000 tonnes
1979	31.5	1.9	58.9	46.0	2.2	100.4	27.3	2.8	76.4
1980	18.8	1.5	27.8	58.3	2.1	121.4	25.7	2.7	68.4
1981	30.7	1.9	60.0	42.7	2.0	83.9	26.4	2.4	63.9
1982	36.1	2.1	77.1	51.7	2.2	114.8	27.2	2.5	67.7
1983	42.7	2.2	95.5	51.6	2.5	127.8	27.3	2.6	71.4
1984	43.4	2.2	76.2	46.3	2.5	113.3	24.0	2.6	61.8
1985	40.1	2.3	92.7	54.9	2.6	140.8	24.6	2.8	68.4
Aver	34.8	2.0	69.7	50.2	2.3	114.6	26.1	2.6	68.3
% of total	31.3	-	27.6	45.2	-	45.4	23.5	-	27.0

* North delta governorates include: Alexandria, Beherah, Kafr El Sheikh, Domiatta, and Dakahlia.

** Middle Egypt governorates include: Gharbia, Sharkiya, Ismailliya, Kalubiya, Minofiya, Giza, Beni-Suif, Fayoum and Menya.

*** Upper Egypt governorates: Assiut, Sohag, Quena and Aswan.

could result in yield losses as high as 45%. In European regions where winter beans are usually grown, rust has not been a problem.

Root rot and wilt limit yields of faba beans in many parts of the world. Wilt is usually caused by Fusarium oxysporum f. fabae, a physiological race which is pathogenic only to V. faba. It has been reported in China (Yu and Fang 1948), Japan (Ikata 1951; Yamamota et al. 1955), Canada (Coulombe 1957), Russia (Dunin 1962), and Egypt (Ibrahim and Abdel-Rehim 1965). F. oxysporum f. pisi and F. oxysporum f. lupini, causing serious wilts on peas and lupins respectively, can cause a mild wilt in V. faba (Linford 1928; Kadow and Jones 1932). Kioshi Kogure (1979) reported that wilt becomes a problem when faba beans and other grain legumes are grown too frequently on the same land. In Japan, it is recommended that beans and other grain legumes be grown no oftener than once every four or five years in order to avoid diseases.

Unfortunately, suitable sources of resistance have not been found. However, some variation in resistance among different cultivars has been reported by Abdel-Rehim et al. (1968) and Hashem (1969) in Egypt; by Bojarczuk et al. (1972) and Tomaszwwski and Furgal (1979) in Poland; and by Kiselev (1976) in Russia.

Studies of Hashem (1969) in Egypt indicate a relationship between resistance and the B-alanine content of seeds, roots, and root exudates. In resistant seedlings, B-alanine was produced during hydrolysis of materials stored in the seed. Hashem and Abdel-Rehim (1967) reported that B-alanine occurred in the resistant cultivar Klein Thuringer, but not in the susceptible cultivar Baali. In 1968 they also found it in root tissue and root exudate of the resistant cultivar Erfordia.

Orobanche infestation is also a major constraint in Egypt, particularly in upper and middle Egypt. Strasburger (1908) described this parasite as a dreadful pest. It inflicts serious damage upon some cultivated crops and is difficult to exterminate. He demonstrated that after orobanche seed germinates, its haustoria penetrate the host roots, and its light-yellow, reddish-brown, or amethyst-colored flower-shoot appears above the ground. Shabatay (1939) listed five oro-

banche species in Egypt, including O. crenata, which attack faba beans. Guidice (1935), Strasburger (1908), Zaghloul (1929) and Chabrolin (1934) reported that a single plant produces 0.5 to 1 million seeds which only germinate when they contact roots of the host plant. Mahmoud and Mohamed (1953) found that germination of O. crenata seed requires a definite exudate secreted by the roots of V. faba just before and during flowering. The parasite spikes constantly appear during the growing period of the faba bean.

FABA BEAN BREEDING METHODS

Pure Line Breeding Method

- A large number of selections are made from the genetically variable original population.
- Progeny rows, from the individual plant selections, are grown for observational purposes. The selections are grown under different environmental conditions. Frequently disease epiphytotics are required to distinguish between resistant and susceptible types.
- Selections are evaluated in replicated trials to compare the promising selections with each other and with commercial varieties for relative yielding ability and other aspects of performance. This stage lasts at least three years.

Mass Selection

This method can improve land varieties. Such varieties include lines that mature too early or too late, are disease susceptible, or for other reasons do not contribute their full share to the total yield. When the unproductive and defective lines are discarded, the remaining lines retain the best features of the original variety in general adaptation and yield, and can be released to growers.

Pedigree Method

The main object of this method is to combine in a single genotype, desirable genes that are found in two or more different genotypes. In the pedigree method, superior types are selected in successive generations, and a record is maintained of all parental progeny relationships.

Selections begin in the F2 generation. Most hybrids will segregate, and every F2 individual plant differs from every other individual plant.

Selection in the F3 generation continues on a single plant basis, but emphasis is on selection from the superior families.

Selection in the F4 is similar to that in the F3 generation, but with more emphasis on selection among families. Many families will have become homozygous, but usually enough genetic diversity remains to make selection within families possible.

In the F5 the potentialities of individual families have usually become fixed.

Preliminary yield trials begin in the F6 or F7, relative yielding ability being used as an additional criterion in reducing the families to a number that can be handled in precise yield and quality experiments.

Bulk Population Method

Several hundred F2 plants are sown in a large plot. At maturity the plot is harvested in bulk, and the seeds are used to plant a similar plot in the F3. Single plant selections are made and evaluated in F4, F5, and F6, and these are evaluated in the same way as in the pedigree method.

Backcross Breeding Method

This method is used for improving varieties that excel in a large number of attributes but are deficient in a few characteristics. A series of backcrosses is made to the variety to be improved. During these backcrosses the character is maintained by selection. At the end of the backcrossing, the gene is trans-

ferred. Selfing after the last backcross produces homozygosity of this gene pair, resulting in a variety with the other desirable characters.

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Seed Quality and Vigor

Ahmed Abu El Gassim
Director General
National Seed Administration
Ministry of Agriculture
Khartoum, Sudan

SEED QUALITY

With the adoption of modern agricultural techniques, growers are becoming more aware of the importance of high-quality seed that is capable of rapid and uniform emergence under a wide range of environmental conditions.

Harrington (1971) and Ware and McCallum (1975) specified the main characteristics that constitute seed quality and that play a major role in the success or failure of a crop. These qualities are as follows:

- The seed must be genetically pure, representing the species or cultivar. The characteristics of the cultivar must be maintained through all the stages of multiplication. In addition, the certified seed that is distributed to the farmer must truly represent the cultivar named on the container or package.
- The seed must be cleaned, sometimes graded, and then tested for purity to determine the percentage of noxious weeds, seeds of other varieties and other crops, and inert matter.
- The seed must be free from pests and diseases. This can be achieved by producing the seed in disease-free areas, applying strict measures and, where appropriate, using seed dressings.
- The seed must be morphologically well developed, undamaged, and have the characteristics typical of

the species or cultivar.

- The seed must be sufficiently dry and must be kept in moisture-proof containers if it is to reach the farmer in proper condition.
- The seed must meet at least the minimum germination standard. Physiological quality includes seed viability and seed vigor.

SEED TESTING

Seed testing emerged as a means of providing the grower with a measure of true sowing value in order to protect him from the sale of impure and poor quality seeds.

The first seed-testing station, established by Nobbe in Germany about 1876, laid down the principles for seed testing, and by the beginning of the 20th century, many seed stations were established in Europe and North America. As seed trade developed between countries, seed testing played an important role in guaranteeing good-quality seed to the farmer (Brett et al. 1973).

A seed-testing conference was held in Hamburg in 1906 to promote uniform testing methods, and in 1921 a European association was formed, which became (in 1924) the International Seed Testing Association (ISTA).

By 1954, ISTA and the Association of Official Seed Analysts (AOSA) agreed upon the definition of laboratory germination as: "The emergence and development from a seed embryo of those essential structures which for the kind of seed in question are indicative of the ability to produce a normal plant under favorable conditions."

Frank (1950) suggested that tests made under optimum conditions using artificial substrates should be called germination tests, and that if the tests were conducted in such a way that the results were similar to those obtained in the soil, that they should be called seedling-vigor tests. Frank's view was generally accepted by the ISTA, and it led to widespread use of the term vigor by seed technologists.

Isely (1950) stated that certain differences

between seed lots cannot be detected under conditions favorable for germination. However, these differences appear when seeds are exposed to unfavorable conditions. In such situations they may make the difference between a good field stand and a totally unsatisfactory field stand. Delouche and Coldwell (1960) found that standard germination under controlled laboratory conditions does not adequately evaluate seed potential since the more favorable the germination conditions, the greater the contribution of weak, non-vigorous seeds to the germination percentage.

SEED VIGOR

The formulation of a definition of seed vigor has occupied ISTA and AOSA since their inception, yet no generally accepted version was adopted by them until recently. However, there is some consistency in definitions previously proposed by different workers (Perry 1972).

Isely (1957) defined vigor as "the sum total of all the seed attributes which favor stand establishment under favorable field conditions." In this definition, the primary factor influencing vigor in the field is the degree of susceptibility to attack by microorganisms. Environmental conditions such as temperature and moisture are important only to the extent that they shift the ecological balance in favor of the microorganisms. Therefore, this definition emphasises the role of microorganisms in the failure of low-vigor seeds to germinate.

Delouche and Caldwell (1960) modified Isley's definition of seed vigor to "the sum total of all seed attributes which favor rapid and uniform stand establishment in the field." They placed emphasis on seed with uniform stand establishment as a seed-quality factor, and included both favorable and unfavorable field conditions.

Isely and Delouche and Caldwell defined vigor in terms which refer only to the seed lot and not to the individual seed.

Woodstock (1965; 1969) put forward a broader defi-

nition, "that condition of active good health and natural robustness in seed which, upon planting permits germination to proceed rapidly and to completion under a wide range of environmental conditions."

Recently, the ISTA agreed to the definition by Perry (1978): "Seed vigor is the sum total of those properties of the seed which determine the potential level of performance of the seed or seed lot during germination and emergence." Here, seed performance under field conditions is incorporated as the most relevant parameter of vigor.

The term vigor is generally used to describe the physiological condition of the seed that governs its ability to produce a seedling rapidly in the soil and to tolerate a range of environmental factors. Seed potential or quality is determined by genetic characteristics combined with other factors such as dormancy, mechanical damage, and seed-borne pathogens.

CAUSES OF LOW VIGOR

Differences in seed vigor are usually observed as variations in one or more properties of the seed. Perry (1978) identified the possible causes of vigor differences as intrinsic variation due to genotype, and as variation induced by interaction between the external environment and the genotype. Factors which cause loss of vigor may also cause loss of viability, and a decline in vigor often leads to death.

The maximum possible vigor is determined by the genotype, but it may be modified by the environment during maturation, harvest, post-harvest handling, and storage. These environmental factors, acting either separately or together, can result in immature seed, variation in size, mechanical damage, deterioration in storage, or invasion by seed-borne fungi (Perry 1978).

In the literature, there is a general trend to accept that seed which is more mature at harvest, has greater vigor, and therefore greater potential to establish a new seedling. Seeds that are removed from the parent plant at different stages of maturity and that are exposed to different sets of environmental

conditions during post-harvest drying result in a heterogenous population with variable vigor.

Pollock and Ross (1972) stated that the causes of variation in seedling vigor that are associated with maturity and post-harvest drying of seed, differ according to the growth habits of the plants. They categorised plants into three general types.

- Type 1 plants are those with dry fruits that dehisce readily at maturity, such as carrots, onions, and certain members of Cruciferae and Compositae. These plants are generally grown for structures other than fruits or seeds, and their seeds are disseminated as soon as they mature. The crop must be harvested before the seeds are fully mature on the mother plant. Since these seeds are lost by shattering shortly after they mature, the practical problem is to find the most immature stage at which the seed may be harvested and still have the vigor required to establish a plant under field conditions. In practice, harvest must be timed to give a compromise between yield and maximum vigor.
- Type 2 plants, such as beans, peas, maize, and grains, have dry fruits that do not dehisce. The seeds are harvested when fully mature on the mother plant. A certain amount of force must be used in threshing to break the pod or fruit, and this may result in mechanical damage which can affect seed vigor.
- In type 3 plants, seeds are produced in fleshy fruits such as tomatoes and cucurbits, and the seeds are separated by acid or fermentation, then washed and dried. The process of seed separation is generally done in an aqueous environment.

Seed size is the most obvious of the several characteristics influenced by the environment during seed development. Within any seed lot and between lots of the same cultivar, there are variations in size (Perry 1978). Variation within a genotype may be caused by nutrition of the mother plant, position on the inflorescence, and stage of maturity at harvest.

Bedford and Mackay (1973) reported a positive correlation between field emergence and seed size in

carrot; Cochran (1974) reported that fewer and smaller seedlings emerged from small pepper seed. Kubka et al. (1974) found that in comparison with smaller seed, larger radish seed germinated better and had larger seedlings with bigger roots.

Mechanical injury during threshing, cleaning, handling, and planting is considered one of the most serious causes of low vigor. Nobbe found that machine-threshed seed was more injured by subsequent copper-sulphate treatment than was hand-threshed seed, because the machine damaged the seed coat, allowing the chemical to penetrate the embryo. The drier and more brittle the seed crops, the greater the threshing injury. Harmond et al. (1961) found that mechanical damage may result from contact of seeds with hard surfaces or other seed during cleaning. Mechanical damage can also occur during planting. Hubbert and Whitney (1934) reported 10% injury to a large, smooth, pea seed during planting with a grain drill, and suggested that seeds should be mixed with graphite to minimize this damage.

Mechanical damage, apart from curtailing the food supply available during germination and the early stages of growth, provides a focal point for microbial attack (Chetram and Heydecker 1967). Toole and Toole (1960) found that the viability of stored garden-bean seed decreases most rapidly in lots with the greatest mechanical damage. The rate of deterioration, which differs from species to species, increases as the temperature and relative humidity increase. Onion seed is among the most sensitive, while peas and beans have a longer storage life (Sijbring 1963). Welch and Smith (1973) reported a decline in the vigor of lettuce seed as measured by seedling root length (at 85% relative humidity and 35° C) regardless of seed size, and the loss of vigor was evident before any decrease in viability was detected.

Herbicides and pesticides applied to control weeds and pests, could affect the seed vigor of the crop. However, the benefits from their use in terms of protection and improved yield are so great that their direct and indirect effects on seed vigor tend to be ignored. Austin and Longden (1968) revealed that pesticides applied to the mother plant may either improve or impair the germination and vigor of the progeny

according to circumstances. They also reported that incorrect desiccant application to seed crops, to hasten drying and facilitate threshing, may prematurely halt embryo development and result in low-vigor seed.

Olympio (1980) studied the effect of sub-lethal doses of 2,4-D and simazine on seed yield and quality, and found that the yield of lettuce seed was not affected by the herbicide but that it improved seed-quality as measured by seedling root length, percentage of vigorous seedlings, and seedling dry weight. 2,4-D applied at the 5-7 leaf stage resulted in increased seed yield and quality. Olympio also investigated the effect of certain desiccants (paraquat and diquat) on the yield and quality of rape seeds. Both affected seed quality, but increasing the rate of diquat to 10% or more than the recommended dose decreased seed quality. Olympio studied the effect of sub-lethal doses of the herbicides trifluralin and diphenamid (used for weed control in tomatoes) on seed yield and quality. The recommended rate of trifluration increased seed yield, while diphenamid decreased seed quality.

TESTS FOR SEED VIGOR

Vigor tests have been devised to measure the ability of seed to germinate and produce useful growing plants under the range of field conditions that can reasonably be expected for the geographical location and kind of crop in question (Woodstock 1973).

Heydecker (1969) said that vigor tests should be cheap, easy to perform on a large number of samples, and that the tests should produce reproducible results that can be objectively assessed, clearly recorded, and meaningfully interpreted.

Virtually all available vigor tests are less than satisfactory in at least one of these aspects. The Vigor Test Committee of the ISTA suggested that several tests should be used because no single test satisfies all the requirements (Perry 1978).

McDonald (1975) divided vigor tests into three main categories: physical tests that measure seed characteristics such as size, weight, or density; physiological

tests that utilize parameters of germination or growth; and biochemical tests that monitor the chemical reactions involved in cellular maintenance.

Physical Tests

Tests of seed characteristics are inexpensive, quick, can be conducted on a large scale, and show positive correlation with vigor (McDonald, 1975). The major feature of seed development is the accumulation of nutrient reserves, which is directly correlated with vigor. In cleaning, volume and density of seed size are used to separate high- and low-vigor seed (Pollock and Ross 1972). It has been also shown that the size-vigor relationship is a reflection of seed maturity. In addition, Smith et al. (1973) used physical parameters such as seed thickness and weight of lettuce seed to determine which parameter could be used to separate high-vigor seeds from low-vigor seeds in a slant test. The average length of the roots of all normal germinated seedlings is also used as a measure of vigor. Heavy seed produces longer roots, and removal of small and light lettuce seeds results in substantial improvement in vigor.

Even though the majority of studies show a positive relationship between seed size and vigor, other reports demonstrate an uncertain association between seed characteristics and vigor. For example, Lang and Holmes (1964) showed that neither germination percentage nor rate of germination was influenced by seed size in swede (Rutabaga). However, Perry found differences in pea emergence with different seed sizes, while Welch and Smith (1973) found that vigor was not influenced by seed size in lettuce.

Peiffer et al. (1972) suggested the rate of imbibition as a vigor test. Seed which require 1 hr of immersion are inferior to those which need 24 hrs to imbibe. However, little work has been done to confirm this as a reliable method for vigor testing.

Seed-coat color was used as a vigor test by West and Harris (1963) in alfalfa and by Gugnani et al. (1975) in cabbage. Off-colored and dark seeds give poorer germination and less root growth. Further investigation on the relationship between this seed

character and vigor are needed to establish this method.

Physiological Tests

There are two types of physiological tests; those that are used when germination occurs under favorable conditions (standard germination, speed of germination, and seedling evaluation tests), and those carried out under unfavorable conditions such as stress conditions.

Standard Germination

In many cases, this test has been shown to be a reliable vigor test under optimum field conditions. It is rapid, inexpensive, requires no specialized equipment, and does not require additional staff training. The main criticisms are the difficulty in standardizing variables such as moisture and temperature, since lack of standardization affects the comparison of results between laboratories. Also, the test relies on the ability of the seed analyst to interpret the results, and this ability varies from one person to another.

Seeds that are capable of extending a root (botanical germination) may not necessarily be vigorous enough to establish a plant under field conditions. This has led to the development of seed regulatory test procedures to evaluate the potential of a seed for field establishment. However, regulatory tests are also the basis on which the marketability of seed is determined (Willington 1965), and this has inevitably resulted in an attempt to maximize germination by utilizing optimal conditions for germination (De Temple 1963). It is therefore not surprising that regulatory germination values frequently fail to provide an estimate of field emergence.

Speed of Germination

Under field conditions, only rapidly germinating seedlings can escape the pre-emergence soil pathogens (Larson 1961). There is fairly good agreement among agriculturists and research workers that speed of germination is an important aspect of vigor. Wanjura et

al. (1969) showed that early emergence of cotton is correlated with the greatest survival of seedlings and the highest yield of lint per plant. Among vegetable producers, the first counts of germination tests are frequently utilized to evaluate relative vigor among seed lots (Pollock and Ross 1972). Ching (1959) used 50% germination potential as an index for the vigor test of Douglas fir seeds. The problem of evaluating slowly germinating seeds in a lot was recognized by Koloweki (1926), who defined a coefficient of velocity in which the late germinating seeds contributed less than the early germinating seeds. More recently, formulae have been proposed for tree seed.

Seedling Evaluation

Proper evaluation of seedling performance needs to be developed to a more advanced stage than is possible on artificial media in the laboratory. Soil or compost may be more accurate media for later growth. Tonkin (1969) described a seedling evaluation method and stated that since the standardization of field soil is impossible, the use of specially prepared compost is preferred. This test is particularly valuable for checking the normal development of the plumular bud, since evaluation can be delayed until at least the first pair of true leaves has developed. Seeds are normally sown in compost and left in a growth chamber or glasshouse for 3-5 weeks, depending on the crop, time of year, and the temperature and light intensity in the glasshouse. A single count is made when seedlings are dug up, examined, and normal seedlings weighed. Seedlings weighing half or more than the largest are classed as vigorous seedlings, whereas seedlings weighing between half and one-quarter of the largest are noted as weak seedlings, although included in the final count. Seedlings weighing one-quarter or less are classed as abnormal, and are excluded from the final count. The main advantages of this test are that it is simple, inexpensive, and can be applied to a wide range of crops. The main disadvantage is the difficulty of standardizing variables, such as temperature and moisture, which have a profound effect on the results.

Stress Conditions

Seeds can be stressed either prior to imbibition or during the germination process. One method of evaluating vigor is to subject the seed to one or more of the environmental stresses then measure its response in terms of survival, rate of germination, rate of growth, and presence of structural abnormalities. The cold test and accelerated ageing tests have greater emphasis. Other tests involving soil moisture stress, and excessive water and soil compaction have been used on a limited number of crops but need further investigation and development.

Cold Test

Under field conditions, low temperature early in the season may cause injury or may slow germination so that the seed is more likely to be attacked by microorganisms.

The cold test is most widely used as an aid in evaluating hybrid maize seed (Isely 1950). Experienced farmers know that unfavorable conditions following planting favor rotting of the seed in the soil, and research has shown that the use of chemicals to protect the seed will improve the chances of obtaining a good stand. However, it is also evident that not all seed lots are influenced in the same way by unfavorable field conditions. Some appear to be able to germinate well after exposure to cold, wet soil, while others having the same initial viability exhibit strongly reduced emergence. Rice (1960) developed a laboratory test to detect and measure such differences between seed lots. Maize seeds are kept at 10° C for 5-7 days followed by germination at 30° C. Field soil infected with fungi such as Pythium sp. is used as a medium, and the test is carried out under high relative humidity. One seed lot of maize with 99.5% germination in sand at 30° C resulted in only 11% germination using the cold test procedure. Cold test results are valuable and widely used by the maize industry, but the results are difficult to standardize. It is especially difficult to obtain and maintain the soil fungal population in a uniformly active stage (Hooks and Zuber 1963).

Other scientists have investigated the cold test for soya bean, spinach, onion, and peas.

Accelerated Ageing

In this test, unimbibed seeds are stored under adverse conditions, usually at 40-45° C in an atmosphere saturated with water vapor. After a period, the seeds are removed from this environment and germinated (McDonald 1975). In general, this technique is inexpensive and does not require additional training of technical staff, but it is time consuming and has the same disadvantages as standard germination with regard to seedling counts. However, Delouche (1969) emphasized that many detrimental changes take place in a seed before it loses its ability to germinate.

Matthews (1980) found that seed lots which are indistinguishable in terms of germination levels could be at different stages of deterioration, and that when there are vigor differences between lots, the imposition of a standard, controlled period of deterioration would result in different germination levels after treatment. Matthews modified Delouche's accelerated ageing techniques into a test called controlled deterioration. In this test, a weighed sample of seed is placed on top of moist filter paper to increase the moisture content. The specific moisture level is attained when the final weight of the seed lot reaches the value calculated using the formula

$$\frac{100 - \text{original seed moisture content}}{100 - \text{desired moisture content}} \times \text{intial seed weight}$$

The partially imbibed seed is then held in a sealed aluminium packet overnight at 10° C to ensure even moisture distribution, followed by incubation in a water bath at 45° C for 24 hours. The seed is then germinated on a moist filter paper at the temperature recommended for standard germination, and the results are expressed as germination after controlled deterioration. This test is rapid, inexpensive, and suitable for a wide range of small-seeded crops. The main disadvantage is that more tests must be done to obtain consistent results.

Biochemical Tests

These tests are derived from methods originally developed to indicate seed viability. They are considered to be indirect methods of assessing seed value and are grouped into four general classes: vital staining reactions, enzyme activity not measured by staining reactions, leakage of metabolites, and respiration.

Vital Staining Reaction

This is called the tetrazolium test (TZ) and it relies upon the action of dehydrogenase enzymes. These enzymes release hydrogen atoms which react with the TZ molecule to form a water-insoluble red pigment called formazan (Grabe 1970). Seeds are pre-imbibed to activate the dehydrogenase enzymes and then submerged in 0.1-1.0% TZ solution. Following the recommended staining period, the seeds are removed from the solution, rinsed, and evaluated.

Lakon (1942) was the first to use TZ on cereals. He found that the staining pattern rather than the intensity was critical in evaluating the results. This method has been extensively used as a quick measure of seed viability, as it estimates the germination potential, appraisal of embryo soundness and diagnosis of cause of embryo disturbance.

The main criticism of the test is that is relies almost exclusively upon subjective judgement, and this can lead to inconsistent results. The test fails to detect phytotoxicity due to seed dressing, heat injury incurred from artificial drying, and seed dormancy.

The test is useful as an indicator of variability rather than vigor, but is difficult to apply to small vegetable seeds as the dissection to expose the embryo is difficult in these seeds.

Leakage of Metabolites

The ability of embryos to retain solutes is an important characteristic in determining leaching and seed vigor. Leakage may be due to a damaged seed membrane. Researchers have also noted a relation between field mortality, fungal infection, and level of exudation. Seed exudation probably stimulates fungal activ-

ity, which in turn causes pre-emergence disease in the field. Powell and Matthews (1978) indicated that cell damage during imbibition and loss of membrane structure in dry seed may be the underlying causes of solute leaching.

A recent proposal for practical tests of seed viability and vigor was based on increased electrical conductivity of steep waters. It is a rapid, precise, and simple procedure in which seeds are soaked in deionized water for 24 hours, after which the seeds are removed and the electrical conductivity of the water is determined. Weak seeds generally possess poor membrane structure, which results in greater electrolyte loss, so the water has a higher conductivity (McDonald 1975).

Other authors have shown that this method shows promise in detecting weak seed lots. Further investigations are needed using small vegetable seeds.

Respiration

Perry (1972) suggested two possible factors underlying the relationship between respiration and germination. Firstly, energy is provided to the embryo through respiratory activity. Secondly, the overall metabolic processes in the seed and seedling are related to total respiratory activity.

The relationship between respiration and seed vigor can be established by measuring oxygen uptake. Thornberry and Smith (1955) obtained 92% correlation between germination and respiration as measured by oxygen uptake. However, it has been suggested that respiratory quotients are more revealing than oxygen uptake alone. Anderson (1970) observed increased respiratory quotient with seed deterioration. This test is rapid and quantitative, and in some crops, especially cereals, it is positively correlated with field emergence. Its main limitation is the need for expensive equipment and skilled personnel.

Other biochemical tests, which include glutamic acid dehydrogenase activity (GADA), protein content, and adenosine triphosphate (ATP) production, have been tried in seed of a number of crops but, due to the high price of equipment and the lack of technical skill, their use is still limited.

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History Supporting Germination and Vigor Tests for Seed Quality

M. Odiemah
Agronomy Department Faculty of Agriculture
Tanta University
Tanta, Egypt

and

A.S. Gomaa
Ministry of Agriculture
Central Administration for Seed
Agricultural Research Center
Giza, Egypt

INTRODUCTION

One of the greatest hazards in agriculture is sowing seed that does not have the capacity to produce an abundant crop. Seed testing has been developed to minimize this risk by assessing the quality of seed before it is sown. The aim of testing is to determine the value of seed for planting.

Seed is a living biological product and its behavior cannot be predicted with the certainty that characterizes the testing of inert or non-biological material. The methods used must be based on scientific knowledge of the seed and on the accumulated experience of seed analysts. As seed moves across international frontiers it is tested in laboratories of different countries. Therefore, it is important that all laboratories use standard methods designed to give the same result within an acceptable range (Anon. 1985).

This paper reviews previous studies on seed quality, germination, and vigor.

GERMINATION

Germination is a major component of any seed-quality assessment. Reproducibility and uniformity of results are best achieved by germinating seeds under optimum conditions. Different species require different conditions, and deviation from these conditions can cause variations in germination percentages, particularly in poor quality seeds. The production of a visible radicle is often used as a physiological criterion of germination, but this is unsatisfactory as a measure of germination in seed testing because the seedling which develops may be abnormal and incapable of establishing a normal plant in the field. Therefore, under the International Rules for Seed Testing (Anon. 1985) seeds must be allowed to germinate until normal and abnormal seedlings can be easily distinguished. Normal and abnormal seedlings of the common crop species are described and illustrated in the Handbook for Seedling Evaluation (Bekendam and Grob 1979).

Evaluations of seed deterioration during storage indicate that germination percentage is a sensitive measure of seed quality (Houston et al. 1957). Standard germination has been shown to be an excellent predictor of field emergence under ideal field conditions (Tekrony 1973; Tekrony et al. 1974; Andrascik and Kecskemeti 1979). In this way, the conflict between the use of optimum conditions to test germination and the objectives of providing an estimate of sowing value has been resolved, but only when the seeds are sown in favorable conditions. Optimum conditions rarely, if ever, occur in the field. Even if temperature, moisture, and aeration are favorable, a mechanical constraint is imposed by the covering soil layer, and attacks by the soil microflora and fauna are common. As a result the proportion of seeds producing seedlings in soil is frequently less than the germination capacity (Perry 1981).

SEED VIGOR

Nobbe (1876) recognized that properties of individual seeds, such as germination rate and seedling growth, varied within a seed lot, and that averages of seed lots frequently differed. He gave the name Triebkraft (literally 'driving force') to this phenomenon and although it has been given a variety of names, the term seed vigor is the one most commonly used.

Any test designed to produce results similar to those that occur in soil should be called a 'seedling vigor test' (Franck 1950).

The International Seed Testing Association (ISTA) Congress in 1977 defined seed vigor as, "The sum total of those properties of the seed which determine the level of activity and performance of the seed or seed lot during germination and seedling emergence" (Perry 1978). Seeds performing well are termed high vigor seeds and those with poor performance are termed low vigor seeds. The definition also specifies aspects of performance associated with differences in seed vigor, i.e. "biochemical processes and reactions during germination such as enzyme reactions and respiratory activity, rate and uniformity of seed germination and seedling growth, rate and uniformity of seedling emergence and growth in the field, and emergence ability of seeds under unfavorable environmental conditions."

The effects of vigor level may influence mature plant growth, crop uniformity, and yield.

Seed vigor involves two components, germination and seedling growth (Ching 1973). Germination can be divided into three distinct but overlapping and interacting phases: (1) reactivation of a pre-existing system, (2) synthesis of enzymes and organelles for catabolism of reserves, and (3) synthesis of new cellular components.

Seed vigor has become very important in the past decade, because it is more closely connected to field emergence under stress conditions than the standard germination test (Johanson and Wax 1978; Tekrony and Egli 1977). Seed vigor may be generally defined as superior performance of a genotype after planting compared to the same genotype or other genotypes under defined experimental conditions. The growth increment

is dependent on the environment (McDaniel 1973). Differences in seed vigor are rarely observed in standard germination tests, because the conditions of these tests are optimal for seedling growth. However, in the field where conditions are often unfavorable for germination, the stress factors cause physiologically weak seeds to die or to germinate and emerge more slowly than their more vigorous counterparts.

The literature indicates no consensus on the relationship between seed quality, seed vigor, and yield. Variability could be due to differences in experimental techniques, environmental interactions, or variability in seed vigor (McDonald 1975). There have been reports of a positive correlation between seed quality, vigor, and yield for barley (Perry and Harrison 1977), oat (Grabe and Frey 1966), rice (Sittisroung 1970), sorghum (Camargo and Vaughan 1973), maize (Funk *et al*. 1962), and cereals (Hampton 1981; Stormonth 1978).

However, Abdalla and Roberts (1969) found no relationship between seed quality and yield for barley (*Hordeum distichon* L.), broad bean (*Vicia faba* L.), and pea (*Pisum sativum* L.) until the quality reached low levels. Egli and Tekrony (1979) obtained the same result for soybean (*Glycine max* (L.). Merr.).

Many results show that low vigor can deleteriously affect cereal yields (Stormonth 1978). Poor field emergence under sub-optimal conditions may be caused by the physiological and/or genetic constitution of the seed lots, rendering them unable to endure environmental stresses such as low or high temperature, anaerobiosis due to high soil-water content, and attack by microorganisms (Perry 1969; Perry and Harrison 1970; Bedford 1971; Ching 1973; Abdul-Baki and Baker 1973).

Agricultural practice would benefit from a laboratory method for vigor (Woodstock 1973).

BIOCHEMICAL CHANGES

During the first six hours of germination, wheat embryos from average and low vigor seed lots synthesise RNA and protein *in vivo* at significantly reduced rates, even when germinated at optimal germination tempera-

tures, compared with those of high vigor seed lots. Sub-optimal conditions amplify the differences. However, under optimal conditions, in vivo RNA and protein synthesis after 24 hours in wheat embryos show that low vigor embryos synthesize RNA at the same rate as high vigor embryos. This is not the case after 24 hours germination at 10°C, where low vigor embryos synthesize RNA at only 53% of the rate of high vigor embryos (Blowers et al. 1980).

Many biochemical changes take place in seeds when they lose vigor, and they might be associated with a change in the membrane properties of one or more organelles. Among these are increased leakage of sugars, amino acids, and inorganic salts, presumably due to increased permeability of the plasmalemma (Matthews and Bradnock 1968; Ching and Schoolcraft 1968; Takayanagi and Murakami 1968); reduced phosphorylation by mitochondrial preparations from seedlings of old soybean seeds (Abu-Shakra and Ching 1967); and reduced cytochrome oxidase and malic and alcohol dehydrogenases in maize seeds (Throneberry and Smith 1965), presumably due to changes in the properties of mitochondrial membranes. Protein and carbohydrate synthesis is also reduced, which may be related to changes in polysomes and Golgi bodies (Abdul-Baki 1969), and there is a decrease in phospholipids (presumably of the membrane type) due to accelerated aging (Koostra and Harrington 1969). Lipid breakdown has been attributed to the increased activity of storage fungi (Anderson et al. 1970). Spherosomes in infested seeds coalesce from large irregular masses, and the protoplasm shrinks away from the cell wall.

The initial slow growth rate of the embryos tends to continue during ontogenetic development into the seedling stage. The deleterious effects which are manifest in the slow germination and decreased growth rate of seedlings are often described as lack of vigor. A corollary of this lack of vigor is that the seeds and seedlings are much more susceptible to adverse conditions such as drought, cold, pathogens, and toxic chemicals, and ability for protracted heterotropic growth (Heydecker 1972).

Poor growth must be related to some impairment of mitochondrial activity. Abu-Shakra and Ching (1967) found that mitochondria isolated from slow-growing soy-

bean seedlings had a higher respiration rate, but lower oxidative phosphorylation rate, than that of fast-growing seedlings.

Genetic factors influencing seed vigor have been intensively investigated by many researchers. The study of biochemical mechanisms active in seed germination and vigor, which are under genetic control, has increased our understanding of vigor (McDaniel 1973).

SUMMARY

When seeds are tested for germination, optimum test conditions in terms of substrate, moisture, temperature, light, and in terms of testing time are used to ensure that maximum germination percentages are obtained. Optimum conditions are rarely encountered in the field and field emergence is often less than that predicted by the germination test.

In the germination tests seeds are considered germinable when they have fulfilled the criteria established in the definition for the production of a normal plant. No distinction is made between strong or weak seedlings. Such information would be useful since we can forecast that weak seedlings might soon deteriorate. Germination testing, therefore, does not provide a complete evaluation of seed lot deterioration or quality.

These weaknesses of the seed germination test have resulted in dissatisfaction among seedsmen and farmers. Consequently, attempts have been made to develop another or supplemental parameter of seed quality. This component is now known as seed vigor. Little effort has been directed towards standardizing these tests and determining which tests offer the greatest accuracy in measuring seed quality.

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Seed Health Testing for Seed Production Purposes in Egypt

Abdalla Mahmoud Abdelmonem
Head of Seed Pathology Research Department
Agricultural Research Center
Giza, Egypt

INTRODUCTION

Seed-borne infections not only affect germination, but are also important in starting disease epiphytotics. Therefore, seed-health testing laboratories in Egypt consider seed health to be as important for seed as germination capacity. Screening of seed before planting is a cheap and effective means for checking the spread of many seed-borne diseases in Egypt. Seed-health testing can also help determine the causes of poor germination or field establishment, and thus supplement germination tests.

Over the past two decades a number of high-yielding varieties have been developed, but many of these were discarded because they were susceptible to diseases. Many diseases causing substantial losses to field crops are seed-borne and can be prevented by careful selection, seed health-testing, and seed treatment.

In Egypt, agriculture is expanding and new areas are being brought under cultivation. If care is not taken, gains from increasing the area under cultivation may easily be offset by losses from diseases. Laboratory seed inspection is an important means for stopping the spread of diseases to new areas.

Techniques for seed-health testing, varying in sensivity and equipment required, are now available in Egypt and are practiced in seed-production programs. Seeds are tested at each stage of multiplication. Testing of breeder seed is especially important because this is the mother material for all future generations.

Trained staff conduct seed-testing in seed-testing laboratories and in the seed-health testing laboratory of the seed-pathology department. The choice of test depends on the properties of the seed and its infection, and on the aim of the health test.

So far, direct methods have been practiced at seed-testing stations. With these methods, the structure of the pathogens or symptoms of the disease can be observed directly, either macroscopically or microscopically, on the dry or soaked seed, in shakings, etc. These methods are fast, but they fail to indicate many important infections.

Recently, most seed-health testing has concentrated on using generalized or specialized tests to detect seed-borne pathogens, i.e. fungi, bacteria, viruses, and nematodes.

Generalized tests such as the blotter test and the agar plate test reveal diseases caused by a wide range of Fungi imperfecti. Specialized tests are used for detecting and identifying individual pathogens. Examples of these tests include the embryo-count procedure for loose smut of wheat and barley and the indicator-plant test for pathogenic races of fungi and bacteria or special strains of viruses. Selective agar media may also be used in testing seed for a special group of fungi, such as fusarium, but only in seed-pathology research projects.

Results are usually expressed in terms of the number of infected seeds as a percentage of the total number of tested seeds. In routine seed-health testing, as currently carried out at seed-pathology departments and seed-testing laboratories, much emphasis is placed upon laboratory incubation methods. Growing-on tests are rarely used in routine testing, because they require considerable space, greenhouse facilities or environmentally controlled rooms, and because they require more time than laboratory procedures.

Treated seeds may be difficult to test, as the pathogen may be so well protected within the tissues of the seed that it is not detected by a particular test. This problem can be overcome by washing the seeds in water to remove excess fungicide, before placing the seeds on the growth media.

The following seed-health testing procedures are commonly used in Egypt for cereal and food-legume crops.

EXAMINATION OF SEED WITHOUT INCUBATION

Dry Examination

This is used to detect the presence of impurities such as nematode galls (ear-cockle of wheat, Anguina tritici), bunt balls (common bunt of wheat, Tilletia caries, Tilletia foetida), and smutted kernels (covered smut of barley, Ustilago hordei). Discolorations, malformations, shrivelling, spots such as brown spot of rice (Drechslera oryzae), soybean mosaic virus, ascochyta infection of chickpea (Ascochyta rabiei), ascochyta infection of pea (A. pisi) and some bacterial symptoms can also be detected by dry examination.

Examination after Softening, Soaking, or Processing

This is used to detect nematodes (the content of anguina galls of wheat may be investigated in water) and fungal hyphae within the seed (Ustilago tritici, loose smut of wheat, Ustilago nuda, loose smut of barley in the isolated embryo, and downy mildews in the seed coats).

The embryo-count test for loose smut of wheat and barley may be summarized as follows:

- the sample is chemically treated to separate the husk and endosperm from the embryo;
- a washing apparatus is used to extract embryos (washing is done through sieves of different diameters, and the embryos are collected in the lowest sieve); and
- The embryos are placed in grooved plastic plates and examined for loose-smut infection.

Examination of Washings from Seed

Seed washings are used to detect surface-borne conidia. A shaker is used to obtain standardized washings, and samples of the suspension are examined under a compound microscope. The method is used to detect bunt of wheat and covered smut of barley, the

oospores of certain downy mildews, and the presence of fungi such as Pyricularia oryzae, Drechslera oryzae, and Trichoconiella padwickii in rice.

INCUBATION METHODS

The detection of seed-borne fungi is carried out by the incubation techniques recommended by the International Seed Testing Association (ISTA).

The Blotter Method

This method provides excellent conditions for fungal growth and is used to detect a number of fungi, such as Pyricularia oryzae (blast of rice), Drechslera oryza (brown spot of rice), D. maydis (leaf spot or blight of maize), Drechslera spp., Trichoconiella padwickii of rice, Alternaria spp., Fusarium spp., Ascochyta rabiei (blight or anthracnose of chickpea), A. pisi (anthraconose of pea), Macrophomina phaseolina (charcoal rot of soybean), and other fungi.

Deep-freezing Blotter Method

In this method, the seeds do not germinate, and thus identification and recording of the fungi become easier. The method has given good results in testing maize for Cephalosporium acremonium (kernel rot of maize), Drechslera maydis, and Fusarium moniliforme (ear rot of maize).

Agar Plate Method

This method is used for A. rabiei, A. pisi, Fusarium spp., and other fungi.

ECIAL METHODS FOR VIRUSES AND BACTERIA

The growing-on test in soil is used to detect rley stripe mosaic virus infection.

Indicator test "inoculation method" detects bean mmon mosaic virus and other infections.

Serological methods are used for many bacterial and ral infections and are carried out only in research ojects.

Seed-Borne Fungal Diseases in Cereals and Food Legumes

Marlene Diekmann
ICARDA
Aleppo, Syria

INTRODUCTION

Most crops are subject to attack by a variety of pests such as viruses, bacteria, fungi, nematodes, insects, and weeds. Hereafter the term pest will be used for any of these organisms, including viruses. The term pathogen is used for any organism able to cause disease, i.e. viruses, bacteria, fungi, and to some extent nematodes. The vast majority of plant diseases are caused by fungi, so we will concentrate here on fungal diseases.

In most cases, crops will tolerate attack by pests to a certain extent or will react with only slight yield losses. Sometimes, however, attacks result in severe yield losses and may wipe out a whole crop.

In general, plant diseases are recognized by certain characteristic symptoms such as yellowing, necrosis, stunting, wilt, and root rot. In some cases, the structures of the pathogen itself are clear signs of diseases, e.g. teliospores of rust and conidia of mildew. Any part of the plant is subject to disease, which may occur at any growth stage. The infection may be systemic, i.e. invading the whole plant, or restricted to the attacked parts of the plant.

Plant pathogens can be disseminated by wind (mildew, rust), water (nematodes), plants (viruses through Cuscuta), insects (viruses), man or man-made tools (nematodes), seeds (bunt, smut), and cuttings (viruses). It is generally accepted that a pathogen may be disseminated but not necessarily cause disease. If that is the case, the term transmitted is more accu-

rate as it includes infection. For example, spores of barley powdery mildew (Erysiphe graminis) are easily disseminated by wind. However, transmission of this pathogen occurs only if the spores meet a susceptible barley plant and if conditions are favorable for infection.

The same holds true for pathogens that are disseminated by seeds (seed-borne pathogens). For example, if wheat seeds are contaminated with Tilletia contraversa, this pathogen will be disseminated with the seeds to wherever they are planted. Again, we would use the term transmission only if infection actually takes place. If these seeds are planted in Egypt, the pathogen will most likely not be transmitted because environmental conditions are not favorable for spore germination.

For some pathogens, such as Ustilago nuda, transmission with seed is the most important, or even the only means of transmission. Tilletia spp. are potentially seed-transmitted, but may also be transmitted through the soil.

We must distinguish between seed pests and diseases where the seed is a "victim" (e.g. storage pathogens like Aspergillus flavus, storage pests like grain weevils and bruchids) and seed-borne pests and diseases where the seed is the vehicle of pest and pathogen dissemination (e.g. plant diseases such as bunt and smut). With some diseases, the seed is both the victim and the vehicle for dissemination. For example, seeds infected with Ascochyta pabiei have lower germinability and may transmit this pathogen.

Usually, storage pests and pathogens are well controlled because they may quickly destroy a seed lot and are easily detected. Optimum storage conditions help to suppress this group. In this introduction we will deal only with seed-borne diseases in the narrow sense.

Seed-borne diseases are of varying significance. The farmer, unless he is reusing his own seed, is concerned only if yield losses result from seed-borne diseases, while the producer of certified seed must expect rejection of a seedlot if a certain level of infection or contamination is exceeded. However, in the international transfer of seeds, complete zero-tolerance is required for specific pathogens because they may not occur in all countries.

It is difficult to obtain reliable data on the economic importance of seed-borne diseases. In some crops such as cereals and soybeans, about half of the total losses due to disease are attributed to seed-borne pathogens. We must distinguish between two types of seed infection.

1. The pathogen is present on or in the seeds and will only attack the seedlings derived from them, for example, loose smut (Ustilago nuda). This presents a relatively simple relationship between a percentage of infected seeds, disease incidence in the field, and crop loss.
2. The pathogen is present on or in the seeds, but may also infect the plants by other means during growth, for example, ascochyta blight (Ascochyta spp.). The relationship between seed infection and crop loss is much more complicated since it depends largely on conditions during plant growth.

SPECIFIC SEED-BORNE DISEASES

The number of seed-borne diseases is very large. In the literature, some 500 different plant species are reported to be hosts for at least one of over 1 300 different pathogens that are potentially seed-transmitted. There are probably very few plant species that are not hosts for one or more seed-transmitted pathogens. Cereals and legumes are among the crops that are seriously affected by seed-borne diseases. For wheat, at least 40 different pathogens are listed, for barley 31, and for faba beans 23 (Richardson 1979). Only those that are economically important will be mentioned here.

Wheat

The most important seed-transmitted pathogens of wheat are bunt and smut fungi, Fusarium, Septoria, Drechslera or Helminthosporium, and Anguina.

In the North African region, only Tilletia foetida and T. caries from the bunt fungi are prevalent. T.

contraversa requires low temperatures for infection and occurs mainly in areas that are covered by snow in winter. T. indica has a different mode of infection, requiring free water during crop flowering. Because of this specific requirement, T. indica is restricted to India, Pakistan, Afghanistan and parts of Mexico.

Loose smut of wheat is caused by Ustilago tritici and can result in significant yield losses, mainly if seeds are not treated. In some areas, flag smut (Urocystis tritici) is important.

Several Fusarium species are pathogenic on wheat and most, if not all, are potentially seed-transmitted. Climatic conditions determine which species prevail. In large parts of Europe Fusarium nivale causes considerable yield losses, while in North Africa, F. graminearum (scab) and F. culmorum (foot and root rot) are predominant.

Potentially important Helminthosporium species include H. sativum, causing spot blotch, and H. tritici-repentis, causing tan spot.

The wheat nematode Anguina tritici, which causes "ear cockle", is widespread in most wheat-growing areas, but rarely causes major yield losses.

Barley

Important seed-transmitted pathogens of barley are Ustilago, Drechslera or Helminthosporium, Fusarium, Rhynchosporium, and barley stripe mosaic virus.

Loose smut of barley (Ustilago nuda) is similar to loose smut of wheat. A different symptom and a different mode of infection is with Ustilago hordei.

Relatively high yield losses are caused by Helminthosporium spp., namely H. gramineum (stripe disease), H. teres (net blotch) and H. sativum (seedling blight, foot and root rot).

Fusarium spp. are largely the same as in wheat and cause the same diseases.

Rhynchosporium secalis causes the characteristic symptoms of scald and is seed-transmitted only to a relatively low extent.

Barley stripe mosaic virus is probably the only seed-transmitted cereal virus. Compared to other virus diseases of barley, such as barley yellow dwarf, it is

less important. However, since it does not occur in all barley-growing areas, it is of quarantine significance.

Lentils

Among the legumes, lentils are affected by relatively few diseases. Important seed-transmitted pathogens are Ascochyta lentis, Fusarium spp. (wilt), and some viruses. Yield losses due to these pathogens are usually less than in other legumes.

Chickpeas

The main diseases of chickpeas are ascochyta blight, and fusarium wilt, and root rot complex. They are potentially seed-transmitted, but are also transmitted by plant debris and other means. Under certain conditions, nematodes (root-knot nematodes Meloidogyne spp. and cyst nematodes Heterodera spp.) could also be of importance. They might be seed-transmitted in the sense that soil which could be infested with nematodes is frequently mixed with seeds.

Faba beans

Faba beans have a large number of disease problems. This is probably due to the fact that they require growth conditions that are also favorable for pathogen development, i.e. warm temperatures, high rainfall, or irrigation. Most of the pathogens, including a number of viruses, are transmitted by seeds. Among these are Ascochyta spp., Fusarium spp., Botrytis fabae, B. cinerea, bean yellow mosaic virus, broad bean stain virus, true broad bean mosaic virus, pea seed-borne mosaic virus, and Ditylenchus dipsaci.

Peas

The Ascochyta complex and different Fusarium species are important pathogens in peas. In certain

environments, bacterial blight, caused by Pseudomonas pisi, can be devastating.

Healthy seed, i.e. seed that is free from pests, is a prerequisite for a high-yielding crop. Seed health is a component of quality seed, as are viability, vigor, and purity. In seed-production schemes all efforts are usually made to supply farmers with pure seeds of a high germination capacity, but little emphasis is put on the health aspect in its narrow sense. Healthy seed can be obtained by producing seed in pest-free areas and with effective pest-control measures, field-inspection schemes, seed treatment, and seed-health testing. Usually a combination of these methods is used, since it is not feasible to rely on only one method.

In many cases, it is not possible to select areas that are completely free from pests. In some cases, however, problems can be avoided by preferring one site to another. For example, production of seed potatoes is recommended for windy areas, which are unfavorable for aphids, a vector of viruses. Also, ICARDA does not multiply seed at stations near the coast, where there is high pressure from fungal pathogens, but in drier areas like Tel Hadya near Aleppo.

During multiplication, a number of pests can be effectively controlled, such as Ascochyta spp. (blight), Ditylenchus dipsaci (stem nematode), and Bruchus spp. (bruchid weevils). Viruses can only be controlled through their vectors, mostly with insecticides. Seed-transmitted pathogens with only one generation per year, such as Tilletia caries, T. foetida (bunt), and Ustilago spp. (smut) cannot be controlled by foliar sprays.

Field inspection is carried out regularly for varietal purity, but is also important for seed health. Usually diseases express symptoms in the field, and so an idea can be obtained about the health status of the seeds. However, some experience is required, especially when dealing with low incidence and severity levels. Virus diseases may be symptomless in the field, but still transmitted in the seeds, while some other diseases, such as Karnal bunt (Tilletia indica), may be difficult to detect in the field.

For seed health testing a number of laboratory methods can be used to determine the health status of seeds (see Chapter on Introduction to Seed Health Practical).

Seed treatment is suitable for controlling a number of fungal diseases, and also to some extent insects, nematodes, and bacteria. Care must be taken to chose a dosage sufficient to eradicate the pathogens, but not to kill the seeds. Seed treatment was discussed by Diekmann (1986).

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Seed Storage and Packaging

P.K. Agrawal
Head and Coordinator
Division Seed Science and Technology
Indian Agricultural Research Institute
New Delhi, India

INTRODUCTION

All seeds lose viability during storage with a loss of vigor preceding the loss in germination. Loss of viability cannot be stopped, nor can viability be increased. The rate of this loss varies from species to species. Cocaine and cinnamon, for instance, lose viability in about 30 days, while Indian Lotus can remain viable for 237 years.

In practice, our concern is the longevity of a seed lot rather than the longevity of an individual seed. The ageing of a seed lot is not uniform. If the lot is homogeneous, the drop in germination can be steep; if the lot is heterogeneous, the decline may be gradual.

Despite inevitable losses in vigor and viability, it is almost always necessary to store seed. Storage times can range from six months (from harvest to the next planting) to 5-50 years for germplasm or breeder seed. Seed is often stored (18-36 months) as insurance against fluctuations in price and market demand, against shortages, and against future crops with poor yields or poor quality.

The purpose of proper seed storage is to minimize losses in vigor and viability.

ORTHODOX AND RECALCITRANT SEEDS

Seeds can be divided into two major groups based on their viability characteristics.

- Orthodox group: A decrease in seed moisture increases the period seeds will remain viable. Seed of pulses, cereals and oilseeds belong to this group and can be kept viable for one to many years depending upon storage conditions. Species vary considerably with respect to storability and can be roughly divided into good storers, e.g. okra and green gram; intermediate storers, e.g. cotton, sorghum, wheat, and maize; and poor storers, e.g. soybean and onion.
- Recalcitrant group: Normally these seeds have short viability periods under ambient conditions. Seeds of coffee, rubber, cocoa, and oilpalm belong to this group.

FACTORS AFFECTING SEED VIABILITY DURING STORAGE

If plants are grown under optimum conditions, at physiological maturity seeds have maximum germination and vigor. However, seeds lose viability during storage and this loss of viability is largely dependent on the following factors.

Genetic factors

Seed longevity is an inherited characteristic at both the species level (Table 1) and at the cultivar level (Table 2).

Lindstrom (1942, 1943) found that inbreds of F_1 single-hybrid maize differed considerably in germination percentage after 8-12 years of storage under ordinary conditions at Ames, Iowa, U.S.A. In crosses of short-lived and long-lived inbreds, the reciprocal F_1 crosses showed a pronounced maternal effect, although good longevity was dominant. Similarly, Haber (1950) concluded that the long-lived seed character was dominant over short-lived. Agrawal et al. (1981), while working with sorghum hybrids, found that seeds of hybrid CSH-1 retained their viability as well as did seeds of their good-storing female parent. However, in another hybrid CSH-5 the poor-storing pollen (male)

Table 1. Germination percentage of quality seed lots of ten species under ambient conditions of Delhi (Agrawal 1980).

Species	Months in store							
	0	3	6	12	18	24	30	37
	Germination percentage							
Pulses								
1. Moong	99	99	99	99	98	-	-	98
2. Lentil	94	94	94	93	93	-	-	25
3. Pea	85	86	85	84	85	-	-	47
4. Soybean	94	93	81	43	14	8	0	0
Cereals								
5. Paddy	89	93	93	89	86	85	-	13
6. Wheat	96	97	94	92	94	91	64	39
7. Triticale	95	83	81	79	74*	86	19	2
Vegetables								
8. Okra	94	94	92	94	94	94	-	73
9. Carrot	76	75	73	58	58	-	-	-
10. Onion	75	70	50	27	0	-	-	-

* 16 months after storage
- not determined

Table 2. Germination of five cultivars of paddy seed stored under insect- free ambient conditions (Agrawal, P.K., Unpublished).

Cultivar	Months in Store								
	0	3	6	9	12	18	24	35	40
Pala	89	90	90	88	89	91	47	0	0
IR-8	89	86	94	85	87	86	90	24	2
P-2-21	91	91	93	93	90	92	88	34	1
Padma	88	84	93	86	91	92	75	12	2
Cavery	90	87	91	86	-	88	75	15	0

parent was dominant. Singh (1985) studying storability of pearl-millet hybrids found that a good storer parent, whether male or female, was dominant.

Preharvest Factors

Location

Mackay and Tonkin (1967), while working on seeds of four forage species grown in different countries, found that red clover seeds grown in Canada and stored under ambient conditions at Cambridge, required 4 years to deteriorate to 80% germination as compared with 3 years for seed grown in England or New Zealand.

Weather

Two different lots of three cultivars of wheat seeds (One lot of each cultivar had received rain before harvest and/or threshing, while the other had not received rain) were analyzed for seed quality and storability (Agrawal and Dadlani 1984). The alpha amylass activity was found to be significantly more in rain-affected lots of all three cultivars. An increased amount of water-soluble sugars was found in the rain-affected seed lots, except in one cultivar (HD-2009), which resulted in increased leaching of sugars during inbibition of seeds. Then these seeds were stored under insect-free ambient conditions. No decline in seed germination was observed in those lots that were unaffected by rain, but significant decline in germination was observed in each cultivar which was affected by rain (Table 3, Agrawal and Dadlani 1984).

Seed Structures

It is well known that the presence of glumes (lemma and palea) in grasses has a positive influence on lifespan. Husk and chaff have an inhibitory effect on mold, suggesting that the increased lifespan of cereal seeds during storage is due to suppression of mold growth by the glumes. Oat and timothy seeds have a longer lifespan when stored with the glumes intact than they do when stored as machine-hulled caryopses.

Table 3. Germinability of wheat seeds, affected by rain, after storage under ambient conditions and after storage at low moisture (4%) at room temperature for 8 months. (Agrawal and Dadlani 1984).

Cultivar	Initial (July, 1982)	Germination (%) Storage under ambient conditions	Storage with low moisture at room temperature
HD-2009			
Rain unaffected	86(10)	90(6)	92(6)
Rain affected	84(14)	70(8)	76(10)
LSD (P=0.05)	2.8	10.6	8.9
(P=0.01)	N.S.	16.7	14.0
2. HD-2189			
Rain unaffected	84(16)	86(6)	86(12)
Rain affected	79(14)	50(14)	68(18)
LSD (P=0.05)	5.2	11.6	10.9
(P=0.01)	N.S.	18.1	17.1
3. OPAN-1676			
Rain unaffected	85(14)	88(8)	86(10)
Rain affected	70(12)	52(8)	58(18)
LSD (P=0.05)	14.6	12.8	10.5
(P=0.01)	N.S.	20.0	16.5

Values in parenthesis denote abnormal seedlings (%).
N.S. = Non-significant.

Generally, small seeds escape injury, whereas large seeds are more likely to be extensively damaged. Size, arrangement of essential seed structures, and composition are factors contributing to seed damage. Bean, lima bean and soybean are examples of seeds highly susceptible to damage. The large cotyledons and locations of the embryo axis represent structures that will tolerate only low level impacts. Spherical seeds usually give more protection than flat or irregularly shaped seeds (Roberts 1972). Of course, the spherical shape is mediated by other characteristics, such as relative exposure of vital parts (root and shoot axes), thickness and strength of seed coat, and brittleness of all seed parts at the time of impact.

Clark (1948) observed a high incidence of abnormal seedlings in onion. This may be because embryonic root tips of onion extend beyond the seed, a condition conducive to mechanical injury (Roberts 1972).

Hard seeds

Little information is available on the viability of hard seeds during storage. Hard seeds are found in the families Leguminosae, Malvaceae, Labiatae, Geraniaceae, Cannaceae, Convolvulaceae and Nymphaeaceae (Indian Lotus). Varying percentages of hard seeds of most species become permeable during storage. Softening depends largely on temperature and relative humidity. Hard seeds are regarded as viable. However, scientific papers attest to the fact that not all hard seeds are viable, for example, Goss (1926) and Toole (1939) for hairy vetch. Dead hard seeds have been reported in okra. In most cases involving cultivated crop species the presence of hard seeds does not extend the mean viability period.

ENVIRONMENTAL FACTORS THAT AFFECT VIABILITY DURING STORAGE

Seed Moisture and Relative Humidity

The amount of moisture absorbed by seeds depends upon relative humidity (RH). Seeds are hygroscopic; they lose or gain moisture depending upon the RH of the atmosphere in which they are stored. Relative humidity is a measure of the water vapor in the air relative to the amount that the air can hold at saturation at a given temperature. As air temperature increases, the water-holding capacity of the air also increases. If the absolute weight of moisture remains constant, RH decreases when air is heated and increases when cooled.

Each kind of seed attains a characteristic moisture content at a given RH at a particular temperature. This is called equilibrium moisture content (Table 4). Of the various compounds present in seeds, protein absorbs the most water, and carbohydrates slightly less. Starch absorbs very little water, and lipids do not absorb water at all.

If the seed moisture content is below the equilibrium of the storage environment, water vapor from the atmosphere will move into the seed until equilibrium is established. If seed moisture is above equilibrium, water vapor from the seed will move to the environment.

Seed moisture will change with changes in RH if seeds are stored in porous containers like cloth or hessian bags.

The rate seeds absorb or lose moisture varies with the type of seed and depends upon, in addition to the RH of the air, moisture content of seeds, seedcoat thickness, and the depth of the mass of the stored seed.

Temperature

Both seed moisture and storage temperature influence viability during storage. In general, the higher the temperature, the more rapid the seed deterioration at a given moisture level. Although low temperatures are more effective than higher temperatures for storing

Table 4. Seed moisture equilibrium at various levels of relative humidity at about 25° C (Wet wt. basis; American Society of Agricultural Engineer Handbook 1972).

	Moisture percent at indicated RH						
	15	30	45	60	75	90	100
1. Barley (*Hordeum vulgare* L.)	6.0	8.4	10.0	12.1	14.4	19.5	26.8
2. Corn, field (*Zea mays* L.)	6.5	8.5	9.8	12.2	13.6	18.3	23.0
3. Cotton, (*Gossypium hirsutum* L.)	-	6.0	7.5	9.1	11.5	18.0	-
4. Flax, (*Linum usitatissimum* L.)	-	5.6	6.3	7.9	10.0	15.2	21.4
5. Oat (*Avena sativa* L.)	5.7	8.0	9.6	11.8	13.8	19.5	24.1
6. Groundnut (*Arachis hypogaea* L.)	2.5	4.2	5.6	7.2	9.8	13.0	-
7. Rice (*Oriza sativa* L.)	6.8	8.6	10.7	12.6	14.4	18.4	23.6
8. Rye (*Secale cereale* L.)	7.6	8.7	10.5	12.2	14.8	20.6	26.7
9. Sorghum (*Sorghum bicolor* (L.) Moench)	6.4	8.6	10.5	12.0	15.2	18.8	21.9
10. Soybean (*Glycine max* (L) Meh)	4.3	6.5	7.4	9.3	13.1	18.0	-
11. Sunflower (*Helianthus annuus* L.)	-	5.1	6.5	8.0	10.0	15.0	-
12. Wheat, bread (*Triticum aestivum* L.)	6.7	8.6	9.9	11.8	15.0	19.7	26.3
13. Wheat, durum (*Triticum durum* Dest.)	6.6	8.5	10.0	11.5	14.1	19.3	26.6

seed, maintenance of low temperature is expensive, and temperatures above freezing, especially between 5° C and freezing, are adequate.

Heat from external sources penetrates slowly into the seed bulk. Diurnal temperature fluctuations usually only affect seed in the top few centimeters of the surface. The amount of heat produced by fungi, insects and other organisms invading the seed is considerably higher than the heat produced by dry or damp seed (Oxley 1948).

Important points to consider when building seed storage structures are:

- Mites do not develop below 5° C, nor insects below 15° C.
- Most storage fungi do not develop below 0° C.
- The effect of temperature on an organism is correlated with the amount of moisture present, because a rise in temperature corresponds with a decrease in the relative moisture in the atmosphere.

Interaction between Seed Moisture and Storage Temperature

Harrington proposed rules of thumb to measure effects of moisture and temperature on seed ageing. These rules are as follows:

1. Seed life is doubled by every decrease of 5° C in storage temperature when temperatures are between 0° C and 50° C.
2. Seed life is doubled with every decrease of 1% in seed moisture content when seed moisture content is between 5 and 14%.

These two rules apply independently and can be combined. Thus, seeds having 10% moisture and stored at 20° C will survive about as long as those with 8% moisture stored at 30° C. When these two rules are applied, the effects are geometric. Thus, if seed with a moisture content of 14% is compared with a second lot of the same seed dried to 13%, the latter seed will live twice as long; if dried to 12%, four times as

long; and if dried to 11%, eight times as long. Similarly, 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.

The rules of thumb may be considered as a rough guide and are not as exact as the nomograph of Roberts (1972). Roberts developed formulae to describe relationships between temperature, seed moisture content, and period of viability. From these relationships he constructed a seed viability nomograph, and this has been done for wheat, barley, rice, broad bean, onion and lettuce.

Gas during Storage

Attempts have been made to store seeds under air, carbon dioxide, nitrogen, helium and argon. Regardless of the kind of seeds or the atmosphere in the sealed container, only adequately dried seeds (about 4% moisture) retained their germination during long periods of storage. In most cases the added expense of using an atmosphere other than air appears unnecessary, since the advantage of such an atmosphere is only realized during storage of 40-50 years.

Oxygen is generally harmful for seed with a seed moisture content of about 10%, but is beneficial for storage if seed moisture content is sufficient (more than 25%) for repair mechanisms to operate.

Microflora, Insects and Mites

Fungi can be divided into two groups: field fungi and storage fungi.

Field fungi (Alternaria, Cladosporium, Fusarium, Helminthosporium, Pullularia) require a seed moisture content of 25-30% to grow. The damage done by field fungi is done by the time the seeds are harvested, and no further damage from them is likely to occur during storage.

Storage fungi are comprised of several "group species" of the genus Aspergillus and Penicillium. These fungi do not cause damage to seed during storage if the seed are stored in a relative humidity of 70%. The

storage fungi do not invade seeds to any large extent before harvest. These fungi may damage seeds by (1) decreasing germinability, (2) discoloring embryos or whole seeds, (3) producing mycotoxins, (4) heating, (5) developing mustiness and caking, and (6) total decay.

Insects can completely destroy the seed, but can be dealt with by adequate packaging and storage (although rodents may still cause damage). Insect multiplication can be reduced or eliminated by proper drying and by storage of seed at low temperatures; a difficult practice to achieve in a commercial store. Insects can be controlled by creating good storage facilities and by using insecticides and fumigants to prevent infestation.

Fungicides and Insecticides

Fungi and insects can be controlled by chemical treatment of seed. However, precautions must be taken when using such treatments; otherwise seed may be damaged. Injury to treated seeds depends on: the length and condition of storage; the rate and method of treatment; the kind of seed and its moisture content, and the condition of the seed coat.

SAFE STORAGE OF SEED IN BULK

The expected storage life of species and varieties should be considered when planning storage. If seed moisture does not exceed 10% during storage, seed of most species can be stored under ambient conditions for at least 18 months in order to meet the minimum limits of germination for seed certification.

When legume seed is infested by bruchids, complete loss of viability occurs within 2-4 months of storage. Since the physiological loss of viability is slow, attempts should be made to protect the seed from insect damage. To achieve this goal, good storage facilities must be provided, and proper care must be taken to prevent insect infestation.

Relative humidity and storage temperature are the two most important factors influencing seed viability during storage. Therefore, if seed is stored in places with low relative humidity and low temperature, it will lose viability very slowly. A RH of 70% is usually the maximum level for safe storage. Temperature of 20° C is considered very safe for seed storage, but in tropical countries like India there are few places that have a mean temperature of 20° C throughout the year, and it is costly to reduce storage temperature to such an extent. An upper limit of 30° C is a reasonable compromise (Agrawal 1976). Data for 30 years (1931-1960) of mean temperature and relative humidity have been analyzed in order to locate suitable seed storage places for different parts of India. Locations in India have been classified as good, moderate, poor, and very poor for seed storage (Agrawal 1976, Agrawal 1982). In places which have been listed as good, seed stores can be constructed with minimum insulation and no temperature control, while places listed as moderate need proper insulation.

A good seed store should have no windows and only one door and should have an entrance about 1 m above ground. There should be a rat-proof lip extending out about 20 cm around the building at about 1 m height. Such construction makes it difficult for rats to enter through the walls unless there are cracks in the foundation. The godowns must be rainproof, relatively moisture-vapor proof and insect proof. There should be no cracks in walls or floors. To control the inflow of heat, insulation of brick walls and ceiling may be considered. The seed bags should not be kept directly on the floor but on wooden pallets, and they should be kept at least 50 cm away from the walls. An exhaust fan may be used for ventilation when outside temperature is lower than the seed stores, but relative humidity of the outside air should also be kept in mind when planning to ventilate the seed store. If ventilation is used carefully it can reduce both temperature and seed moisture.

Seeds are invariably attacked by various insect pests during storage. In a few cases, such as in pulses, the insect infestation comes from the field. Insect infestation generally remains undetected until adults are seen. This occurs when there are internal

feeders. By the time these adult insects are detected, they have already destroyed some seed. To avoid losses and to keep seed free from insect pests during storage, one must adopt the following preventive and remedial measures.

Pre-storage Preventive Measures

- Before arrival of new produce, all processing and storage structures should be thoroughly cleaned, white-washed if possible, then disinfected with residual sprays of insecticide such as malathion 50 EC (one part in 25 parts of water : 5 litres per 100 m^2 area) or fenitrothion 50 EC (one part in 100 parts of water). Seed containers should be treated in a similar way to kill hidden insects.
- Seed should be cleaned and its moisture content reduced, preferably below 9%. Most insect species do not breed or multiply at such a low moisture content. The moisture content fluctuates during storage in cloth or hessian bags, but if the seed store is reasonably moisture-vapor proof the fluctuation in seed moisture content will be small.
- In most cases, insect infestation starts when seed is kept in preprocessing sheds or similar structures. Delays in processing and storage create problems, and seed can get badly damaged. In such cases, and in seed of pulses, where insect infestation (bruchid) comes from the field, seed lots should be fumigated under cover with aluminium phosphide (2 tablets of 3 g each per tonne, with an exposure of 5-7 days). Moisture content of seed should not be more than 12% during fumigation. This kills bruchid grubs hiding inside the seed, and seed then remains free from infestation during processing.
- Processed seed may be treated with benzene hexachloride (BHC) 5% dust (1 g per kg seed) or malathion 5% dust (premium grade: 0.5 g per kg seed). These treatments help eliminate early fumigation and protect seed from insect pests. Insecticide-treated seed should never be used as food or feed.
- New bags are preferred for storage in order to

avoid both insect infestation and mechanical mixture. If old bags are used, they must be thoroughly cleaned and treated with either malathion sprays or a fumigant such as ethylene dibromide (32 mg/l) or aluminium phosphide (1 tablet of 3 g per m^3 space), with an exposure of 5-7 days in airtight condition. Processed pulse seed that is free from insect infestation may be bagged in a thick-weave cloth bag which does not have any loose weaves. Bruchids do not easily penetrate such fabrics.

- Processed seed should be stored and stacked properly and should not be kept in an area where unprocessed or carryover seed is kept.

Care during storage

- Some seed is attacked by a large number of insect species, and others by only a few. Therefore, it is advisable to store different types of seed, such as cereal, pulses, and vegetables, separately. This helps in better management of insect pests.
- Seed should be inspected fortnightly. If any living insect or infestation is detected, seed must be fumigated under airtight conditions with any one of the following fumigants:

  (a) Alumunium phosphide: 2-3 tablets of 3 g each per tonne of material, or 1 tablet per m^3 space, with an exposure of 5-7 days (depending on temperature).
  (b) Ethylene dibromide (EDB): 32 g per m^3 space with an exposure of 5-7 days.
  (c) Ethylene dichloride carbon tetrachloride (3:1) EDCT mixture: 320-480 g per m^3 space with an exposure of 24-48 hours.

  Aluminium phosphide is the safest of these fumigants for the seed. Its repeated application does not impair seed quality. A maximum of three fumigations may be given at intervals of 40-60 days.
- After fumigation, seed godowns should be aerated and thoroughly cleaned with a brush or broomstick to remove all dead and dying insects. To prevent

reinfestation, surface treatment with malathion 50 EC or fenitrothion 50 EC or malathion dust 5% (3-4 kg per 100 m^2), should be given. DDVP (dichlorovinyl dimethyl phosphate: dichlorvos) can also be used (1%) for the treatment of processing sheds, because it has volatile action and is effective against flying insects.

- Surface treatment of seed godowns and processing sheds should be carried out every 2-4 weeks depending on the severity of pest occurrence. Alternate use of malathion, fenitrothion, and DDVP helps prevent reinfestation and insect resistance to insecticides.
- Seed godowns and processing sheds should be kept clean. All sweeps should be kept far away from the seed godown so that insects cannot breed and reinfest the seed.
- Extreme care should be taken when using these insecticides; they are highly toxic to humans.

Storage of Germplasm

Storage of germplasm for long periods requires special attention. Loss of viability is associated with chromosomal damage and mutations in the surviving seeds. Knowledge of the viability percentages will enable a reasonably accurate prediction of the amount of genetic damage in the living seeds (Roberts 1972). However, the genetic damage will not show up in the first generation. Therefore, it is important to store the breeders' materials carefully to ensure minimum loss of viability and genetic damage. As soon as viability of the breeding materials has fallen by 20-30% from the initial viability of 90-95%, the seeds should be regenerated.

Such seeds should be stored under controlled storage conditions. A guideline for storing seeds for longer durations is given in Table 5.

SEED PACKAGING AND PACKAGING MATERIALS

Seed should be packed in smaller units to avoid risks of physical gradients, particularly vapor pres-

Table 5. Suggested conditions for storing breeders' seed and germplasm.

Duration of storage years	Temperature (°C)	Relative humidity (%)
5 - 7	15 - 20	45 - 50
20 - 25	2 - 4	40 - 45
50 or more	-10	40 - 45

sure, which arise in large bulks. Packaging in smaller units makes identification, transportation, handling, and marketing easier. The choice of packaging materials and the amount of seed to be packaged will depend on factors such as the kind of seed, duration of storage, storage environment, seed moisture content, cost of packaging material, and geographical area where the seed will be stored.

Packaging materials can be classified into the following types:

- Moisture-vapor permeable containers, e.g. jute bag, cloth bag, paper bag, or multiwall paper bags.
- Moisture-vapor resistant containers, e.g. jute bag laminated with thin (200-300 gauge) polythene film.
- Moisture-vapor proof containers, e.g. tin cans, polythene bags of 700 gauge or more, or aluminium-foil pouches.

There are three types of commercially available polythenes, low, medium, and high density. Density differences are due to differences in molecular structure, and molecular structure determines the physical structure. Low density polythene is the most satisfactory for seed storage. Polythene deteriorates, although slowly, on direct exposure to strong sunlight or ultraviolet radiation. Therefore, it should be protected.

In India, certified seed of cereals, pulses, and oilseeds are normally packed in either jute bags or cloth bags. However, paper bags, cardboard boxes,

almunium-foil pouches, and polythene bags are used for packaging flower and vegetable seed.

If moisture-vapor proof containers are used for packaging flower and vegetable seeds, moisture content must not exceed a critical level, which varies for different kinds of seeds (Table 6). Therefore, adequate facilities should be available for seed drying.

Table 6. Safe seed-moisture levels for vegetable seed packaged in moisture-vapor proof containers and stored at ambient temperature.

Moisture (%)		
4.0	5.0	6.0
Pepper	Lettuce	Watermelon
Onion	Tomato	Carrot
Cabbage	Cucumber	Celery
Cauliflower	Brinjal	Pea
Radish	Muskmelon	Spinach
Turnip	Pumpkin	
	Squash	

Seed moisture may be kept at 5.0% for other kinds of seed stored in moisture-vapor proof containers.

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Control of Storage Pests

Marlene Diekmann
ICARDA
Aleppo, Syria

WHAT ARE STORAGE PESTS?

There is a wide range of storage pests. In general, any organism that reduces the quantity and/or the quality of stored grain or other food is a storage pest. This includes rodents, birds, insects, mites, fungi and bacteria.

ECONOMIC IMPORTANCE OF STORAGE PESTS

Losses due to storage pests, sometimes referred to as post-harvest losses, vary according to climatic conditions, crops, and storage facilities available. Quantitative losses are estimated to reach up to 30%. Qualitative losses (such as those that occur when Aspergillus flavus, a fungus producing aflatoxins, which affect germination) and losses in seed viability are more difficult to determine or even to estimate. In absolute figures the losses in food or feed stuff are much higher than in seeds, but the consequences of losses in stored seed may be more drastic. If the quantity of seed is reduced considerably, a country might need to import seed and become dependant on the world market. In addition, the imported varieties may not be suitable for the country's specific conditions, and unsuitable varieties inevitably result in poor harvests. For these reasons the prevention of storage losses in seed crops deserves special attention. We

will concentrate here on cereals and food legume seed, because of their great importance. A few special cases will be mentioned briefly.

RODENTS AND THEIR CONTROL

Rodents, mainly rats and mice, can be very destructive, not only to seed, but also to buildings, electrical wires (thus causing fires), etc. They can consume substantial amounts of seed, and damage packages. Different species of rats differ in their susceptibility to control measures.

An effective, though expensive, way of control is to build rodent-proof stores. However, due to the high costs of concrete buildings and silos, much seed stock is still stored in facilities that are easily accessible to rodents. Traps are cheap and efficient if the rodent population is small. Biological control by predators (cats, hawks, etc.) or pathogens (which cause rat diseases) depend on too many factors to be reliable.

The most widely used method of rodent control is poisoning, and a wide range of rodenticides is available. Those that are extremely toxic to humans have been replaced by less hazardous ones (anticoagulants). Poisoning of rodents can be effective in the long run only if reinfestation is prevented, e.g. by rat-proof buildings.

INSECTS AND MITES AND THEIR CONTROL

While mites play a role mainly by transmitting spores of storage fungi and by causing skin irritation and allergies in people who handle infested seed, insects can be very destructive to the seed. The most important storage pests for seeds are those that develop inside the grain. Others, like flour beetles (*Tribolium*) and mealworms, are more important in stored food grain.

Different species feed on cereals and legumes, and their different life cycles affect the appropriate control measures. In legumes, especially faba beans, Bruchus spp. infest seeds in the field, and the insects complete their life cycle in the store. There is only one generation per year, and no reinfestation in the store. However, Callosobruchus spp., and Bruchidius spp. are mere storage pests. The eggs are laid on dry seeds, and several generations develop in the store through reinfestation.

In cereals, only the latter type, the true storage pest, occurs. There are more than 20 different species, most of them belonging to the Coleoptera (weevils, beetles, grain borers), and some to the Lepidoptera (grain moths, mealworms). Most frequently encountered are the lesser grain borer (Rhizopertha dominica) and the granary weevil (Sitophilus granarius). Some of the storage insects, such as the Khapra beetle (Trogoderma granarium), are considered quarantine pests in some countries.

In general, development of insects occurs at faster rates as temperatures rise. About 35° C is the maximum for development, and about 38° C the maximum for survival. Of course there are differences among the different species, Rhizopertha dominica being an example of a heat-tolerant species. Below 0° C most insects cannot survive for more than two to three weeks.

In addition, a certain moisture level is required for insect development. Seed moisture of 10 to 11% is generally the minimum for insect development; and the number of insects increases with increasing moisture, up to a level where conditions are unfavorable for insect development and are more favorable for microorganism development (about 15-16%).

It is important to know the sources of infestation in order to control them. As mentioned, Bruchus spp. infestations develop in the fields. Spraying the fields with insecticides during the time of oviposition can prevent infestation, but may be too expensive unless other insects have to be controlled at the same time. Care should be taken to select insecticides that are not toxic to bees, since at least some plants will be at the flowering stage.

It is possible to get an indication of the level of infestation by looking at the seed after it is harvested. Infected seeds have characteristic dark spots, where newly hatched larvae have penetrated into the seeds. If high infestation levels are detected, the seed can be fumigated. This helps to stop larval feeding and will thus retain germinability. Moreover, since adults are carried with the seeds to the fields, fumigation will reduce infestation for the next season.

For the "true storage pests", there are many sources of infestation. An important one is contamination from stored infested seeds. Frequently, the stores have a hidden focus where a stock of insects survives attempts at control. This can be a crevice, corner, spilled seed outside the store, a nearly empty sack containing some leftover seeds, etc. It is extremely important to control such areas.

It is desirable to detect infestation at early stages before the insect population increases too much. It helps to carefully inspect the stored material at regular intervals. There are also methods for detecting infestations before they become clearly visible. Some are simple (flotation of grains), others very sophisticated (X-ray). However, insect infestations are mainly detected by visual inspection.

Chemical methods are most often used to control storage pests. When grain is stored for food or feed, there is concern that residues may be hazardous to warm-blooded animals. This is not a problem when the grain is to be used for seed. With seed, the main concern is the possible effect of chemicals on seed viability. In any case, the chemical should have a low toxicity to humans in order to protect the workers, as well as a high and long-lasting effectivity against a wide range of insects. Last but not least, it should be inexpensive. There is a difference between insecticides which kill the insect population and have a longer lasting effect (pyrethroids, organo-phosphorous insecticides), and insecticides which kill insects, but have no residual effect (fumigants). These insecticides are not true alternatives, but should be used in a complementary manner and in combination with storage sanitation.

There is a wide range of insecticides on the market. Table 1 gives some examples. There are several ways of applying insecticides.

Table 1. Insecticides for control of storage pests (Formulations for spraying, dusting, fogging, etc.)

Active ingredient(s)	Trade name(s)	Manufacturer
Bromophos	Nexion	Celamerck
Dichlorvos	Nuvan, Nogos, Vapona	Ciba Geigy, Shell
Fenitrothion	Folition, Sumithion	Bayer, Sumitomo
Jodfenphos	Nuvanol	Ciba Geigy
Lindane	Nexit, Perfektan, Lindane	Celamerck, BASF, Gustafson
Malathion	Malathion	American Cyanamid
Metacrifos	Damfin	Ciba Geigy
Phoxim	Baythion	Bayer
Pirimiphos-methyl	Actellic	ICI
Tetrachlorvinphos	Gardona	Shell

Dusting

Dusting is the easiest way; a powder formulation is either mixed with the seed, or applied in layers ("sandwich method"), or dusted over stacks. Dusting over stacks can prevent only reinfestation (e.g. after fumigation), since most powder insecticides do not penetrate the sacks well enough to control internal infestation.

Spraying

Spraying uses either a suspension (solid insecticide suspended in water, usually a wettable powder formulation) or a solution (liquid insecticide diluted in water). The suspension or solution can be applied with a knapsack sprayer. For suspensions, care

should be taken that the particles remain suspended and do not sink to the bottom of the sprayer. This can be achieved by using a special stirring device or by shaking the container frequently.

Fogging

Fogging is a technique used especially in stores. It requires special equipment and produces droplets that are much finer than those produced by spraying.

Evaporation

Evaporation uses volatile insecticides and can be used in special cases to control flying insects (moths).

Fumigation

Mainly, two products are used in fumigation, methyl bromide and aluminium phosphide (Table 2). These two, as well as others such as ethylene oxide and hydrogen cyanide, have the following features in common: they are active in the gas phase, they are hazardous to

Table 2. Fumigants for control of storage pests

Active ingredient	Trade Name(s)	Manufacturer
Ethylene dibromide (EDB)	Dowfume W	Dow Chemicals
Hydrogen cyanide (HCN)	Cydon	Degesch
Methyl bromide (MB)	Dowfume MC Haltox	Dow Chemicals Degesch
Aluminium phosphide Phosphine (PH3)	Phostoxin	Degesch

humans, and they have a good capacity for penetration into piles of sacks and other materials. This results in important prerequisites for fumigation. The most important is to hermetically seal the area. Where this is not possible, the piles of sacks can be covered with large plastic sheets, which should be overlapping by at least 50 cm and fixed to the ground by sand bags or other heavy objects.

Methyl bromide and aluminium phosphide have some marked differences. Methyl bromide is heavier than air and therefore tends to accumulate near the ground. For this reason fans should be used to distribute the chemical within the fumigated space. Methyl bromide also leaves residues in the fumigated seeds and accumulates when fumigation is repeated frequently. Therefore, it is more hazardous for operators. Methyl bromide is a gas at temperatures above 6° C, whereas aluminium phosphide comes in solid tablets or pellets, and is thus easier to handle.

Recommended concentrations depend on exposure times and temperatures. At a given temperature, the product of concentration and time required to kill all stages of insects is constant, which means that a high concentration requires a short exposure time, and a low concentration requires a longer exposure time. For methyl bromide, at 20° C this product of concentration and time (c x t) equals 166. So with a concentration of 80 mg/l a two hours exposure will be required, with 16 mg/l ten hours. For a concentration of 1 tablet per m^3 Phostoxin, exposure time should be three days at temperatures above 25°C, four days at 20° C, and five days at 15° C. Below 15° C, no fumigation should be executed. For a more detailed description, including recommended safety measures, see Diekmann (1986).

Storage in Controlled Atmosphere

A more recent development is the storage of grain and seed in controlled atmosphere. This method is often used to store fruits, particularly apples. The air in stores is replaced by an inert atmosphere of less than 1% oxygen, about 9% carbon dioxide and the balance nitrogen. This inert gas is generated in special devices that combust air with propane.

No storage pests can survive in this environment, and seeds retain their viability over years. Such a controlled atmosphere is much better for storage than normal air. However, this method is quite expensive. In addition to equipment for changing the atmosphere, it is absolutely necessary to have airtight stores in order to retain the inert atmosphere during the entire storage period.

SPECIAL CASE: POTATO TUBER MOTH

This pest attacks potato plants in the field as well as seed potatoes in the store. The damage in the field is minor and seldom results in severe yield losses. However, this pest does lessen the quality of the tubers for consumption.

The insect has several generations per year, depending on temperature. Stores with constant high temperatures offer ideal conditions. When the pest is controlled in the seed store, its cycle is broken. This prevents planting of infested tubers, and thus helps control the pest in the field.

Effective pest control in the store requires several measures.

- Only uninfested tubers should be stored.
- If there is infestation, it should be controlled by fumigation.
- Doors and windows should be protected with insect-proof mesh to prevent moths from invading the stores.
- Containers such as bags should be treated with malathion.
- Traps, such as pheromone traps or light traps, should be installed for monitoring infestation. To some extent they can also reduce the population.
- The store and its surroundings should be kept clean.

CONTROL OF FUNGI AND BACTERIA

Here we deal only with those fungi that infect seeds in the store, and not with the seed-transmitted fungi that cause plant diseases in the field.

Bacteria normally do not attack stored seed unless the moisture content is very high and the temperature has already been raised by fungi.

Fungi require a high moisture content to grow (minimum about 14% seed moisture), so they do not play a very important role in dry climates. The most important genera are Aspergillus and Penicillium. They are mostly saprophytes, which means they are unable to attack living tissue. They grow on dead cells of the seed surface, where they produce toxins, which cause seed decay and kill the embryo. Affected seed should not even be used for feed because of the toxins many fungi produce.

The best way to control storage fungi is to maintain low moisture and a low temperature in seeds and store. Fungicidal seed treatment often fails to give the expected results, because of lack of free water, which is required for many fungicides to become effective.

The use of propionic acid to control storage fungi is restricted to grain for feeding purposes.

In summary, the best control is accomplished with solid buildings and rigorous storage hygiene.

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Seed Production of Cereals

A.J.G. van Gastel
ICARDA
Aleppo, Syria

INTRODUCTION

In order to produce the grains needed to feed a country, the handful of breeder seed has to be multiplied until there is enough seed to plant large areas. Often several generations of seed growing are involved, and extreme care must be taken in the early generations in order to produce later generations of a high quality.

The production of seed and the production of a commercial crop can involve two completely different technologies. A flowering ley is considered low-quality food for animals, but flowering is a prerequisite for seed production. Hybrid seed production involves the growing of parent plants, of which the female must be detasseled (maize) or be male sterile. Commercial maize production does not involve any detasseling. Every farmer is not necessarily a good seed grower, and in many countries farmers are thoroughly screened before they can become seed growers.

In general, seed producers should be more quality than quantity conscious. They are often distinguished from commercial crop producers by their attitude towards contamination, not only of the crops in the field, but also of planting and harvesting equipment, means of transport, storage facilities, etc.

Fortunately, in cereals, seed production and commercial crop production are similar. Moreover, the majority of cereals are self-pollinators. These two features diminish the number of constraints. However, due to the similarity between the two production meth-

ods, grains can easily be mistaken for seed, and mixing of grain and seed in processing plants, where both commodities are processed, can easily occur. Moreover, since a poor seed crop can always be sold as grain, a seed grower might not be willing to give the seed crop the special care and attention it needs. The price difference between seed and grain also plays an important role. Is the extra premium for the seed grower sufficient to cover the farmers' extra efforts?

In this paper we will use the term breeder seed for the very early generations. Certified seed is the end product of the seed-production program. Basic-seed generations are intermediate stages.

LAND SELECTION

Seeds should, as much as possible, be produced in areas where: 1) the variety is adapted (to prevent genetic shift); 2) climatic and soil conditions are optimal (to avoid losing the crop due to climatic hazards such as frost and drought); and 3) the variety can be economically produced. This is extremely important for the early generations.

The land selected for basic seed growing should have been free from cereals for at least two years. Exceptions are often made if the land has been under exactly the same variety.

For certified seed growing, no cereal crop should have been grown in the preceding year and only other cereal species are allowed in the second preceding year.

Previous cropping for cereals could be clean fallow, pulses, vegetables, or industrial crops, but other cereal and forage crops should be avoided. Heavily infested fields with noxious weeds and weeds from which the seeds are difficult to remove upon processing should be avoided. In this connection, it is worth mentioning wild oats. Too many seed production fields in too many countries are infested with wild oats, a noxious weed which is very difficult to eradicate. Campaign-type measures must be taken to control this weed.

When selecting fields for seed multiplication, easy accessibility should also be taken into account. Such

fields can be more easily managed and field inspected than fields that are far away, and in cases of emergency, quick action can e taken.

Thus, with regard to land selection, the most essential prerequisites are the selection of easily accessible clean fields in the correct agroclimatic zone(s).

PLANTING AND CROP CARE

After the land has been carefully selected for seed production, the seed has to be planted. Seed bed preparation is the same for seed crops as for commercial crops. Slightly less than the optimum amount of nitrogen should be used; a crop that lodges badly cannot be inspected and will thus not be approved.

When planting one should remember that the maximum yield per hectare is not as important as the maximum multiplication rate. The more rapid the increase, the sooner a country will benefit from an improved variety. To achieve a rapid multiplication the seed rate is usually decreased, and the initial amount of breeder seed should be as large as possible.

Unpublished ICARDA data on seed-rate/yield relationships clearly show that decreasing the seed rate increases the multiplication rate (Table 1). Using

Table 1. Relation between seed rate and multiplication factor.

Seed rate kg/ha	Yield kg/ha	Multiplication ratio
17	3 500	208
28	4 100	149
69	4 700	67
128	4 000	31
193	3 800	19

these data, very high theoretical multiplication rates are obtained (Table 2). In practice, multiplication rates are much lower because very low seed rates are too risky. Upon producing certified seed, the areas become too large to use the low seed rates. Risks of failure will become too large. Therefore, certified seed is often planted at the normal or a slightly lower

Table 2. The influence of seed rate, yield/ha and initial amount of breeder seed on the multiplication rate.

Assumptions				
Seed rate (kg/ha)	128	17	17	basic 80 cert. 100
Yield (qx/ha)	40	35	35	basic 35 cert. 35
Initial amount of breeder seed (kg)	50	50	100	100
Calculation				
Basic seed				
area (ha)	0.4	2.9	5.9	1.25
yield (qx)	15.6	102.9	205.9	43.8
Certified seed				
area (ha)	12.2	605.5	1 211.1	43.8
yield (tonnes)	48.8	2 119.4	4 238.8	153.3
Multiplication rate	1 000	40 000	40 000	1 500

Field rejection and losses upon processing are not included.
qx = quintal (100 kg)

seed rate. Multiplication ratios of 11 000 have, however, been obtained (Nelson 1983).

A number of rows should be left unplanted for the farmer to walk through when he rogues the crop. The unplanted rows should coincide with the width of the tractor tires in order to minimize damage when the crop is sprayed.

Cleanliness: Not only the fields, but also the drills used for planting and the vans and trailers to transport the seed to the fields, should be completely clean to avoid any contamination.

To summarize, low seed rates coupled with high initial amounts of breeder seed, increase the multiplication rate significantly. Cultural practices are the same as for a commercial crop.

ISOLATION

The early generations (breeder seed), should be located in the middle of a field with the same variety. Upon harvesting, the surrounding area should be dealt with first, before the breeder seed is harvested. The early generations can be planted at two different locations to spread the risk of losing the complete generation.

For basic and certified seed, minimum isolation distances are usually prescribed depending on generation and crop. Since cereals are self-pollinating it is usually sufficient to have a small strip of land between fields to avoid mechanical admixtures. A physical barrier, such as a ditch between two fields, is preferred. For wheat-seed production in India, an isolation distance of at least three meters is required to separate it from a field of the same variety (not conforming to the standard). But in the Netherlands a strip of 0.5 m is required for separation of certified seed, and a strip of 1 m for basic seed.

If a certain species or variety has a relatively high percentage of outcrossing, larger isolation distances may be required. Fields planted with smut-susceptible varieties should have larger isolation distances. In Morocco, a 150 m isolation distance is

required if the loose smut infection is beyond 0.5%. In the Netherlands, only fields within 80 m are taken into account during field inspection.

There are often regulations concerning the number of varieties to be planted on one farm. In Tunisia, only one wheat variety can be multiplied on a farm. In the Netherlands two varieties of self-pollinating crops may be grown on a multiplication farm.

To summarize, isolation distances have only limited importance in the case of the self-pollinating cereals. Only in case of loose smut infection do they become very important. Growing only one variety per farm reduces the risk of admixture.

ROGUING

Roguing is carried out to maintain the varietal purity of the crop, and is an important aspect of seed production. When roguing, one must be careful not to attempt any selection; the genetic make-up of the variety should remain the same. For this reason, roguing in the early generations should be carried out by the breeder or under the supervision of the breeder.

In addition to roguing all plants which do not conform to the variety description, noxious weeds (wild oats, wild barley, *Vicia* spp., *Raphanus raphanistrum*, *Sinapis arvensis*, *Astragalus* spp. etc.) plants of those crops, and weeds which are difficult to remove upon processing (wheat in barley, barley in wheat, etc.), should be removed from the field. Roguing may need to be carried out several times. All tillers and roots should be removed. Off-types should be removed before they have flowered.

Plants with seed-borne diseases should also be rogued. However, *Ustilago* has done its devastating work once the plant has headed and roguing does not help. Therefore, the certification service often does not allow removal of smut-infected plants. Reports from India indicate that loose smut plants do head earlier and can thus be rogued before flowering.

To summarize, roguing is one of the most important aspects of seed crop care.

HARVESTING

Precautions are no less stringent at the end of the season when the crop is harvested. The cleanliness of the combine-harvester is extremely important. Early generations are harvested by hand or by plot combine and do not constitute many problems. It is, however, advisable to first harvest the surrounding area (which was planted with the same variety), then clean the plot combine before harvesting the early-generation multiplications. The plot combine should be cleaned between the harvesting of each different variety.

Basic seed and certified seed must be harvested with commercial combine-harvesters, which are often difficult to clean. The parts of the machine which may still harbor contaminating seed, even after thorough cleaning, are described by Feistritzer (1975). Before harvesting, the combine should be properly cleaned by running it empty for several minutes at high and low speeds. The first 500 kg should be discarded because of contamination still present in the combine-harvester.

During harvesting the straw and harvested seed should be checked at regular intervals, and the combine should be adjusted if necessary. Proper adjustment is essential in order to avoid spoiling and damaging a large proportion of the seed crop.

After the seed has been harvested, the vehicles and trailers to transport the seed should also be thoroughly inspected. Trailers to transport seed in bulk, elevators, conveyers, etc. may easily harbor contamination. Cleanliness during harvest is extremely important for seed production fields.

PROCESSING AND STORAGE

Processing

All commercial grain processing should be well separated from seed processing. A separate processing plant for the cleaning and treating of basic seed (with

different lines for different species) is ideal.

The cleaning of the seed processing machines (and the cleanliness of the plant) is very important. The cleaning machines should all be thoroughly cleaned, not only between different species, but also between different varieties. All sieves, cylinders and decks should be taken off and properly cleaned. Compressed air, brushes, etc. should be available at all places in the processing plant to properly clean the sieves and insides of all machines. Vacuum cleaners are indispensable. Let the machines run for several hours at full speed to discharge hidden grains.

Plan the early generations in the middle of the processing of the same variety, in the following sequence: certified seed, basic seed, prebasic seed, certified seed.

Every processing plant should have a complete set of hand sieves, a small air-sieve cleaner and an indented cylinder to determine the proper processing requirements. This is particularly important when a new variety is processed. It would also be useful to have a small seed-testing facility to permanently monitor the quality of the seed.

Seed treatment

Seed treatment is a powerful tool for controlling internal, external and damping-off fungi, and pests. Incorrect application levels can, however, significantly reduce germination and vigor.

Since the early generations of seed are a particularly expensive commodity, the loss of an early generation will have serious consequences with respect to the supply of certified seed. It is, therefore, always recommended to use the most effective chemicals for the early generations of seed, even if these chemicals are more expensive than less effective ones. For the certified seed, where the volume becomes very large, it might be too expensive to treat all seed with expensive chemicals. However, where renewal rates are low, a very positive effect is expected from treatment of certified seed.

Warning color: Since many chemicals contain toxic substances, it is important to add a warning color to

the seed-treatment compound. The more dirty-looking the color the better. This will prevent people from eating the seed. It is also advisable to add a warning on the tag such as "Treated seed, not fit for human consumption".

Storage

After the seed has been processed it often has to be stored. It is important to realize that poor storage can easily destroy the quality of the seed. All measures taken so far will have been for nothing without good storage (Gregg 1984).

SUMMARY

In cereal crops, seed production (basic and certified) and grain production are rather similar. Seed growing is, however, more quality-based than grain growing. Good seed growers can be recognised by their attitude towards contamination, not only of the crop in the field, but also in all other farm operations. Moreover, a seed crop needs some special care, and therefore seed growers usually receive a premium for the seed crop.

One of the differences between seed and grain growing is the interference of the quality-control authority. All operations may be checked by this agency, and the field may even be rejected as not suitable for seed. The seed grower often has to carry out roguing (removal of undesired plants) to make sure that the crop will be up to standard.

The growing of the very early generations of seed involves a different approach than has been discussed here, but breeders are usually responsible for these generations, not seed growers.

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Rice Seed Production in Egypt

A.F. Elazizi
Principal Rice Investigator
Field Crop Institute
Cairo, Egypt

and

M.F. Abdel-Kader
General Director Central Administration for Seed
Cairo, Egypt

INTRODUCTION

Rice is one of the major crops in Egypt, where it is both a basic food and an important source of export earnings.

The Arabs introduced rice about 600 A.D. It was initially recommended in the northern central areas of the Nile delta, where widespread salinity made cultivation risky and productivity low. Rice was initially used as a crop for reclamation of the salty areas, however the cultivated area has increased to more than 400 000 hectares, and the expanded area includes fertile and semi-fertile soils in addition to newly reclaimed land.

Rice has always played an important role in the Egyptian economy, and in 1917 the Ministry of Agriculture started to breed high-yielding, good-cocking rice varieties and took steps to maintain the genetic purity of the developed varieties.

SEED CERTIFICATION ENACTMENTS

Egypt has developed a fairly comprehensive seed program. Seed acts were proclaimed in 1926, 1932, 1960

and 1966. Certification was included in the 1960 act, and the 1966 act covered all aspects of the seed industry. There has been little change since 1960 when a new system for producing certified seed was initiated as part of the first five-year plan. The general seed policy was to produce and distribute enough certified seed to cover one-third of the total rice area each year.

AGENCIES INVOLVED IN CERTIFIED SEED PRODUCTION

The Rice Research Section of the Field Crops Research Institute, under the Agriculture Research Center, does the plant breeding and produces the breeder and foundation seed. The Agricultural Production and Experiment Station Sector (State Farms) produces the registered seed on state farms under the supervision of rice researchers.

The Central Administration for Seeds (CAS) produces certified seed through contracts with individual farmers, agrarian reform cooperatives, and other agricultural cooperatives. The CAS is further responsible for seed testing and seed certification. Its work includes the selection, supervision, and inspection of contract fields, the roguing of off-type plants, the sampling of seed for testing, and the distribution of certified seed to farmers. The CAS works closely with several other departments and agencies within and outside the Ministry of Agriculture.

The CAS has two rice-seed cleaning stations (Sakha and Gemmeiza) to clean foundation and registered rice seed. Seeds produced on contract and by other agencies are processed in six cleaning stations belonging to the Egyptian Agricultural Organization. All these operations are under the technical supervision of resident representatives of the CAS. There are two official seed-testing stations (Giza and Tanta). The Giza station is a member of the International Seed Testing Association. Each station handles more than 80 000 seed samples annually. The Agricultural and Cooperative Credit Banks (ACC) handle financing, purchasing, transporting, and supplying seed to the agricultural cooperatives.

DISTRIBUTION OF SEED

Farmers have full access to their own seed crop, and this has to be considered in any seed program. Egypt currently produces enough certified seed to cover about 50% of the rice area annually, and it aims to increase this to 60-70%.

The new rice varieties are designated for planting in specific governorates, and include: Giza 159, a salt-tolerant variety for newly reclaimed areas, northern delta districts with salinity problems, and Demietta; Giza 171, a variety used in Sharkia, Gharbia and Behira; Giza 172, a variety used in Kafr El Sheikh, Dakahlia, Demietta, and Fayoum; and IR 28, a long-grain, short variety grown in selected areas of all governorates. This separation prevents mixtures and ensures a homogeneous supply of paddy to each milling complex.

The rice seed production program applies to all registered varieties recommended by the Ministry of Agriculture. It is supported by an annual government premium of 20% over the current market price, in order to encourage the certified seed producers.

Table 1 presents the acreage and production in the different multiplication cycles of four varieties. Production of registered seed is sufficient to plant more than 25 000 ha of certified seed, which is sufficient for more than 60% of the total rice area.

CONSTRAINTS

Existing varieties have become contaminated and should be purified. New varieties should be released. The CAS contracts growers to produce certified rice seed. However, no complete inspection of fields is carried out, and certification relies on samples taken after threshing.

Samples are taken from lots of six tonnes and are tested for off-types and red rice. Approved seed lots are cleaned and sampled for grain weight, color, insect and disease damage, purity and germination. The CAS is

Table 1. Seed production results, 1985.

Variety	Class	Feddans	Tonnes
Giza 171	Breeder	0.25	0.9
	Foundation	50	159.0
	Registered	908	2 232.1
Giza 172	Breeder	0.25	0.7
	Foundation	39	80.4
	Registered	871	1 435.9
IR 28	Breeder	0.1	0.4
	Foundation	15	40.8
	Registered	318	968.3
IR 1626	Breeder	0.1	0.4
	Foundation	16	47.2
	Registered	194	969.0

1 feddan = 4 200m^2

under severe pressure to provide enough seed to plant 50% of the rice area. Therefore, it releases a "class B" seed that has a lower purity. This procedure increases the percentage of red rice and off-types, and millers complain about the low-quality rice.

This situation occurs for the following reasons:

- The seed-cleaning plants are old and are inadequate for a proper job. Hulled grain is not removed, and the percentage of small, unfilled grains, and of weed and grass seed is too high.
- Field inspection is almost impossible and control of transport and storage is very difficult, because many growers are contracted who have small plots (often of less than half a hectare).
- Grower identity is not maintained. Many small lots

are involved, and a single six-tonne sample represents several seed growers.

- Certified-seed growers receive only a small premium, and this does not encourage farmers to produce seed. Rice production is highly subsidized, and the government requires each grower to sell 1.5 t/acre (approx. 3.5 t/ha) to the government at a low price. The farmer may then sell the balance on the open market. This system restricts the quantity of certified seed available for seed purchases. Larger acreage is needed in order to produce the necessary amount of certified seed.
- Transport facilities are insufficient for the needed travel to seed producers' fields for inspection, sampling, and delivery of seed.
- The state farms where the breeder, foundation, and registered seed is produced have a record of production far below the national average. This complicates multiplication of registered seed due to the limited available acreage. The state farms also lack adequate machinery and budget to effectively perform the required production practices.

Maize Seed Production in Egypt

Abdrabboh A. Ismail
Deputy Director Maize Program
Agricultural Research Center
Cairo, Egypt

INTRODUCTION

Maize, the most important cereal crop in Egypt, is cultivated on 2 million acres (850 000 hectares), with a production of about 4.5 t/ha. Egypt's total production (3.7 million tonnes) does not meet the annual consumption of 5.5 million tonnes, so about 1.8 million tonnes are imported.

Experimental plots on research stations and in farmers' fields, as well as demonstration plots, continue to show that yields of twice the national average could be attained if low-yielding local varieties were replaced with new improved ones and recommended agronomic practices were followed. This would require a continuous supply of good quality seed, as well as an efficient extension system. The current concern is to produce seed of newly developed, high-yielding varieties; a composite (Giza 2), two double-crosses (Giza 202 and Giza 204), and two, 3-way crosses (Giza 309 and Giza 310). The immediate target is to have at least half of the maize acreage cultivated with hybrids and the other half covered with high-yielding composites by 1987. This will double the country's maize production.

There are three private seed production companies operating in Egypt, of which two are local (the National Seed Company and the Egyptian Seed Company) and one is a joint foreign/local venture (Misr Pioneer Seed Company). A seed-production unit was established in 1985 at the Field Crops Research Institute of the government's Agricultural Research Center.

The two local companies, along with the seed-production unit, produce only certified seeds of the composites and hybrids developed by the maize program, which in turn is responsible for providing all necessary foundation seed. The Misr Pioneer Seed Company produces seed of one double-cross hybrid (Pioneer 514) that has been approved, and conducts research at the Pioneer Research Station in Egypt to develop better hybrids.

SEED PRODUCTION OF THE COMPOSITE VARIETY GIZA 2

Seed production of open-pollinated varieties is not as complicated as that for hybrids, even though it requires the same isolation precautions throughout all stages of production.

Since farmers can save seed from their fields for 2-3 successive plantings without an obvious decline in productivity, the seed-production program for Giza 2 has been planned to produce seed for only one-third of the composite target area, i.e. for about 350 000 acres (approx. 150 000 hectares). Such an area would require about 5 000 tonnes of certified seed (seed rate 14 kg/acre; approx. 30 kg/ha).

The different steps of seed production are outlined below.

Breeder Seed

A total of 500 individual ears (females) are planted in a 4:1 (4 female rows: 1 male row) crossing block. A seed bulk of all the ears is used to plant the male rows. Rows are 12 m long and 80 cm apart with a plant-population density of 20 000 plants/acre (approx. 48 000 plants/ha) and a total area of about one hectare. Fields must be isolated from other maize plantings by a distance of not less than 300 m or by a minimum period of 21 days between plantings. Male rows are rogued prior to flowering to discard undesirable plants, while female rows are detasseled prior to pollen shedding. The progeny of an ear represents a half-sib family. Flowering data are recorded for all families.

Selection is based on agronomic performance i.e. higher productivity, resistance to diseases (late wilt and common smut), shorter plants, lower ear placement, earlier maturity, and good stand. About 250 families are selected. At harvest, the best 1 000 plants within selected families are harvested individually, then the rest of the selected plants are harvested as a bulk. Unselected families are discarded. A second selection is carried out on ear characteristics, keeping only the good ears with the varietal characteristics. A number of 500 individual ears are chosen, shelled separately, and stored for the next generation of breeder seed. Other selected ears are shelled together and only 1 tonne of seed will be saved for production of foundation seed.

Foundation Seed

The total area for foundation seed production is about 20 hectares. Fields must be isolated from other maize plantings by either 300 m or 21 days between plantings. Planting density is 17 000 plants/acre (approx. 40 000/ha) and roguing is practiced before flowering to discard plants with undesirable characteristics. Fields are mechanically harvested and the ears are dried in the open. An intensive selection is performed based on ear characteristics before selected ears are shelled. A minimum of 45 tonnes is saved for delivery to seed companies.

Certified Seed

The total area managed by seed companies for certified seed production is 1 500-1 700 hectares. Production is done through contracted farmers who must produce the crop following the required isolation conditions, otherwise their fields will be rejected. Harvested ears are dried in the open. Ear selection is mainly carried out on the farm under the company's supervision. The crop is then transferred to company facilities where the ears are shelled and seeds are processed, bagged, and stored.

Staff of the Central Administration for Seed, along with representatives of the maize program, periodically inspect seed-production fields for isolation measures and varietal purity. Samples of each seed lot are tested by the seed-testing laboratory and a certificate is issued indicating the percentages of germination, impurities, and insect infestation.

SEED PRODUCTION OF MAIZE HYBRIDS

Local hybrids

Egypt entered the field of hybrid development in the late 1940s, and commercial production of maize hybrids began in the mid-1950s. A local seed company undertook the certified-seed production operation under the supervision of the maize program and the seed-testing laboratory of the Ministry of Agriculture. The expansion in hybrid-seed production almost came to a halt in the early 1960s due to an outbreak of the late wilt disease, which resulted in drastic yield losses. The disease was not reported in any other country, and in 1963 the pathogen was identified as Cephalosporium maydis. Later, the disease was reported in India. The screening of available maize germplasm, as well as a large number of exotic inbreds, yielded a few resistant lines. However, these lacked the combining ability necessary for high-yielding hybrids. A program for developing resistant lines was initiated, and although a number of hybrids were developed, their performance was not satisfactory.

In 1981, some outstanding single and double crosses were developed. Because of the low productivity of the inbreds involved, the possibility of commercially releasing single crosses was temporarily abandoned. One double-cross hybrid, Giza 202, was released for commercial production in 1983 and recently, one new double-cross hybrid (Giza 204) and two 3-way crosses (Giza 309 and Giza 310) were proven to possess superior performance to that of the hybrid Giza 202. These hybrids will be commercially produced in 1986.

A seed-production plan was made to produce enough seed of these hybrids to cover 50% of the maize acreage (one million acres; approx. 425 000 hectares) by 1987. The Egyptian and National Seed Companies and the seed-production unit at the Agricultural Research Center will produce the certified seed (3-way and double-cross seeds), while the maize program will provide the necessary amounts of foundation seed.

Generally, seed-production fields must be isolated from other maize fields. Isolation can be established by maintaining a minimum distance of 300 m between fields or a time difference of 21 days between plantings. Planting is at the ratio of 2 female : 1 male for seed production of single crosses, and 1 male: 4 female for seed production of double crosses. Fields must be rogued to discard off-type plants. Detasseling of female rows must be performed properly, starting at tassel emergence. Breeder seed is produced by self-pollination, while foundation seed of the inbreds is obtained by sib-pollination.

Exotic hybrids

Exotic hybrids cannot be produced or marketed in Egypt unless they have been evaluated and approved. The evaluation program requires 1-2 years of on-station testing and 1 year of on-farm testing in farmers' fields. So far, the double-cross hybrid, Pioneer 514 is the only hybrid that has been approved for commercial production in Egypt. Most of the exotic hybrids appear to be highly susceptible to late wilt, because they were developed under different environmental conditions to those prevailing in Egypt. Some foreign seed companies such as Pioneer and Ciba-Geigy have now established their own research stations in Egypt to develop high-yielding, resistant hybrids.

Although the Pioneer hybrid 514 has been cultivated since it was approved in 1979, the area in 1985 was less than 80 000 acres (approx. 35 000 hectares). The reason for this limited expansion is the apparent increased susceptibility to late wilt. All certified seed is supplied by the Misr Pioneer Company through local production and importation. All seed-production fields are periodically inspected by staff of the Cen-

tral Administration for Seed and by the maize program. A new Pioneer hybrid (Karnak) is in the seed production stage to replace hybrid 514.

SEED PRODUCTION PLAN

A seed-production plan was designed to provide enough certified seed of recommended varieties (hybrids and composites) to cover half the maize acreage with hybrids and the other half with composites by the year 1987. This would be followed by a gradual increase in the area cultivated to hybrids to reach almost 90% by 1990. At the same time there would be a decrease in area under composites.

Target areas and amounts of certified seed for the hybrids and composites during 1985-90 are shown in Table 1. The quantities of seed of the composite Giza 2 shown in Table 1 are not compatible with the target area. The reason is that farmers can save seed for two successive plantings without the need to renew their seed stock. Accordingly, the amounts of seed shown are enough to cover only one-third of the target area.

Table 1. Target areas (1 000 feddans) and certified seed (tonnes) for hybrids and composites, 1985-1990.

	Composites (Giza 2)		Hybrids	
Year	Area	Seed	Area	Seed
1985	1 000	5 000	500	7 500
1986	1 000	5 000	750	11 250
1987	1 000	5 000	1 000	15 000
1988	750	4 000	1 250	18 750
1989	500	3 000	1 500	22 500
1990	250	1 500	1 750	26 250

* One feddan = 4 200 m^2

Faba Bean Seed Production

S.A. Khalil
Food Legumes Research Section
Field Crops Research Institute
Agricultural Research Center
Giza, Egypt

and

F. Abdul-Kader
Central Department of Seed Production
Agricultural Research Centre
Giza, Egypt

INTRODUCTION

Faba bean (Vicia faba L.) is the most important food legume crop that is grown for seed in Egypt. Quality seed of improved varieties is the key to agricultural progress, and seed is the carrier of genetic potential for higher crop production.

So far, Egypt has released three improved varieties for distribution, Giza 2, Giza 3, and Giza 402. However, the benefits of improved varieties cannot be realized until enough high-quality seed has been produced to allow the new varieties to be grown on a commercial scale.

Therefore, the agricultural policy of faba bean seed production in Egypt aims to cover 305 000 feddan (approx. 130 000 ha) with the three improved varieties, on the basis of three years replacement (Table 1).

Table 1. Faba bean seed requirements

Cultivar	Area feddan*	Annual cultivated area(feddan)	Certified seed requirements (ardab)**
Giza 3	70 000	12 000	6 000
Giza 2	35 000	16 600	8 300
Giza 402	200 000	80 000	40 000
Total	305 000	108 600	54 300

* One feddan = 4 200 m^2
** One ardab = 155 kg

IDENTIFICATION OF CULTIVARS

There are three types of faba bean; large-, medium-, and small-seeded. It is relatively easy to differentiate between the three types, but within a given type it is often difficult to differentiate one cultivar from another.

Nevertheless, there are criteria that can be helpful in making such differentiations. Some of the important characters are: Plant height, days to 50% flowering, color of flowers, number of days to maturity, pod length and shape, 100-seed weight, and seed coat and hilum color

VARIETIES

All three recommended varieties Giza 2, Giza 3 and Giza 402 are characterized by medium-sized seeds, black hilum, black-spotted wings of flower, and by light-brown seed coat covers. Differences among the three varieties are shown in Table 2.

Table 2. Comparison of the three faba bean varieties that are recommended for use in Egypt.

Characteristics	Giza 2	Giza 3	Giza 402
Tolerant/resistant to		chocolate spot and rust diseases	orobanche
Plant height (cm)	60–100	70–120	80–130
Days to 50% flowering	45–50	50–55	80–130
Pod length (cm)	5–7	6–8	7–9
100-seed weight (g)	45–50	50–60	65–70
Release to farmers	1955/56	1979/80	1980/81
Recommended for	middle Egypt	north delta region	upper Egypt and to gradually replace Giza 2 in the southern governorates of middle Egypt

STAGES OF MULTIPLICATION

There are five stages involved in seed multiplication i.e., production of breeder seed, nucleus seed, nuclei seed, foundation seed and certified seed. In Egypt, the Food Legumes Research Section produces the breeder, nucleus and nuclei seed. Contracted farmers produce the foundation seed and the certified seed (1 800 feddan; approx. 750 ha).

PRECAUTIONS FOR SEED PRODUCTION

Precautions are taken at each stage of seed production in order to ensure high-quality seed.

- Proper basic seed of each variety is grown in a suitable area. Seed-production specialists should select the land and growers as early as possible.
- Representatives of the Central Administration for Seeds and the Food Legumes Research section make field inspections to check roguing of off-types and other factors that might influence genetic purity, and later make inspections to observe harvesting, seed cleaning, storage and labeling. They sample each seed lot and inspect the samples for purity, insect damage, germination and other factors affecting quality. Seed is either accepted (certified) or rejected on the basis of these tests.
- The seed is transported to seed-processing stations, where it is cleaned and fumigated against bruchid infestation. In most cases only one variety is processed at a time at each station.
- Seed is tested for impurities such as seeds of other crops, weed seeds, and inert matter such as broken seeds, chaff, pieces of leaf, and soil particles.
- A germination test, which distinguishes between normal and abnormal seedlings, is performed in the laboratory. This is important, because there appears to be a close relation between laboratory germination and field emergence.

- Seed is sampled for seed-borne diseases, an important process because a number of fungal, bacterial and viral diseases can be seed transmitted. The demand for seed-health testing is increasing, because even minor occurence of pathogens in a seed lot can cause severe damage to a crop.
- Seed is classified with respect to its purity, and only seed with a high level of purity is used for further multiplication. Laboratory tests are used to determine which seed falls into which class.
- The government pays a fee to compensate faba bean growers for the abnormal cost involved in seed production, and it subsidizes the price of high-quality seed.

Problems of seed production in faba bean include: the difficulties of official routine work; the low prices paid to farmers; the limited area available for seed production; the shortage of seed stores; and the toxic effects of fumigation under abnormal conditions.

Constraints in Production of Soybean

S.A. Khalil
Head Food Legume Research Section
Field Crop Research Institute
Agricultural Research Center
Giza, Egypt

INTRODUCTION

Soybean production has increased dramatically in Egypt since 1972 (Table 1) and this has resulted in increased research to improve cultivars and management methods. A recent economic study by Quenemoen et al. (1981) using farm-gate prices, showed that farm income from a soybean/Berseem clover (Trifolium alexandrinum L.) annual rotation was USD 850/ha greater than for a comparable cotton (Gossypium barbadense L.)/Berseem clover annual rotation.

The soybean plant is subject to a number of constraints. One is soil-crust formation which leads to poor emergence, and hence to a poor stand. In heavy clay soils clods of 25-40 cm are common and weed control is difficult. There has been much interest in developing high-yielding varieties with improved emergence. Nassib et al. (1983) found significant varietal differences in emergence potential at four experimental sites. Varietal performance across locations was consistent (Table 2), with no correlation between emergence and seed size. This suggests that genotypic differences in emergence exist among the 12 varieties tested. Before planting an experimental field, germination tests are conducted to achieve the desired stand.

Another constraint to soybean production is that Rhizobium japonicum is not present in Egyptian soils and yet inoculation is not practiced. Instead, nitro-

Table 1. Development of soybean production in Egypt, 1972-84.

Year	Area (ha)	Yield (t/ha)	Total production (tonnes)
1972	1 190	1.14	1 356
1973	2 630	0.95	2 500
1974	1 820	1.14	2 070
1975	3 570	1.35	4 820
1976	7 120	1.60	11 410
1977	13 910	1.90	26 450
1978	34 320	2.30	78 850
1979	42 180	2.51	106 000
1980	34 760	2.66	92 460
1981	45 960	2.84	130 500
1982	64 260	2.64	169 800
1983	61 830	2.62	161 945
1984	52 308	2.74	143 324

Department of Statistics, Ministry of Agriculture, Cairo, Egypt

gen fertilizer application is recommended at 180 kg N/ha in three equal, split top dressings. When nodulation has been achieved in field experiments, the yield from inoculated plots is often more than double the yield of uninoculated plots and is equivalent to the yields obtained at high N application rates (Table 3). Using imported and locally produced inoculum as well as several carrier sources, well nodulated soybean plants have been obtained in on-farm trials whenever the inoculum contained at least 10^7 viable rhizobia at planting.

Finally, early maturing varieties do not perform well when planted in June, since they have little resistance to leaf-feeding insects such as the cotton leaf worm. Insect control is difficult and costly since the vegetative and flowering stages occur during

Table 2. Differences in field emergence 3 weeks after seeding (Nassib *et al.* 1983).

Variety	100-seed weight	In-vitro germination %	Actual field emergence %	Viable seed emergence %
Will	13.2	96	75	78
Kent	16.7	92	66	72
Crawford	13.4	94	65	68
Pella	18.0	97	64	66
Delmar	14.1	95	64	68
Mitchell	13.9	94	59	62
Desoto	18.4	93	56	60
Clark	17.0	79	52	66
Union	17.4	86	51	59
Cutler 71	13.8	95	50	53
Columbus	14.7	89	49	54
Calland	15.7	75	45	59
LSD 0.05			9	10
Coefficient of Variation			11%	11%

Averages over four sites are presented. Actual field emergence is the (number of seedlings/m)/(total seeds sown/m).
Viable seed emergence is the (number of seedlings/m)/(viable seeds/m) using the in-vitro germination % to obtain the number of viable seeds sown per m.

late June and July when cotton leaf worm populations are at a maximum. Nine soybean lines were identified as having resistance to leaf-feeding insects in Mississippi. Results of Nassib *et al.* (1983) showed that standard varieties all had defoliation in the 70-80% range. In contrast, tolerant lines had less than 20% defoliation, a level below which insecticide application is not required.

Table 3. Relation between nitrogen application and Rhizobium inoculation (Nassib, et al.).

Nitrogen application rate (kg/ha)	Seed yield (kg/ha)	
	Inoculated	Uninoculated
0	4 010	1 920
70	4 010	2 860
140	4 060	3 630
210	4 040	4 040
LSD 0.05	180	

SEED DEVELOPMENT

Cell division is completed in the embryo approximately two weeks after flowering (Kato et al. 1954). There is a slow increase in seed dry-weight during the same period, followed by a rapid increase during the period 2-5 weeks after flowering (Garner et al. 1914). Andrews (1966) observed several distinct stages of seed development and reported that dry weight of the developing seed increased slowly after flowering, while moisture content was decreasing slowly from 90% to 80%. This was followed by rapid growth of both pods and seed, while moisture content decreased gradually to approximately 60%. As physiological maturity was approached, the seed grew slowly to maximum size, and seed germination capacity and vigor were maximum.

Recent reports on compositional changes (Yazdi-Samadi et al. 1977), phospholipid accumulation (Wilson and Rinne 1974), and CO_2 exchange (Andrews and Svec 1975; Quebedeaux and Chollet 1975; Sambo et al. 1977) provide a better understanding of the seed-development process.

During desiccation of the seed, the moisture content declines to harvestable levels (14-15%) in 1-3

weeks (Tekrony et al. 1978). Seed-moisture content is influenced very little by environmental conditions during seed development, but during the desiccation period atmospheric conditions have a great effect on water loss (Howell et al. 1959).

SEED MATURATION

Two terms have been used to describe maturity in soybeans: physiological maturity and harvest maturity (Phillips et al. 1976; Tekrony et al. 1980).

Physiological maturity is related to the maximum accumulation of dry-seed weight, which can be identified morphologically by the occurrence of yellow pods and seeds on the plant.

Harvest maturity is defined as the point at which the seed dries to a moisture content of 14% or less, which allows commercial harvesting and storage without supplemental drying.

These terms offer a simplified means of describing the maturation process and could also be applied to other crops. At physiological maturity, the seed achieves maximum dry-seed weight and severs its vascular connection with the parent plant. At this point it has had no opportunity for deterioration as an independent biological unit and should have maximum seed quality (Andrews 1966; Delouche 1974; Tekrony et al. 1980). It should be recognized that this quality may still be well below a commercially acceptable value of 80% germination.

FACTORS AFFECTING SOYBEAN SEED QUALITY

Field environment

Moore (1971) concluded that exposure of mature seed to alternate wetting and drying in the field resulted in lower quality.

Mondragon and Potts (1974) showed that sunlight also resulted in poorer quality seeds. They found that if plants were shaded (removal of 50% of the sunlight) seeds deteriorated at a much slower rate than those from unshaded plots.

Another factor important in seed quality is temperature. Extremes such as hot, dry weather (Green et al.1965; Harris et al. 1965; Tekrony et al. 1980), and frost (Robbins and Porter 1946; Moorse et al. 1950) occurring during maturation are detrimental to seed quality. Green et al. (1965) reported that seed produced on plants which reached maturity after hot, dry weather had ended, generally exhibited higher laboratory germination and field emergence than seed which matured during hot, dry weather.

Seed-borne diseases

Pathologists have extensively studied the infection cycle of some seed-borne fungi and concluded that Diaporthe phaseolarum var. sojae and Phomopsis spp. are most detrimental to seed quality (Chamberlain and Gray 1974; Kmetz et al. 1974; Sinclair 1977). These fungi have been shown to cause the greatest reduction in the germination when present on 25% (or more) of the seed. The use of systemic fungicides such as benomyl has reduced the occurrence of seed-borne fungi in some areas, but still does not assure high seed quality.

Cultural practices

Conditions of seed at harvest and handling methods during harvest, storage, and processing also have a detrimental effect on seed quality. The harvesting phase is probably the most critical, and mechanical injury can easily reduce seed quality if the combine-cylinder speed is too fast or the seed is too dry. Phillips (1975) showed that mechanical threshing of soybean seed at 10-12% moisture content and a relatively slow cylinder speed (600 rev/min) had no detrimental effect on seed germination or vigor. Recent advances in harvesting equipment and education of seed growers and seedsmen will help prevent the physical abuse that leads to reductions in seed quality.

Genetic influence

Several plant and seed traits can be genetically altered to improve the resistance of seed to detrimental environmental influences. These include hard seedness, seed coat thickness, pod thickness or composition, and resistance to seed-borne diseases.

Improved practices for soybean seed production

The problem of soybean viability and emergence is well recognized. Almost every operation (pre-harvest technique, and post-harvest handling, as well as conditions at planting) influences germination, seedling emergence, and plant density. Soybean seed viability and emergence is certainly a serious problem in the tropics because climatic factors during ripening and harvest are seldom ideal, drying and storage facilities are far from adequate, and conditions of planting are seldom favorable for germination and hypocotyl elongation.

Weeds, pests and diseases must be controlled so that they will not reduce seed yield and quality. The cultivars recommended to farmers should not be based only on yield potential, but also on their resistance to disease and on their storage characteristics.

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SEED STANDARDS IN EGYPT

Crop	Minimum purity %	Maximum other crop seed %	Maximum weed seed %	Minimum germination %	Maximum of other varieties			
					Foundation seed	Registered seed	Certified seed	Commercial seed
Cotton	to be decided upon annually							
Wheat	95	0.5	1.0	85	0.1	0.5	2.0	3.0
Barley	93	0.5	1.0	85	0.1	0.5	2.0	3.0
Rice	95	–	0.3	85	0.1	0.3	1.0	2.0
Maize	95	–	–	85	0.1	0.5	3.0	5.0
Faba bean	93	0.3	1.5	85	–	–	–	–
Soybean	90	0.5	0.5	75	0.1	0.5	1.0	2.0
Lentil	90	0.5	0.5	85	–	–	–	–
Chickpea	90	0.5	0.5	85	–	–	–	–

Wheat: not more than 3% of the seed should pass through a round hole with a diameter of 2.5mm

Maize: moisture content should not be more than 15%

Rice : moisture content should not be more than 15% during October and November and should not contain red rice seeds

Introduction to Cereal Field Inspection Practical

A.J.G. van Gastel
ICARDA
Aleppo, Syria

INTRODUCTION

Seed certification is a seed-quality control system that aims to ensure that the seed sold to farmers is of the indicated variety, is sufficiently pure, is of good germination capacity, and is disease-free. Certification includes field inspection, seed inspection, and pre- and/or post-control. This paper deals only with the practical aspects of field inspection.

FIELD INSPECTION

Before examining a field, the crop inspector first confirms the details on the inspection form regarding the seed source, hectarage planted, previous cropping, and the labeling of the field. Then the actual field inspection starts, and the inspector assesses the identity, purity, diseases, and isolation.

Varietal Identity

Is the variety indicated on the field-inspection form indeed the variety grown? It is not always possible to establish varietal identity, especially in some cross-pollinated crops, where differences are often very small and of a quantitative nature. In many self-pollinating crops, it is possible to obtain a reliable

answer to the question of varietal identity by careful observations. Results should be compared with varietal descriptions.

Purity and Diseases

The whole field must be inspected using a special walking pattern. The crop inspector assesses at least the number of off-types, the number of plants of other crops and of other varieties, and the number of noxious weeds and seed-borne diseases. To do this, random counts must be carried out. The number of counts is usually 10 (10 areas of 20 m^2), but can be increased depending on the crop, size of the field, and the extent of contamination.

Off-types

Off-types are usually assessed on the basis of differences in length, shape, and color. In doubtful cases, more detailed observations must be made.

Weeds and Admixtures

Noxious weeds are taken into account. Other weeds and plants of other crops considered are those which have seeds that can not be removed during processing or which have seeds that are difficult to remove. In cereals, the presence of wild oats or other cereals is important.

Diseases

Only diseases transmitted by seeds are taken into account.

Wheat	*Tilletia caries*	(bunt)
	Ustilago nuda	(loose smut)
Barley	*Ustilago hordei*	(covered smut)
	Ustilago nuda	(loose smut)
	Pyronophora graminea	(barley leaf stripe)
	P. teres	(net blotch)

Pyronophora = *Drechslera* = *Helminthosporium*

For diseases like Ustilago neighboring fields are taken into account and isolation distances are often set.

General Stand of the Crop

Often an inspector assesses the general stand of the crop, taking into consideration those weeds and admixtures that are not considered to be dangerous or difficult to remove during processing. Moreover, the inspection often estimates the yield.

Isolation Distances

The inspected crop must be effectively isolated from other varieties of the same crop, from the same varieties in a different multiplication cycle, and from crops which can cross-fertilize with the inspected crop. When individual plants of such varieties or crops are growing in the neighborhood they should also be taken into account.

Cultural Practices/Previous Cropping

In certain certification schemes, the inspector should also check on all field operations and previous cropping. Growing a different variety for seed in each of two subsequent years might easily result in reduced varietal purity, so a specific number of cropping seasons should elapse between two seed crops. The number of seasons varies considerably depending on local conditions. In advanced certification schemes, the cultural practices are often the responsibility of the seed grower.

Time and Number of Inspections

An inspector may visit any field to be inspected at any time, without the permission of the grower. The field inspections must be carried out at all important stages of crop growth, because all factors affecting

quality are not apparent at the same time. This may entail inspections before planting or sowing, upon planting, and during vegetative growth, flowering, ripening, and harvesting. Checks may be made on processing, equipment, bags, and sampling methods.

The crop is inspected at least twice; once in the vegetative stage and once in the generative stage. The number of inspections may also depend on the generation to be inspected. For instance, the lower the generation, the more often it is inspected. Special inspections may also have to be carried out for diseases.

Roguing

Roguing is the removal of off-types, diseased plants, and contaminants from the seed production field. The field inspector should check on the roguing, but the roguing itself is the responsibility of the seed grower. Roguing is only necessary for fields not meeting the standard, and it is allowed in all cases, except for diseases like smut where, once the spores have spread, the infection has taken place.

PRACTICAL

These instructions are based on the Organization for Economic Cooperation and Development (OECD) Scheme for the Varietal Certification of Cereal Seed moving in International Trade (1971).

The following information should be available to the crop inspector.

a) At what generation must the crop be inspected (pre-basic, basic, certified I or certified II seed)? We assume here that the crop has to be inspected as basic seed.
b) What is the standard for such generations? According to the OECD scheme the basic seed standard is 99.9%.

Thereafter the inspector should:

1. Determine the plant (ear) population per hectare using the formula p= m/w x 1 000 000, in which m=average number of plants (ears) per meter for 10 counts, and w=row width in centimeters. Instead of calculating the plant population, one can use Table 1.
2. Determine the OECD reject number (Table 2) for the population size (e.g. 3.0×10^6), standard (99.9%), and sample area (200 m^2). The reject number in this example would be 74. A reject number corresponds with a stated risk of wrongly accepting or rejecting a lot. For low standards, no reject number is given because the actual amount (for 99% i.e. 1 out of 100) is very close to the reject number. In such cases often the complete 200 m^2 is not studied, but only the 1 m rows for estimating the number of heads.
3. Count the number of impurities in 10 random 20 m^2 (walk across the sowing direction). In this way approximately 100 000 plants are examined, which is considered sufficient.
4. Reject the field if the number of impurities is 74 or more and accept the field if less than 74 off-types are found. Species and varietal purity should be assessed separately and should be satisfactory.
5. Enter all information in the inspection form (Table 3).

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Table 1. Plants or ears per hectare.

Mean no. of plants/m	Drill width (cm)					
	15	18	20	25	30	45
1	66 700	55 600	50 000	40 000	33 300	22 200
2	133 300	111 100	100 000	80 000	66 700	44 400
3	200 000	166 700	150 000	120 000	100 000	66 700
4	266 700	222 200	200 000	160 000	133 300	88 900
5	333 300	277 800	250 000	200 000	166 700	111 100
6	400 000	333 300	300 000	240 000	200 000	133 300
7	466 700	388 900	350 000	280 000	233 300	155 600
8	533 300	444 400	400 000	320 000	266 700	177 800
9	600 000	500 000	450 000	360 000	300 000	200 000
10	666 700	555 600	500 000	400 000	333 300	222 200
20	1 333 300	1 111 111	1 000 000	800 000	666 700	444 400
30	2 000 000	1 666 700	1 500 000	1 200 000	1 000 000	666 700
40	2 666 700	2 222 200	2 000 000	1 600 000	1 333 300	888 900
50	[illegible] 333 300	2 777 800	2 500 000	2 000 000	1 666 700	1 111 100
60	4 000 000	3 333 300	3 000 000	2 400 000	2 000 000	1 333 300
70	4 666 700	3 888 900	3 500 000	2 800 000	2 333 300	1 555 600
80	5 333 300	4 444 400	4 000 000	3 200 000	2 666 700	1 777 800
90	6 000 000	5 000 000	4 500 000	3 600 000	3 000 000	2 000 000
100	6 666 700	5 555 600	5 000 000	4 000 000	3 333 300	2 222 200

Wellving 1984.

Table 2. Reject numbers for some ear or panicle populations in a sample area of 200 m^2 (OECD Cereal Scheme).

No. of ears or panicles/ha ($x\ 10^6$)	Reject numbers	
	Basic seed 99.9%	Certified seed 1st generation 99.7%
0.6	19	47
0.7	21	54
0.8	24	61
0.9	26	67
1.0	29	74
1.1	31	81
1.2	33	87
1.3	36	94
1.4	38	100
1.5	40	107
1.6	43	113
1.7	45	120
1.8	47	126
1.9	49	132
2.0	52	138
2.1	54	144
2.2	56	150
2.3	58	157
2.4	61	164
2.5	63	171
2.6	65	177
2.7	67	183
2.8	70	190
2.9	72	196
3.0	74	203
3.1	76	209
3.2	78	216
3.3	81	223
3.4	83	230
3.5	85	237

Note: Crops are rejected if the total number of impurities found in 10 quadrants (total area 200 m^2) is equal to or exceeds the number given for the appropriate ear or panicle population and standard. Note that species purity and varietal purity should be assessed separately and both must be satisfactory for the crop to be accepted.

Table 3. Field-inspection report.

Report no ..... Crop ..... Variety .....

Lot no ..... Field no .....

Location of the field .....

Previous cropping .....

Name and address of seed grower .....

Class of seed ..... Source of seed.....

Acreage inspected ..... Isolation distance.....

Stage of seed crop .....

Date of sowing .....

Expected time of harvest .....

Estimated seed yield .....

Count	No. of heads/plants of other varieties		No. of heads/ plants of		
	definite	doubtful	inseparable other crops	objectionable weeds	with seed-borne diseases
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
Total					

Percentage of:

Definite off-type plants .....

Doubtful off-type plants .....

Inseparable other crops .....

Objectionable weeds .....

Seed-borne diseases .....

Name of: Seed-borne diseases .....

Inseparable other crops .....

Objectionable weeds .....

Name of nonseed-borne diseases present .....

Condition of crop .....

Does this crop meet the standards for certification

.....

Is this final report Yes/No .....

Date of next inspection .....

Was the producer or his representative present during inspection .....

Remarks: .....

Date, name and designation of inspector .....

Signature Inspector .....

(Modified from Doerfler 1976)

Introduction to the Practical on Varietal Identification and Verification

A.J.G. van Gastel
ICARDA
Aleppo, Syria

INTRODUCTION

When a new variety is released, it should be described using morphological, physiological, cytological or any other characteristics. Varieties should be distinct, uniform, and stable.

Descriptions are necessary for varietal identification and verification (VIV). VIV is a common exercise throughout the seed production and distribution system. During field inspections the field inspector has to verify the variety and identify other varieties. The test for genuineness after each cycle of multiplication verifies the variety. A seed buyer wants to verify whether or not he received the correct variety. In a highly evolved seed program where breeders can be granted proprietary rights (Plant Breeders' Rights), the varietal description is extremely important, both upon granting PBR and in case of a dispute.

VIV is rather simple in vegetatively propagated species where all individuals of a variety are alike, and in self-pollinating species where all individuals are homozygous. In cross-pollinating species VIV often has to rely on segregation percentages, averages and standard deviations. Any characteristic which is stable and sufficiently uniform can be used for VIV; the more easily observable and the less influenced by the environment the better. Observations can be made on seed, seedlings, or mature plants; and can be made in the laboratory, growth chamber, or experimental field.

In Testing for Genuineness of Variety (Van Gastel, 1986) a number of laboratory methods have been de-

scribed that can be used for VIV. This introduction to the practical on varietal identification and verification will describe the characteristics suggested by the International Union for the Protection of New Varieties of Plants (UPOV).

The UPOV is an inter-governmental organization based on the International Convention for the Protection of New Varieties of Plants. Broadly speaking, UPOV has two main aims: (a) to promote PBR and (b) to achieve uniformity in the PBR systems of different countries. Although PBR is not an issue in the countries of North Africa and West Asia, the guidelines produced by the UPOV committees are very useful.

UPOV GUIDELINES

- Characteristics for varietal description. Such characteristics can also be used for VIV. In Lists 1-6 the important characteristics for distinguishing between varieties are given for wheat, barley, rice, maize, broad bean and soya bean. These lists can be used as guidelines. Certain characteristics may not be useful for the range of varieties in some countries, and in some cases additional characteristics may have to be included. A number of characteristics require very detailed observation, which may not be necessary when only a limited number of varieties are available. Certain characteristics are of a qualitative nature, whereas others are quantitative. Qualitative characteristics are usually recorded visually; quantitative characteristics can be measured. In hybrids (maize) segregation is expected (for certain characteristics) on the basis of the genetic constitution of the inbred parents. In such cases, segregation percentages have to be studied. Characteristics are usually scored or transferred to a 1-9 scale (Table 1).
- Stage of scoring. The optimal time for observation of each characteristic is indicated in the guidelines.
- States of expression of the characteristics. The

Table 1. Examples of scoring for three characters.

Character	Score				
	1	3	5	7	9
Presence of anthocyanin	absent				present
Intensity of anthocyanin color	absent or very weak	weak	medium	strong	very strong
Plant growth	erect		inter-mediate		prostrate

guidelines also suggest which different states of the characteristic can be expected and how to transfer them to the 1-9 scale.

Guidelines can be obtained from the UPOV and are available for a range of species. In addition to the UPOV, the Organization for Economic Co-operation and Development (OECD 1971), the International Board for Plant Genetic Resources (IBPGR) and ICARDA have also published guidelines, including characteristics that can be used for varietal identification and verification.

Other textbooks are available that supply useful information for the description of varieties (e.g. ISTA 1973; Hervey-Murray 1980; Milatz 1970).

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List 1. Wheat characteristics used for varietal description.

Coleoptile	: anthocyanin coloration
Plant	: growth habit
Flag leaf	: attitude
	: anthocyanin coloration of auricles
Ear	: time of ear emergence
Flag leaf	: glaucosity of sheath
	: glaucosity of leaf blade
Ear	: glaucosity
Culm	: glaucosity of neck
Anthers	: anthocyanin coloration
Culm	: hairiness of uppermost neck
Plant	: height
Straw	: cross section
Ear	: color
	: shape
	: density
Awns or scurs	: presence
	: distribution
Scurs at tip of ear	: length
Awns at tip of ear	: length
Apical rachis segment	: hairiness of convex surface
Lower glume	: shoulder width
	: shoulder shape
	: beak length
	: beak shape
	: extent of internal hairs
	: internal imprint
Lower lemma	: beak shape
Grain	: color
	: shape
	: brush hair
	: coloration with phenol

Source: UPOV wheat guideline.

List 2. Barley characteristics.

Plant	: growth habit
Lower leaves	: hairiness of leaf sheaths
Flag leaf	: attitude
	: anthocyanin coloration of auricles
	: glaucosity of sheath
Ear	: time of ear emergence
Awns	: anthocyanin coloration of the tips
Ear	: glaucosity
	: attitude
Plant	: height
Ear	: height
	: number of rows
	: shape
	: density
Awn	: length
	: spiculation of margins
Rachis	: length of first segment
	: curvature of first segment
	: humping of segments (two-rowed barley only)
	: degree of zig-zagness (more-rowed barley)
Sterile spikelet	: attitude
	: length of lemma
	: shape of tip
Median spikelet	: length of glume and awn relative to grain
Grain	: rachilla hair type
	: husk
	: anthocyanin coloration of nerves of lemma
	: spiculation of inner lateral nerves of lemma
	: hairiness of ventral furrow
	: disposition of lodicules
	: kernel color of aleuron layer
Reaction to DDT	

Source: UPOV barley guideline.

List 3. Rice characteristics.

Leaf	: color
	: distribution of anthocyanin coloration
Penultimate leaf	: pubescence of blade
	: anthocyanin coloration of auricles
Flag leaf	: curvature of blade
Time of heading	: (50% of plant width heads)
Lemma	: anthocyanin coloration of keel
	: anthocyanin coloration of area below apex
	: anthocyanin coloration of apex
Spikelet	: color of stigma
Stem	: thickness
	: length (excluding panicle, excluding floating rice)
	: anthocyanin coloration of nodes
Panicle	: length
	: curvature of main axis
Spikelet	: hairs on lemma
	: length of hairs on lemma
	: color of tip of lemma
Panicle	: length of longest awns
	: distribution of awns
Time of maturity	
Grain	: weight of 1000 fully developed grains
	: length
	: width
Decorticated grain	: length
	: width
	: shape (in lateral view)
	: color
Polished grain	: size of white core
Endosperm	: type

Source: UPOV rice guideline.

List 4. Maize characteristics.

First leaf	: anthocyanin coloration of sheath
	: length of blade
	: width of blade
	: ratio length/width of blade
	: form of tip
Leaf	: attitude (in central third of plant)
Tassel	: time of emergence (50% of plants)
	: time of beginning of anthesis
	: anthocyanin coloration of anthers
Ear	: time of silk emergence
	: anthocyanin coloration of silks
	: anthocyanin coloration of glumes
	: closed anthocyanin ring at base of glume
Stem	: anthocyanin coloration of nodes
	: anthocyanin coloration of internodes (in middle of plant)
Leaf	: anthocyanin coloration of sheath
	: hairs on margin of sheath
Tassel	: angle between main axis and lateral branches (in lower third tassel)
	: attitude of lateral branches
	: number of primary lateral branches
	: length of main axis above lowest side branch
	: length of main axis above upper side branch
Plant	: length (tassel included)
Ear	: height of insertion of ear relative to total plant height
	: length of peduncle
	: length
	: diameter (in middle of ear)
	: shape
	: number of rows of grain
	: type of grain (in central third of ear)
	: color of tip of grain
	: colcr of dorsal side of grain
	: anthocyanin coloration of glumes of the cob
	: intensity of anthocyanin coloration of glumes of the cob

Source: UPOV maize guideline.

List 5. Broad bean characteristics.

Seed	: tannin
Plant	: height
	: number of stems (including tillers more than half the length of the main stem)
Stem	: number of nodes (up to and including first flowering node, and including the scale nodes)
	: anthocyanin coloration
	: intensity of anthocyanin coloration
Foliage	: color
	: intensity of green color (before flowering)
Leaflet	: length (basal pair of leaflets)
	: width
	: folding (along the main vein, terminal pair of leaflets)
Raceme	: number of flowers (at 2nd or 3rd flowering node)
Time of flowering	: (50% of the plants with at least one flower)
Flower	: length
Wing	: melanin spot
Standard	: anthocyanin coloration
	: extent of anthocyanin coloration
Truss	: number of pods
Pod	: attitude
	: length (without beak)
	: median width
	: degree of curvature at green shell stage
	: intensity of green color
	: number of ovules (including seeds)
	: thickness of pod wall
Seed	: shape of median longitudinal section
	: shape of cross section
	: 1000 seed weight
	: color of testa (immediately after harvest)
	: black pigmentation of hilum
Time of full development of pod (first fully developed pods)	

Source: UPOV broad bean guideline.

List 6. Soya bean characteristics.

Hypocotyl	: anthocyanin coloration
Plant	: growth type
	: growth habit (at flowering)
	: height (at maturity)
	: color of hairs
Leaf	: shape of lateral leaflet
	: color
Leaflet	: size
Flower	: color
Pod	: color
Seed	: size
	: shape
	: color of testa (excluding hilum)
	: hilum color
Plant	: time of beginning of flowering (1 flower open on 10% of plants)
	: time of maturity

Source: UPOV soya bean guideline.

Introduction to Seed Health Practical

Marlene Diekmann
ICARDA
Aleppo, Syria

INTRODUCTION

There are a number of methods available for seed-health testing, most of which destroy the seed. For different pests/pathogens different methods are appropriate and, in all cases, a sufficiently large sample is required to ensure reliable, reproducible results. Inspection and testing of soil (for nematodes and soil-borne fungi) and plant debris give clues on the general health status of the crop, but not necessarily on the inoculum in the seeds. A brief description of some of the test methods used at ICARDA's Seed Health Laboratory is given here.

DIRECT INSPECTION

This is the only non-destructive method of seed-health testing, and it is limited to the detection of parasitic weed seed (e.g. Orobanche spp., and Cuscuta spp.), other weeds, nematode cysts (Heterodera spp.), bunt balls, and insects. The seeds are checked under a low-power stereoscopic microscope at a magnification of 40-60x. In some cases pathogens cause discoloration or deformation of the seed (Ascochyta spp. and broad bean stain virus), but other tests are required to confirm the diagnosis.

EXAMINATION OF WASHING SUSPENSION

Nematodes (Ditylenchus dipsaci)

Seeds are placed in a funnel, covered with water, and the funnel closed with a rubber hose and pinchcock. For best results constant aeration is required. After 24 hours at cool temperatures (10-20° C), the pinchcock is opened and a few ml of water are collected and examined under the stereomicroscope. If a low-population density is expected, centrifuging at 500 rpm for 10 minutes will help to concentrate the nematodes. For identification, the nematodes are removed to a microscope slide using a very fine brush (or preferably a plastic hair from a dishwashing brush), are covered with a cover glass and are heated over an alcohol burner for about 30 seconds without boiling. Identification can be done at 100 or 250x magnification with a compound microscope.

Fungal Spores Adhering to the Seed Surface

A seed sample is placed in a reagent tube, covered with water and a drop of detergent, and shaken vigorously on a reagent tube shaker for 30 seconds. The liquid is then centrifuged at 2 000 rpm for 10 minutes, and the concentrated spores examined at 100-400x magnification under a compound microscope. For quantitative analysis, the seed-water relation must be constant. The concentrated spores are diluted in 0.5 ml water, and counted in a counting chamber (e.g. Fuchs-Rosenthal haemocytometer). Normally, an estimate of the degree of contamination is sufficient, and for this it is sufficient to examine an area the size of a cover glass (18x18 mm) for spores.

This method mainly detects spores of Tilletia spp., and Urocystis spp. For Tilletia indica testing, water should be replaced by 0.2% sodium hydroxide and the seeds soaked for 24 hours. The liquid is treated as for other fungal spores, and the seeds are also examined visually for the typical black teliospore masses.

BLOTTER TEST

Staff from seed-testing laboratories will be familiar with this method, which is similar to the standard germination test.

Seeds are placed on moistened absorbent paper in petri dishes, germination boxes, or any other container which can be sealed to prevent evaporation. Substrata such as paper towel, filter paper, or cotton pads can be used. For routine testing, it is advisable to cut standard paper to a suitable size; the paper should be thick enough to absorb moisture for the duration of the test (e.g. Schleicher and Schuell filter paper No 8272 for large-seeded crops such as legumes or pleated strips for cereals). A constant amount of distilled water is added, depending on the substratum used, size of container, crop, etc.

The seeds are incubated for 7-10 days at 20° C. Sporulation is stimulated by near UV light in a cycle of 12 hours UV light/12 hours dark, applied after 4-5 days incubation at 12 hours white light/12 hours darkness.

Evaluation is done with a stereoscopic microscope, but confirmation under a compound microscope is necessary until the tester becomes familiar with the appearance of the different pathogen species on seeds. Not every fungus growing on seeds is a pathogen, in fact most of them are not. Surface sterilization suppresses saprophytes but also affects the pathogens, so it is not generally recommended.

Evaluation is easier when seed germination is suppressed. Some fungi, e.g. Helminthosporium spp., tolerate very low temperatures. In tests for these pathogens seeds are incubated for 24 hours at 20° C, then placed overnight in a freezer at -18° C, then incubated again at 20° C for 7 days.

AGAR PLATE TEST

This method requires some equipment and skills for working under sterile conditions. With specific media, reliable results can be obtained, but it is essential

to avoid contamination with saprophytes. Proper sterilization of petri dishes, media, working area, seeds, and tools is important.

Petri dishes

If glassware is used, it must be thoroughly cleaned and sterilized. The petri dishes should be placed in special metal containers, or wrapped in aluminium foil and sterilized with either dry, hot air (oven, 180° C for 20 minutes) or moist heat (autoclave or pressure cooker, 15 psi for 15 minutes). Presterilized disposable plastic petri dishes are available, packed in plastic bags of 25.

Working area

A laminar air-flow bench provides an ideal working area. If this is not available, a corner away from drafts and thoroughly cleaned with 70% alcohol will do.

Seeds

Surface sterilization of seeds in sodium hypochlorite (3-5 minutes in a 10% solution of commercial bleach) suppresses saprophytes.

Tools

Needles, tweezers, etc. can be sterilized by dipping into 70% alcohol and then heating to redness over a Bunsen burner or alcohol burner.

Media

Media should be sterilized in an autoclave as indicated above. Distilled water should be used for media preparation and flasks should be filled to only 50% capacity. At about 45-55° C, the media can be poured evenly into plates. Care should be taken that

this is done in a clean working area and that the rim of the flask is sterilized over a flame. Petri dishes should be opened in a way that reduces contamination.

Potato Dextrose Agar (PDA) and Malt Extract Agar (MEA) are available, dehydrated, from Merck and Difco, and are general media for the isolation of fungi. To prepare, follow the instructions on the label.

Ox-gall agar medium is suitable mainly for testing for Fusarium. After autoclaving and cooling 1 liter of PDA, add 2 g of Ox-gall and 100 mg streptomycin sulphate.

Host media (legumes) is suitable for detection of Ascochyta. Mix 40 g of ground seeds with 1 liter of distilled water, autoclave for 40 minutes, and filter the suspension through cheesecloth. Add water to 1 liter, 20 g dextrose, and 20 g agar, and reautoclave.

Method

After surface sterilizing, seeds are placed on the surface of the medium, with sufficient space between seeds to allow the development of distinct colonies. For example, 10 chickpea seeds or 15-20 lentil seeds should be placed in one 9 cm petri dish. Seeds are incubated for 7 days at 20° C. Exposure to NUV light after 3-4 days is recommended to increase sporulation.

For evaluation, some colonies can be easily identified by characteristic growth, color, and fruiting bodies. For others, checking at high magnification under the compound microscope is necessary.

AGAR PLATE METHOD FOR BACTERIA

There are only a few specific media available. It is important to distinguish between the colonies of pathogenic and non-pathogenic bacteria. Non-pathogenic are often present in abundance. Colony color, size, shape, and fluorescence help identification, but serological methods and/or host plant inoculation are indispensable. In general, seeds are ground in an analytical mill. If such a mill is not available, a

coffee grinder will do. It is important to disinfect the mill/grinder with formaline after each sample. Ground seeds are covered with sterile water or sterile saline (0.75% NaCl) in a beaker, and are incubated overnight, usually at 27° C.

Small samples of the liquid are streaked onto suitable media with a sterile inoculation loop and incubated for 2 days at 27° C. Some bacteria, such as Xanthomonas spp., might require more time for growth.

Media

Pseudomonas F agar is available, dehydrated, from Merck and Difco. On this medium colonies of Pseudomonas pisi are fluorescent under long wave UV light (366 nm).

Semi-selective medium for Xanthomonas (XTS medium Schaad) is prepared by autoclaving 23 g Nutrient agar with 5 g glucose. After autoclaving and cooling 200 mg cycloheximide, 8 mg gentamycin and 10 mg cephalexin, each dissolved in 75% ethanol, are added. Colonies of Xanthomonas appear yellow and mucoid.

Both nutrient agar and broth are available, dehydrated, from Difco and Merck. To prepare, follow the instructions on the label. These are suitable media for general bacterial growth and are not selective.

EMBRYO METHOD

This method was developed for testing for Ustilago spp. and has been modified by several authors. At least 2 000 seeds are soaked for 18 hours in 5% sodium hydroxide (NaOH) with 200 ppm aniline blue or trypan blue. About the same amount of 5% sodium chloride (NaCl) is then added, and the mixture stirred well. The embryos are separated by a set of sieves (2.5 mm mesh to collect endosperm and chaff, 1 mm mesh to collect embryos) by adding warm water to the mixture of chaff and embryos and stirring constantly. The embryos fall through the large sieve and are collected in the fine sieve. Alternatively, a Fenwick can, as used in

nematology, could be used as it speeds up the procedure.

The sample is transferred to a funnel and covered with a mixture of lactophenol and water (3:1). The funnel is closed with a rubber tube and a stopcock. If the specific gravity is correctly adjusted, the embryos will float (while chaff and other debris sink down), and can be removed by releasing the stopcock.

The embryos are transferred to fresh lactophenol and boiled for approximately 30 seconds, and are then inspected for mycelium in the scutellum in glycerol at about 20x magnification with substage illumination.

GROWING-ON TEST

This method is closer to field conditions. Greenhouse or growth-chamber facilities are required, and plants are grown in sterile media (sand, soil, or vermiculite). Environmental conditions should be favorable for pathogen growth, i.e. for *Tilletia contraversa* and *Helminthosporium gramineum* the temperature should be low, and for bacteria the humidity should be high. A major disadvantage of this method is the time required for growth and the expression of symptoms, which may take several weeks or even months. An advantage is that seedlings can be used from the routine germination tests, thus saving on seeds.

OTHER METHODS

There are very specific serological methods used for identifying bacteria and viruses. The International Seed Testing Association (ISTA) working sheets on Seed Health Testing give specific methods for some important seed-borne pathogens.

USEFUL REFERENCES

See chapter: Seed-borne fungal diseases in cereals and food legumes.

LIST OF EQUIPMENT REQUIRED

The items marked * are essential, the others are required only for certain tests.

* Compound microscope, preferably with phase-contrast
* Stereomicroscope, magnification up to 50x, preferably with sub-stage illumination
* Incubator, preferably with NUV light ("black light")
* Refrigerator
* Deep freezer
* Water-still or deionizer
* Autoclave or pressure cooker
* Seed treater for small samples
  Centrifuge
  Reagent tube shaker
  PH meter
  UV lamp 366 nm
  Water-bath
  Shaker
  Oven
  Analytical mill
  Alcohol burners
* Petri dishes
* Flasks (up to 2000 ml)
* Beakers (up to 1000 ml)
* Microscope slides
* Cover glasses
* Reagent bottles of different sizes
* Counting chamber (haemacytometer)
* Funnels
* Reagent tubes
* Microscope instruments, i.e. tweezers, dissection needles
* Inoculation loops
* Scissors
* Rubber tubes, pinchcock clips
* Set of sieves, 1 and 2.5 mm mesh
* Filter paper
* Plastic germination boxes with transparent cover
* Aluminium foil
* Labels

National Seed Program/Industry in Egypt

A.S. Gomaa
Under-Secretary of Agriculture
for Seed Affairs
Central Administration for Seed
Giza, Egypt

and

M.S. Abdel Wanis
Head,Technical and Statistical Office
Central Administration for Seed
Giza, Egypt

INTRODUCTION

The objective of the seed program is to develop adequate supplies of foundation and registered seed. This in turn will facilitate production of certified seed for distribution to farmers. Plant breeders in the Agricultural Research Center (ARC) have developed high-yielding varieties of several crops. For most crops, the lack of adequate quality seed is a major constraint.

A successful seed program should include seed production, seed processing and packing, and seed certification and testing.

Production and processing are concerned with producing enough seed to meet demands, while certification is concerned with ensuring quality.

BACKGROUND INFORMATION

In 1922 a seed-production and distribution unit was established to produce cotton seed. Later the unit was

expanded to include seed production for other crops. The unit became a branch in 1942, a section in 1957, a directorate in 1960, and an under-secretariat in 1980.

This gradual upgrading was accompanied by a number of seed laws. The seed law of 1926 regulated cotton-seed production and trade. Law 125 (1946) promoted seed production of major field crops and law 52 (1957) regulated seed testing and handling. Other laws included number 58, which regulated production of cotton seed and preservation of its purity, and number 146 (1960), which covered supervision of certified-seed production for all major crops. Law 53 (1966) regulates production and distribution of all field crops and vegetables, and covers seed-certification procedures, cultural practices, crop rotations, and designated areas for growing certain crop varieties.

The seed program is handled by the Central Administration for Seed (CAS), and is headed by an under-secretary, who is assisted by three director generals, by technical directors, and by finance officers. The director generals are responsible for seed production, seed testing, and for cotton ginning and seed processing. Seed offices have been established in each of the 18 governorates. Each has two inspectors, one who is responsible for production, testing and sample control, and one who is responsible for field inspections. In some cases there may be special inspectors, e.g. in areas where ginneries are located.

ORGANIZATIONS INVOLVED

Agricultural Research Center (ARC)

The ARC and the technical institutes are responsible for variety development and release. The Seed Release Committee (chaired by the director of ARC) is responsible for deciding which varieties should be multiplied.

The ARC seed-production unit produces the foundation seed and in certain crops also the registered seed. In addition, staff members of ARC play an

active role in field inspection, roguing, and general supervision of seed produced under CAS. Once the variety is increased beyond the basic or foundation seed stage, the CAS is responsible for further multiplication. This multiplication is carried out on state farms or on farmers' fields under contract. However, in some cases (maize and some vegetables), initial seed increases are handed over to local seed companies, which then produce the certified seed.

Central Administration for Seeds (CAS)

The main responsibilities of the CAS are planning and implementing seed-production policies. The CAS

- contracts and supervises production authorities,
- inspects contracted seed-production fields,
- prepares, processes, and distributes seed,
- inspects and certifies seed,
- supervises ginning factories and oil extraction plants,
- recommends and implements seed-pricing policies for raw and processed seed, and
- samples and tests seeds for germination, purity, and sanitation.

Seeds are processed at 11 processing centers and tested at three seed-testing centers. Seed production, processing, and testing are carried out according to established procedures, regulations, and standards.

Egyptian Agriculture Authority (EAA)

This organization owns (Table 1) most of the seed-processing plants (which it operates in cooperation with CAS), produces some vegetable seeds, and imports vegetable seeds for multiplication.

Seed Companies

Nubaria Seed Company is a public sector company, which is involved in vegetable seed production in

Table 1. Seed processing facilities in the Government sector.

Location	Original capacity t/hr*	Year and source of equipment (year/country)		Operational status	Owner
1. Sakha	13-15	1953	UK	poor; 4-5 t/hr max.	CAS
2. Gemeza	2-3	1955	UK	inoperable	CAS
3. Sids	4-6	1976	DRG	fair; poor design	CAS
4. Tanta	9-12	1955	UK	poor; 4-5 t/hr max.	EAA
5. Damanhour	12-15	1971	DRG	good; 8-10 t/hr actual	EAA
6. Shoubra El Khema	3-7	1952	Austria	poor; 2-3 t/hr	EAA
7. El-Mansura	3-7	1955	Austria	poor; 2-3 t/hr	EAA
8. Wadi El-Nil	3-5	1955	Austria	very poor	EAA
9. El-Minia	7-9	1955	UK	very poor	EAA
10. Deirout	3-7	1950	Austria	poor	EAA
11. Bahtim	20	1985	Switz.	very poor	EAA
12. Sakha	9	1985	USA	new	EMCIP
13. Sakha	12	1985	USA	new	EMCIP
14. Gemmeiza	6	1985	USA	new	EMCIP
15. Sids	6	1985	USA	new	EMCIP
16. Shandaweel	6	1985	USA	new	EMCIP

* Capacity based on wheat seeds: rice = 60%, maize = 75%, soybeans = 100% of wheat capacity.

reclaimed areas. The company operates a vegetable seed-processing facility.

The Ministry of Agriculture encourages private companies such as the Egyptian Seed Company, the National Seed Company and Misr Pioneer Seed Company. The National Seed Company operates a 2-3 t/hr plant for maize seed and will construct a 4-5 t/hr plant in middle Egypt. Egyptian Seed Company will construct a 10 t/hr plant (maize seed) in Sids in 1985/86. Misr Pioneer Seed Company will construct an 8 000 t/year plant (maize seed) in 1985. The CAS no longer produces maize or sorghum seed. Private seed companies are focusing attention on hybrid maize, sorghum, vegetable and forage crops. These are essentially unregulated crops. Hence, there is good opportunity for profit.

Principal Bank for Development and Agricultural Credit (PBDAC), Village Bank, and Cooperatives

The Bank is mainly involved in the handling, storage, credit, marketing, and distribution of seed.

The Principal Bank for Development and Agricultural Credit (PBDAC) acts as a transport and financial agent for CAS in these operations. It transports the raw seed from the grower to the processing center, pays the contract grower, transports the processed seed to the village credit banks or cooperatives, and sells the seed to the seed growers or commercial farmers.

SEED PRODUCTION

General

There are four stages of seed production, i.e. breeder, foundation, registered, and certified seed. Basic seed (breeder and foundation seed) is produced under direct supervision of ARC technical staff. Registered and certified seed are grown on state farms and in farmers' fields under the supervision of the CAS. Certification is based on international schemes (OECD). Seed-testing methods are according to the International Seed Testing Association (ISTA).

State Farms

The ARC production sector operates 18 seed-production farms with a total area of approximately 12 000 hectares under contract with CAS. The seed produced includes cotton, rice, wheat, barley, broad bean, lentil, maize, soybean, groundnut, clover, flax, and onion.

General Policy

The general policy has been to produce enough seed of cotton, onion, and soybean to permit farmers to replace their seed every planting, and enough seed of wheat, rice, faba bean, and other high-value crops for seed replacement every two plantings.

The production of maize and sorghum seed by CAS was suspended in 1983 to permit rapid and full development of maize and sorghum-seed supply (mostly hybrids) by the private sector.

The Field Crops Research Institute (FCRI), Horticulture Research Institute (HRI), and ARC, continue to produce maize, sorghum, forage and horticultural crop foundation seed for private and public seed companies.

Quantities produced

CAS processed the following quantities (tonnes) of seed in 1985.

Cotton	85 000
Wheat	100 000
Rice	80 000
Barley	7 000
Maize	8 000
Faba bean	20 000
Onion	100
Sesame	30
Groundnut	700
Lentil	1 100
Soybean	6 000

The yearly quantities (tonnes) of vegetable seed pro-

duced in Egypt are:

Watermelon	220
Melon	50
Cucumber	70
Squash	85
String bean	500
Phaseolus bean	1 500
Pea	850
Pepper	9
Egg plant	10
Carrot	36

With regard to tomato seed, only a fraction is being produced in the country, and annual imports of this crop range from 75 to 80 tonnes.

In addition, seed of all the varieties and hybrids required for plastic-culture plantings is imported.

General Seed Production Procedures

Basic seed and much of the registered seed are produced on state farms. The rest of the registered and certified seed is produced by CAS under contract with private farmers.

The premium for seed growers is 20-50% over the government market-price for grain, with small additional increments for purity higher than 95%.

Field inspections are rigorous for cotton, but hardly adequate for most other crops.

When seeds are produced through contracts, they are sampled after harvesting and threshing and, if approved, delivered to the appropriate center for processing. After processing, the seeds are sampled again and, if approved, distributed through the stores of the Agricultural Credit Bank (seed for contract seed producers) or the cooperatives (seed for farmers).

Distribution, Marketing and Pricing

The Agricultural Credit Bank and the village cooperatives distribute the seed. CAS sets the prices for regulated crops (wheat, rice, barley, lentil,

onion, soybean, groundnut and sesame). The pricing system includes the price paid to the contract seed growers for raw seed and the prices charged to farmers for the processed certified seed.

The seed prices of controlled crops are heavily subsidized. In 1985, L.E. 5 million was assigned for subsidizing seed sales to growers, with L.E. 3.5 million allocated for wheat seed alone. There are no price controls for maize, sorghum, or for most vegetable and forage crops. The open market for these crops is one factor that has attracted the private sector to seed production.

CONSTRAINTS IN SEED PRODUCTION

The following constraints impede improvements and progress in seed production and supply.

- Lack of a high-level, effective national seed-policy board to develop policies for the development, operation, and control of the seed industry. Such a board is needed to sort out responsibilities for each component of the seed industry and to modernize the industry, preparing it for the expected technological breakthroughs in crop production.
- Lack of a variety-release committee with ample representation from credit agencies and private seed companies. Such a board is needed to develop realistic standards for introducing and releasing new varieties and for discarding obsolete varieties.
- Inadequate inspection of seed-production fields, drying floors, transport means, processing plants, and stores.
- Poorly designed, antiquated, worn out seed-processing facilities (Table 1).
- Seed-testing laboratories that have no concept of the modern principles and purposes of seed quality, and that lack equipment.
- Inadequate provisions for seed storage, including sanitary measures, to prevent losses and damage from pests.

- Inadequate transport facilities to collect seed from growers and to inspect and supervise fields.
- Poor coordination of distribution and marketing. As a result seed is sometimes not available at planting time.
- Lack of educational and training facilities. There is no university program dealing with seed production. Universities do not even offer one seed-technology course. The lack of trained manpower and the absence of training opportunities contribute to the poor performances of the seed industry.
- Dispersal of resources and responsibilities in the public sector among several agencies. There are no provisions for cooperation and coordination.
- Problems in the emerging private sector companies, which include delay in the importation of germplasm (parental lines), inadequate supply of basic seed from ARC units, lack of training opportunities and technical assistance, lack of adequate hard currency to import equipment, and uncertainties about MOA policy with respect to private sector participation in the supply of basic agricultural inputs.
- Inadequate capability for applied seed-technology research.

RECOMMENDED ORGANIZATIONAL AND POLICY ISSUES

The national seed industry requires a major overhaul in order to play its full role in increasing production.

Although steps are being taken to control the purity of breeder and foundation seed, the two remaining stages, registered and certified seed, are carried out in a manner that does not ensure varietal or even general purity in most field crops. This is due to the fact that field inspections are sub-standard and seed-processing plants are obsolete (Table 1). The processing plants need to be overhauled, new ones need to be built and the laboratories need to be better equipped.

In addition, the respective roles of the public and private sectors need to be carefully defined in relation to plant breeding, seed multiplication, and marketing. Aspects of pricing and subsidies need review

in the light of promoting a strong seed industry. The strategies of increased agricultural production that are being promoted and implemented by MOA will place demands on the delivery systems for services and materials. In order to intensify crop production above its already high level (indeed, to achieve levels of productivity realized in only a few agricultural areas in the world) limiting factors such as inadequate supplies of good-quality seed must be eliminated.

Recommendations and major policy issues for further improvement of the seed program/industry in Egypt include the following.

- Create clear policies, guidelines, and formal mechanisms for updating and revision of the seed industry. These are needed to support the development of a coordinated private/public-sector seed industry, and to assign responsibilities and resources to those seed production/supply operations which are not attractive to the private sector.
- Separate seed certification from seed production and processing. The certification group should not certify its own work.
- Assign clear responsibilities to the public sector for production of foundation seed and for production, processing and storage of registered and certified seed. The present system, which disperses seed quality control, production, and processing among CAS, EAA, and ARC should be discontinued, and the facilities and resources should be concentrated in one agency.
- Gradually shift the emphasis from quantity to quality of workers and technicians.
- Plan and conduct a study of the purposes, accomplishments, strengths, weaknesses, needs and future direction of the seed-program industry in Egypt.

CONCLUSION

Egypt's seed industry suffers from fragmented organization. Assignment of tasks is not always clear, and accountability and authority do not always coincide

with what is assigned. There is a lack of coordination in the planning and procurement of new facilities. Reorganization is needed if the country is to meet its demand of high-quality seed. Organizations responsible for the seed industry should be reorganized and the Minister of Agriculture should establish a National Seed Council to assist and advise on national seed policies.

This council should be responsible for overall planning and coordination. One of its priorities should be clarification of the division of responsibilities between the CAS and the EAA.

The CAS might, for example, retain operational responsibility for the planning and supervision of seed production, while the EAA becomes fully responsible for production of certified seed, including grower contracts and processing. The council might consider merging the production of basic seed within the Agricultural Research Center under a new Basic Seed Authority.

The Bank of Development and Agricultural Credit should continue to be in charge of marketing and distribution, but with more emphasis on upgrading storage and transportation facilities (Table 2).

Table 2. Proposed organization of the Egyptian seed program.

	Basic seed	Certified seed
Overall policy & coordination	NSC	NSC
Planning	CAS	CAS
Certification & quality control	CAS	CAS
Production	BSA/ARC	EAA+
Processing	BSA/ARC	EAA+
Distribution	BSA and PBDAC	PBDAC

NSC - National Seed Council
BSA/ARC - Basic Seed Authority, to be established in the Agricultural Research Center
EAA+ - Egyptian Agricultural Authority plus other companies contracted by CAS.
PBDAC - Principal Bank for Development and Agricultural Credit.

The Ethiopian Seed Industry

Gugsa Indeshaw
Ethiopian Seed Corporation
P.O. Box 2453
Addis Ababa, Ethiopia

INTRODUCTION

Ethiopia is a topographically and ecologically varied country. In the east and south are semi-arid lowlands, which support a pastoral system of agriculture. From the lowlands the land ascends into a central plateau (1 500-3 000 m above sea level), which is intersected by a number of river systems and the Rift Valley. This plateau is the major crop-producing area, and due to the wide variation in agro-ecological conditions, practically all tropical and temperate-zone crops can be grown. The only major climatic limitations are annual rainfall and its distribution.

The extremes of agro-ecological variability have also contributed to an almost unique feature of Ethiopian agriculture: there is a very wide range of genetic diversity among the major cereals and legumes, and Ethiopia is the center of diversity for several species of cultivated crops. This, plus thousands of years of selection, has led to considerable heterogeneity in the basic cropping patterns. In many cases, each pattern has genotypes specific to that pattern or locality.

This situation makes the development of widely-adapted superior varieties, and their subsequent multiplication and distribution, a difficult and complex task. However, a start has been made, and a range of crop varieties has been identified that has broad adaptability.

THE SEED INDUSTRY

Before 1979, the Ethiopian seed industry was very much ad hoc, and seed multiplication and distribution were carried out by a number of small, uncoordinated agencies. These agencies ranged from the Institute of Agricultural Research (which multiplied and distributed seed to the farmers in the vicinity of the various research stations), to project-related agencies such as the Arssi Rural Development Unit (which provided seed of improved varieties to farmers).

In 1978, a National Seed Council was established to draw up recommendations for a system to produce, process, and market seed of released and recommended superior varieties. The council, composed of representatives from all sectors of the agricultural industry, recommended one body to coordinate the seed industry and act as a link between plant breeders and crop producers.

In 1979, as a direct result of the council's recommendations, the government sanctioned the establishment of the Ethiopian Seed Corporation (ESC). The ESC was designated as the primary agency for implementing a comprehensive national seed plan and developing a system for multiplying and distributing improved seed. The ESC is responsible for:

- assessing national requirements for seed of improved varieties and for making arrangements to meet the demand,
- cleaning, processing, packing, and storage of all classes of seed,
- developing a system of multiplication and quality control, which, with appropriate legislation, will lead to the production of certified seed,
- coordinating and controlling seed importation, promoting the use of new and superior crop varieties, and
- increasing farmer awareness of the importance of these varieties.

Setting up an effective seed industry is complex, and it may take many years to get a return on investment. Therefore, the Government sought external

assistance for the formation of the ESC. Three agencies offered financial and technical assistance.

A FAO/UNDP project provided funding for basic quality control facilities, a seed cleaning factory, and a range of vehicles to assist in the management and operation of the ESC.

USAID proposed a major investment program, which was aimed at strengthening the agricultural services component of a much wider national program. The projects' major focus was the development of a network of seed-cleaning factories throughout Ethiopia. When USAID assistance was withdrawn from Ethiopia, the possibility of loans from commercial banking sources was explored, but this would have required ESC to be a commercially viable enterprise from the beginning. Also, the high cost of such funds and the effect on seed prices would have had a counter-productive effect on the demand for seed and the future of the infant seed industry. The search for commercial funding was thus abandoned.

Financial support was finally obtained from the second National Agricultural Minimum Package Project (MPP II) which was under consideration by the World Bank and the International Fund for Agricultural Development. The ESC Seed Multiplication Project was included in the overall credit, with a baseline development cost of USD 7.4 million. Funded under the project were:

- a Head Office and a National Seed Testing Laboratory,
- a number of seed processing and storage complexes,
- lorries, trailers, and pick-ups for field operations,
- in-country and overseas training for ESC personnel,
- fiscal support for the ESC over a 2-year period, and
- support, advisory and training personnel.

The proposals were based on over-ambitious estimates of seed demand, and many basic precepts for the development of a seed industry were overlooked.

The management of the ESC recruited technical staff, procured equipment, and established the demand for seed. Constraints in developing an effective seed

industry were then identified, and a number of amendments were proposed, which aimed to increase investment in processing facilities. It was decided that greater importance should be given to the production of high quality seed.

The IDA credit for MPP II ended in December 1985, and the ESC is now a full-fledged seed company with a permanent work force of 168, assets in excess of USD 8 million, an average annual throughput of 23 000 t of commercial seed (Tables 1 and 2), and an annual sales/services turnover of over USD 6 million/year.

The headquarters in Addis Ababa is supported by five zone offices, which are located in the major agricultural areas of Ethiopia. Seed processing facilities are provided by four seed plants, each with a capacity of 4-6 t/hr, and by three mobile units with a combined capacity of 8 t/hr. Twenty-six, 24-ton, truck-trailer units transport seed from contract producers to factories.

ESC's primary long-term objective is to produce certified seed in accordance with internationally accepted standards. This has not been easy, because plant breeding in Ethiopia tends to be biased toward the requirements of limited locations. However, since the late 1970's a growing number of new releases have been included in the multiplication scheme.

Table 1. ESC production of seed (in metric tonnes), 1979-85.

Crop	1979/80	1980/81	1981/82	1982/83	1983/84	1984/85
Wheat	19 079	18 847	16 434	16 573	12 393	21 776
Barley	256	744	287	865	1 652	1 726
Maize	1 162	2 355	1 419	2 495	1 324	13 481
Sorghum	25	135	270	221	130	774
Teff	198	172	139	51	267	87
Haricot	30	14	235	23	84	288
Other	178	97	28	26	34	130
Total	20 928	22 364	18 812	20 254	15 884	38 262

Table 2. Seed distribution (in tonnes) by ESC farming sector, 1979-85.

Sector	1979/80	1980/81	1981/82	1982/83	1983/84	1984/85
State	19 006	16 796	16 052	15 273	12 607	14 777
Peasant	1 922	5 568	2 760	3 981	3 277	23 485
of which:						
AISCO*	1 277	3 456	684	2 471	1 743	16 485
RRC**	645	1 827	[illegible]	1 376	780	829
Others***	-	285	1 893	134	754	6 171

* Agricultural Inputs Supply Corporation
** Relief and Rehabilitation Commission
*** Non-governmental organisations and sales direct to peasant farmers

To make the production of certified seed possible and to improve the quality of seed, the ESC is planning two basic seed farms. In the first phase, these farms will cover 1 600 ha and will produce a wide range of crops for the medium- to high- altitude areas of the central Ethiopian plateau (i.e. wheat, barley, maize, teff, rape, haricot bean, horsebean, and sunflower).

The Ethiopian Seed Corporation's greatest achievement has been the provision of over 23 000 t of seed (out of a total of almost 34 000 t) to farmers in famine areas that were affected by the 1984/85 drought. This distribution ensured that there was no significant reduction in the area planted for the 1985 season, and it undoubtedly reduced the hardship that occurred.

A number of secondary objectives have been identified that are related to the 1983/84 drought. The objectives, which are aimed at the rehabilitation of agriculture during and after such droughts, include:

- The development of a strategy for seed reserves, to provide affected farmers with drought-resistant material of local cultivars. This will also safeguard the wealth of genetic material, one of Ethiopia's greatest natural resources.
- The production of a range of pasture and forage crop seed, an important element in soil and water conservation. This will play a major role in the long-term rehabilitation and development of the drought-affected areas.

CONSTRAINTS

The seed industry in Ethiopia is still in its infancy, and the agencies responsible for promoting and assisting small farmer development do not have a complete understanding of the seed industry's aspirations and requirements.

When the Ethiopian Seed Corporation was planned, investments were almost entirely centered on the construction and erection of seed cleaning and processing facilities. Post-project effectiveness of the planned

investments was reviewed and changes, aiming at a system of certified seed production, were made. Legislation supporting certification has yet to be drawn up.

A considerable amount of research is needed to define the crop characteristics needed by small farmers and to develop appropriate varieties. The seed industry has the capacity to produce substantial quantities of good quality commercial seed of the few recommended varieties. More careful consideration should be given to some of the policy issues which affect the rate and scale of adoption of new technologies and the increase in agricultural productivity. A few of the constraints are discussed below.

Pricing

The price structure for seed at the producer and buyer levels is an important constraint, and this has a major effect on both the production of good quality seed and on the demand for seed among potential buyers. In the context of current seed prices in Ethiopia there are a number of significant aspects which require consideration.

- Except for hybrids, there has been no adjustment in the price of seed since 1979, although the costs of seed production have increased substantially.
- The retail price of seed is sometimes lower than the open market price of grain, for instance in years of drought and for crops such as teff.
- The ESC is operating in a market where there are two separate reference levels for prices paid to the seed grower but only one reference level for the retail price of seed (Table 3).
- The price of seed sold ex-factory is based on one quintal (100 kg) of chemically-dressed seed. As such, it does not take into account whether or not the seed is treated, the type and cost of treatment, the type and unit size of packaging, or the assessed relative genetic potential.

The reason for these different prices is that the raw seed price is directly based on the grain prices

Table 3. Purchase and sales prices of bread wheat in Ethiopia.

Sector	Raw seed purchase price	Ex-factory seed price
State	47.00	65.25
Peasant	38.00	65.25

relevant to the two sectors, and the ex-factory processed seed price is based on the state sector grain price plus a factor for ESC processing and overhead costs.

Fixing seed prices in this way has several counter-productive effects.

- As there is no difference between the price of grain and the purchase price of seed, there are no incentives for the contracted seed growers to give additional attention to obtain maximum quality. The result is that there is little difference in quality between grain and seed crops. This has become serious in recent years as there has been a steady decline in the proportion of clean seed that the ESC is able to recover from raw seed. In the middle of the 1985/86 cleaning season, the average recovery rate is approximately 75% with, in the case of the maize variety A 511, the recovery rate of many seed lots falling below that. The balance of the unrecovered grain is made up of substandard kernels (undersized, shrivelled, broken, oversized), chaff, straw, weed seeds and seeds of other crops, stones, and miscellaneous detritus. The proportion of this fraction is directly related to crop husbandry, from seedbed preparation to harvesting operations. With seed production, it is necessary to carry out additional operations (roguing, detasselling, extra weeding, etc.) to ensure quality as well as quantity. The quality of seed is determined in the field, not by the processing.
- Some varieties of certain crops, particularly the

more drought-tolerant varieties such as Katumani (maize), Dereselgn (wheat), and Gambella 1107 (sorghum), will give lower yields in the better seed-producing localities than the commercial varieties normally grown in these areas. Any producer contracted to grow the drought-resistant varieties would thus automatically be subjected to a cut in farm income.

- The larger differential between grain and seed prices in the peasant sector, which is traditionally extremely cost conscious, mitigates against the sale of seed to this sector. The situation is even worse than indicated in the earlier example as the peasant farmer is generally obliged to purchase seed from the Agricultural Inputs Supply Corporation and he pays a higher price than that paid by the state farms to the Ethiopian Seed Corporation (ESC) (Table 4).

The peasant farmer is at a further disadvantage, though it may not be immediately apparent, in that he frequently buys his seed undressed, yet still pays for the dressing (Birr 3.20/quintal, approximately USD 1.6) as there is only one price.

In summary, the present seed pricing makes it very difficult for the ESC to generate a commitment to qual-

Table 4. Peasant and state sector seed prices in Ethiopia.

Sector	Grain price	Ex-ESC wholesale price*	Ex-AISCO retail price*
State	47.00	65.25	-
Peasant**	30.00	-	79.50

* Prices quoted in birr/hundred kilo (1 Birr = app. 0.5 USD).

** Peasant sector price quoted is price for mixed wheat as paid to the individual by a service or producer cooperative.

ity amongst contract growers, and even if a good range of superior varieties were available it would be difficult for the ESC and the inputs supply agencies to promote seed sales.

Farmers' Acceptance and Seed Demand

For a farmer to purchase and use improved seed, he must know about the seed and must believe that he will benefit by using the seed. Farmers will always form some perception about the cost, effort, and risk involved in introducing a new variety. The refinement of the level of perception will depend on the depth of the information communicated by extension and advisory agencies. Generally, the factors considered by the farmer are varietal superiority, price, and price-related market factors.

In determining the extent of varietal superiority, the main consideration is the relative advantage that the new variety has over varieties currently grown by the farmer. This advantage depends on a number of factors.

- The compatability of the variety with the farming system, the resources available, and in the case of basic food crops, the culinary acceptability of the variety.
- The consistency of the variety in its ability to provide, over time and under variable climatic conditions, the farmer's minimum food and income requirements. Occasionally, screening and breeding programs release a variety which out-yields all others under better-than-normal conditions. This may satisfy the needs of farmers in low-risk areas and the few farmers of above-average farming ability, but often it does not meet the needs of high-risk areas or the needs of those farmers whose resources and abilities accentuate the risk.
- The extent to which the improved variety raises benefits in terms of yield per unit area; yield per unit of labor; and the value of the incremental yield over the cost of the seed (after taking other inputs into account).

Many of the cultivars currently available in Ethiopia fail to satisfy these considerations. This in itself constitutes a major constraint to the development of the seed industry, as it is not possible to operate without varieties that have a substantial demand amongst the farming population. However, the problem is not insoluble, and by adopting a more farming-systems oriented approach towards agricultural research, the Ethiopian research agencies are giving the problem the attention required and are applying the necessary degree of urgency. Only research into the requirements of the peasant sector will identify the varietal characteristics that these farmers require. By combining these requirements with the needs of the urban or agro-industrial user, breeders can develop varieties which will have a market demand. The results of this approach may not be significantly apparent for a number of years, and until then expansion of the seed industry may be limited.

In addition, there are a number of less evident factors which must be taken into account when considering the overall constraints to the acceptance of improved seed and the development of the seed industry. These include the overall availability of seed and the ease of saving seed, the price received for farm output, and the existence of a total production package plus the means to secure the various elements of the package (i.e. credit for fertiliser, seed, pesticides, etc.). Overall seed supply has its greatest effect on the farmers' decisions and is primarily related to the alternatives for obtaining seed and the frequency of purchase. In the case of non-hybrids the primary alternative for the farmer is farm-saved seed. In this instance, the cost of purchased seed must be compared with the local grain-market price. In the absence of any deterioration of genetic or physical quality, the level of competition between purchased seed and saved grain will be extremely high and, in the majority of cases, will tend to favor the use of saved grain. This is particularly pertinent in the case of wheat, barley, and teff in the Ethiopian highlands, where low ambient temperatures and relatively low humidity mean that seed can be saved on-farm with only marginal losses in germination capacity and viability.

A further consideration is that before the farmer will commit financial resources to seed purchases (particularly in conjunction with other inputs), he must be convinced that they will generate a return that is sufficiently in excess of the incremental cost of production. In a low-risk situation the acceptable norm is that the ratio between the value of incremental output and the cost of incremental inputs should be equal to or greater than 2:1. In the medium to high risk situation found in much of Ethiopia a more acceptable ratio would be 3:1. This infers that in addition to the consideration given to yield increases and relative advantage, a balance must be drawn between the value of crop production per se and the cost of inputs. At present, under the current crop prices, this relationship does not necessarily give the farmer a high enough level of return.

Another factor affecting seed demand is whether or not there is a viable production package in which seed, in conjunction with other purchased inputs and applied improved cultural practices, can give an acceptable increase in production. A farming-systems approach to agricultural research will lead to the development of appropriate packages, but the value of any package will be negated if the infrastructure for input supply is inadequate and if the farmer's opportunity for purchasing the inputs is limited or restricted. Such an infrastructure is dependent on the availability of good communications, on the existence of a strong system of rural credit, and on the existence of an agency able to translate farmer needs into a readily available supply of inputs. Because of Ethiopia's topography, communications can be very difficult, and as many of the input and rural credit agencies post-date the revolution, the total inputs supply infrastructure is not yet fully developed. This obviously has implications for seed demand.

Other Constraints

Finally, and more practically, there are two further constraints on the development of the Ethiopian Seed Corporation and the seed industry at large.

Certified seed production requires the backing of

legislation if standards are to be enforced. Although the ESC has now been in existence for almost 7 years, no legislation for seed multiplication exists.

There is no system for the multiplication of early generations on the scale necessary to ensure early release to the farmer. To overcome this, the ESC is setting up two basic-seed farms which will produce pre-basic and basic seed.

These are but a few of the more readily identifiable constraints to the development of the Ethiopian Seed Industry. Agricultural development is a dynamic process, and only by being aware of constraints is it possible to achieve progress. The ESC is addressing itself to the solution of these constraints and will undoubtedly identify further constraints.

Seed Improvement Program in the Sudan

Ahmed Abu El Gassim
Director General
National Seed Administration
Ministry of Agriculture
Khartoum, Sudan

INTRODUCTION

The Sudan, the largest country in Africa, lies between 3-23° N and 21-39° E and covers some 2.5 million square kilometers. Of this area about one-third is classified as arable land, about 17% of which is under cultivation. Topographically, Sudan consists of a vast plain traversed from south to north by the Nile River and its tributaries, and interrupted by widely separated mountains and hilly areas.

Sudan has a tropical continental climate, except for a narrow fringe along the Red Sea coast which has a maritime climate. Based on annual rainfall and type of vegetation, the country may be divided broadly into three major zones:

- The northern, light-rainfall (0-400 mm) zone, which covers one-third of the country and where crop production is mainly by irrigation.
- The central savannah zone (400-750 mm), which covers about half of the country. The most important rainfed developments, including mechanized farming, lie in this zone, which can be divided into two distinct regions:
  a) the sandy area in the western part of the country where rainfall is relatively low, and where sorghum, millet, and seeds are produced using shifting cultivation, and
  b) the central clay plain in the east, where rain-

fall is relatively high and where cultivation of sorghum, sesame, and some oilseed is mechanized.

- The southern, heavy-rainfall zone (750-1 500 mm) which covers about one-sixth of the country, and where rainfall is adequate for practically all tropical crops including tea and coffee.

In the northern part of the country, the summers are invariably hot (mean maximum 41° C and mean minimum 25° C) with large variations and with low relative humidity (average 25%). Winters can be cool, with temperatures around zero occurring frequently. The number of hours of sunshine is high. Such a climate is favorable for seed production of a range of crops, mainly vegetables, legumes, wheat, and spices.

The development plans of the Government of the Sudan allocate high priority to agricultural development and aim for a growth rate of about 6.5%.

The important agricultural area in the Sudan is divided into three sub-sectors.

- The modern irrigated area, with more than 1.5 million hectare around and along the Blue Nile, White Nile, and the main Nile, mainly in the central and northern regions.
- The mechanized rainfed area with more than 2.5 million hectare in eastern, southern, and central regions.
- The traditional rainfed area in western Sudan, with 4 million hectare.

Sudan needs about 100 000 t of quality seed annually, but specialized seed farms (both public and private) produce only about 10 500 t annually.

NATIONAL SEED ADMINISTRATION

Organized seed multiplication activities in the Sudan started in the early 1950's in the northern region. At first, they mainly served as a seed-multiplication arm for the Agricultural Research Corporation (ARC). In 1968, it was decided that the scope

of seed multiplication should be expanded to cover a larger part of the country's needs by bringing new areas under plant propagation command. Subsequently, the Plant Propagation Section was separated from the Agricultural Research Corporation. Two irrigated seed stations were established in the central and the eastern regions, and one rainfed station was established in the eastern region.

In 1975, an FAO project was initiated to assist in the expansion of seed-production activities and to establish a sound basis for seed certification and testing. Under this project, the existing seed-production centers were strengthened and new processing units were installed in the major producing schemes. This was continued with a grant from the Iraqi government for oilseed production.

In 1982, the African Development Bank and African Development Fund approved funding for the Sudan Seed Project, which provides for:

- Formation of the National Seed Administration (NSA) with two main branches; one for seed production and one for seed certification.
- Establishment of two irrigated stations in the northern region at Hudeiba and Dongola and one in western Sudan at El Obeid.
- Strengthening of the existing seed station.
- Support to the ARC to ensure a continuous supply of breeder seed.
- Funding to cover operational inputs and maintenance.
- Establishment of credit facilities to enable production corporations to expand the area under seed production and to build seed-processing facilities.
- Technical assistance from expatriates.
- Staff training in seed technology.

NATIONAL POLICY CONSIDERATION

Through the Sudan Seed Project, the Government of Sudan also established a comprehensive seed policy.

Specific targets were set for the amount of seed to be produced for individual crops and for areas in which the seed would be produced within a 4-year period. In the program, different targets were set for different sectors, e.g. the modern irrigated, mechanized rainfed, and traditional rainfed sectors. Sorghum, millet, sesame, groundnut, wheat, bean, and castor were identified as priority crops for seed production. Even though there are plans to strengthen the various components of seed programs, mechanized seed production and seed-quality control are expected to receive most emphasis.

There was an initial set back, due to lack of funds, which affected the progress in various activities. Initial trends indicate that the target levels for wheat and sorghum seed production will not be met. A steady improvement is expected in the amount of groundnut and sesame seed produced.

With the exception of Hageen Durra 1 (hybrid sorghum) and Deberia (wheat), which were released recently, there are very few new varieties. A strong breeding program is essential for the success of the seed program. Maintenance of existing cultivars has recently been initiated, although such maintenance was neglected in the past. Latest production strategies, using better management of available inputs, are currently being employed and are expected to raise production levels significantly. Recently, seed-processing facilities were augmented with the installation of a high-capacity automatic seed-processing plant with a capacity to process 5 t/hr. Seed-storage facilities of the National Seed Administration and of agricultural corporations can be further improved. There is also ample scope for improvement in the marketing sector (distribution, mobility, pricing, and packaging). Technically qualified staff is available, and facilities exist for on-the-job specialized training of staff.

Management of the seed-improvement program was given top priority so that the available resources could be fully and efficiently utilized. Consultants were engaged to analyze the critical areas for improvement and their recommendations are being implemented in phases. A small team of FAO experts is assisting the project in overall management and technical matters.

Time scheduling, monitoring, and backstopping are being done to ensure the success of the program.

The latest advances in seed technology, with appropriate technologies relevant to Sudan, are employed. A close link is maintained with the ARC to solve the specific problems of each location through research. Physical facilities (seed farms, irrigation network, offices, stores, workshops, processing sheds, and residential houses) have been improved. Vehicles, field and laboratory equipment, processing plants, fertilizers, agricultural chemicals, spare parts, and fuel have also been provided.

Pricing policy and price movement are under constant review and a more flexible seed-pricing policy vis-a-vis grain is being developed. Seed is the cheapest input in crop production, and seed prices should be higher than grain prices to encourage seed production.

Special programs of seed production and distribution have been undertaken for some important crops such as Hageen Durra 1 (hybrid sorghum), Deberia (wheat), and Exbornu and Bioda (millet). With respect to the increase in the acreage under sorghum hybrid, the program is successful. The program on Barberton (groundnut) is behind schedule due to an initial shortage of breeder seed, but is expected to catch up.

Various components supporting facilities are at different levels of attainment. The seed project has strengthened the agricultural research centers in Sudan, enhancing their capacity for breeder-seed production. On the other hand, seed-technology research, which is considered a component of crop research, has not received sufficient attention, and facilities are limited. Seed production, processing, storage, and quality testing have yet to be tackled.

In addition, variety testing should receive more attention, and maintenance and control have scope for further improvement. An autonomous certification agency has been established with well defined rules for field certification and seed testing, and quality control is being stressed. Considerable improvement is also possible in the extension services available for the seed program, and plans are in progress to use modern extension techniques.

FUTURE PROSPECTS OF SUDAN NATIONAL SEED PROGRAM

Expansion of the Program

Even though seed production and testing have been carried out in Sudan for some time, there was a need to reorganize the setup in order to give a new dimension to the whole seed program. Therefore, the National Seed Administration was established with clear-cut objectives and a time schedule. The Seed Improvement Project aims at producing 50% of the country's seed requirements by the end of 1986. Considering the various constraints, it may be worthwhile to evaluate the status periodically and to take whatever steps may be necessary in order to progress.

While the present phase of seed-program development is in progress, it is important to plan the next phase by extending the program to increase the area. More rainfed areas should be planted with improved seed, especially in the drought-affected areas in the western part of the country.

Introduction of New Crops

Attention has mainly been focused on major cereals and some oil crops, but there is considerable scope for other crops such as lentil, chickpea, sunflower, and safflower. The success of large-scale production of these crops in Sudan will depend on the availability of quality seed. After careful selection of varieties showing promise in arid and semi-arid areas, the selected varieties should be considered for introduction in a phased manner.

Vegetable Seed Production

It is feasible to undertake seed production of the major vegetable crops in Sudan. Appropriate crops and areas should be identified, so that high-quality seed can be economically produced. The production of vegetable seed is a priority for the NSA.

Since vegetable-seed production is often highly remunerative, it is likely that the private sector will

become involved. Apart from the cool-season crops (carrot, beet, brassica, etc.), it is economically feasible to produce good-quality seed of most vegetable crops. Potato seed could also be produced in the high-altitude areas of the west, south and north.

Forage Seed Production

Sudan is suitable for raising livestock, but one of the limiting factors is the availability of fodder. There are a variety of grasses and other fodder crops that can be cultivated. Some suitable fodder crops can be introduced in the rotation. There is tremendous scope for forage-seed production.

Hybrid Sorghum Seed Production

Sorghum is the main staple food of Sudan, and the release of hybrid sorghum offers great potential. The National Seed Administration would like to exploit this potential. As hybrid-seed production is highly specialized and the seed must be replaced every year, a well organized system needs to be developed in order to satisfy the country's seed requirements. A pilot project, with the participation of NSA, ARC and several agricultural corporations, has operated during the past 2 years. This project produces, certifies, processes and distributes seed. The hybrid shows great promise and the extension of the area cultivated to hybrids will no doubt have a tremendous impact on production. However, careful demand assessment is essential in order to avoid over or under production. The availability of adequate amounts of good-quality foundation seed must be ensured. The production of foundation seed is the responsibility of NSA, whereas both public and private producers are fully involved in certified hybrid-seed production. In the 1985 season, the total area under certified hybrid-seed production was 3 000 acres (approxim. 1 250 ha), shared equally between the private and public sectors. The demand for hybrid seed is increasing fast, and more areas must be brought into production in order to satisfy this demand.

Regional Training Facilities

Sudan has trained a large number of scientific and technical personnel - mostly outside the country in major scientific and technical centers - in seed science and technology, and well trained staff is now available. Good facilities for seed production, seed certification, and seed processing are available, making Sudan suitable for regional training courses in various aspects of seed technology. During the past 10 years, seven short courses were organized with the assistance of the FAO and the Industry Council of Development, New York. Staff of adjoining countries can be trained in Sudan through regional courses.

SEED SECURITY

Due to the severe drought in many African countries, the Sudan experienced an acute shortage of seed during the autumn of 1985. An emergency program to set up a seed-reserve stock of early-maturing sorghum and millet seed was developed with USAID help. About 4 000 t of sorghum and 3 000 t of millet seed were procured, locally processed, and distributed.

The maintenance of a seed reserve stock for major seed crops has not been possible in the past, but the NSA would like to provide them for the future. Currently, only 10% of the national requirement of quality seed is met by the NSA, but efforts are under way to improve the situation. While seed quality has generally improved, there has been little expansion in the total amount of seed produced during the last decade. The overall seed production by the NSA increased in the past two years, and production of quality seed is expected to rise to 50% of the requirements during the next three years.

SEED FOR THE LOW-INPUT FARMERS

In Sudan a substantial area is in the traditional rainfed sector, which includes lands farmed by low-

input, subsistence-oriented farmers. Very little has been done for this sector in the past, and a well-organized effort, with appropriate financial and technical support, is needed in order to enable the low-input farmer to manage his farm to the best of his abilities.

Needed efforts can be summarized as follows:

- Research and breeding of varieties for the low-input sector should be intensified.
- Seed farms should be established in this area.
- A well organized quality-oriented seed program should be established.

A total technology package for this sector is being planned within the Sudan Seed Project.

The National Seed Company

INTRODUCTION

The National Seed Company, a private company in Egypt, was established in order to meet the rising need for high-quality seed, especially of Giza 2 maize seed. The Agriculture Research Center of the Ministry of Agriculture had developed this high-yielding variety, but until the National Seed Company was founded, there was no organization or company to multiply the seed.

SEED PRODUCTION

The National Seed Company has its main processing plant and storage houses in the Mollack farm, which is located in Sharkia Governorate, the leading governorate for maize production.

The National Seed Company obtained foundation seed from the Agriculture Research Center, contracted growers, and produced 465 tonnes of certified Giza 2 seed the first year (1981).

Fields were inspected during the growing season to make sure that they were treated in the right way and that they were sufficiently isolated from neighboring maize fields to minimize contamination.

The company's engineers supervised field operation until harvest, at 20-25% kernel moisture content. Ears were then dehusked and sun dried to a moisture content of 12-14%. During drying, disease and insect-infected ears were removed. Healthy ears were then put in 60 kg sacks and sent to the processing plant. Dried ears were put in a processing line for shelling, cleaning, treating and packing.

In 1982, the company increased production of maize seed and started production of seed of vegetables and of summer forage crops. That year the company produced

1 150 tonnes of Giza 2 maize seed, 20 t of Giza 1 sweet sorghum, and 5 t of vegetable seed, all of which were processed and packed in the company's processing plant.

In 1983, the company tripled its production of certified seed, and in both 1984 and 1985 it produced five times as much seed as in 1981.

The company plans to increase production by another 60% in 1986. The main increases will be for vegetable and fodder seed.

SCHEME OF WORK

Approximately 200-250 feddans (approx. 80-100 ha) are assigned to an engineer, who then makes the contracts, inspects the land, supplies the registered seed, supervises planting and other field operations, makes sure that all the plants are true to type, and makes sure that all plants infected with seed-borne diseases are removed. He also supervises harvesting and seed extraction. The final receipt of seeds is made only after the Ministry of Agriculture (Central Administration for Seeds) has tested samples of the seed. If the seed is approved, the company pays the seed grower. Seed is then transported to the processing plant, where it is cleaned, polished, treated with fungicides and insecticides, and packed.

In order to facilitate the engineers' work, the company supplies each engineer with a vehicle.

As soon as the company makes a contract, it gives the Central Administration for Seeds (CAS) the name of the contractor, the crop, the area, the location and the name of the cultivar. Inspectors of the CAS inspect the fields during the growing season to make sure that the standards are met.

SEED PROCESSING

The company has its own seed processing plant and storage houses, including a packing machine for veget-

able seed. It uses rented vehicles as well as the company fleet to transport seed from the contractors to the processing plant. It has also established a seed quality-control laboratory in Mollack to ensure the quality of the seeds and to help the company to select better growers for following years.

SEED DISTRIBUTION

The rapid growth of the seed-production program and the company's success in selling all of the seed it produces, indicates how much growers and distributers appreciate the company's product. Demand is so high that watermelon and sweet melon seeds are sold out by the end of October, a full four-to-five months before they are usually sown.

In order to facilitate distribution of seed to small farmers, seeds are packed in 15 and 30-kg quantities, an amount sufficient for 1 or 2 feddans (1 feddan = 4200 m^2).

The company distributes seed through the Agricultural Credit Bank and its branches. It also supplies seed to seed agents, representatives of agricultural syndicates, growers, agricultural cooperatives, and directly to growers.

Pioneer's Role in the Development of the Seed Industry in Egypt

Hari R. Shukla
Resident Representative
Pioneer Overseas Corporation
Cairo, Egypt

INTRODUCTION

In 1976 Pioneer Overseas Corporation (POC) started its activities in Egypt by introducing and testing Pioneer-brand varieties. As a result, a white-maize hybrid named 514 was found. This hybrid, which is tolerant to late wilt and suitable for Egypt, was released for commercial cultivation in 1979.

In addition, a survey made at that time indicated the need for a research station in Egypt to develop late wilt-resistant/tolerant hybrids. Toukh Research Station was established in 1980, and has grown from a staff of two in 1980 to a staff of 40 in 1986.

POC had the following objectives when it started in Egypt: to breed high-yielding hybrids with resistance or tolerance to late wilt; to develop seed-production facilities and advance technology to benefit seed producers and farmers; to develop an efficient marketing system throughout the country; and to diversify activities to include other crops such as forage sorghum, grain sorghum, alfalfa and sunflower.

HIGH-YIELDING VARIETIES RESISTANT TO LATE WILT

In order to develop high-yielding resistant varieties, POC needed to: identify and study the nature of inheritance of the main diseases and pathogens that

affect maize production; obtain breeding material from various parts of the world and test this material for late wilt disease; identify the most effective way of artificially inoculating plants; and follow adequate breeding methods to select the best possible hybrids in the shortest possible time.

Isolates of Cephalosporium maydis were collected from various governorates of Egypt and were used to build up disease inoculum. Two methods of inoculation were used; the soil technique and the toothpicks technique. It was concluded that the soil inoculation technique is more effective and easier to implement than the toothpicks method. In addition, the soil inoculation technique helps to identify the material that is most resistant and tolerant to late wilt.

We started producing two crops a year and intensifying its activities, in order to develop high-yielding hybrids that were adapted to the environment of Egypt and resistant or tolerant to late wilt. POC has coded 32 inbred lines and will code an additional eight white and yellow inbred lines.

The company tested 2 509 white and 311 yellow hybrids at its research station in Egypt. The best two white hybrids and one yellow maize hybrid are at the pre-commercial stage and are presently undergoing tests at the Agriculture Research Center. These hybrids show 20-25% yield superiority and are highly tolerant to late wilt.

KARNAK, the first commercial hybrid developed in our research center, was released in January 1986.

PRODUCTION AND DISTRIBUTION

POC expects to produce 10 000 tonnes of hybrid maize, hybrid forage sorghum, hybrid grain sorghum, sunflower, and alfalfa by 1989, and has taken steps to ensure that the seed will reach the farmer who is, after all, the end user.

So far, we have signed a Producer-Distributor Agreement with the Agrarian Reform to produce and distribute seeds to Egyptian farmers; have trained our Egyptian staff locally as well as abroad to enable them

to carry out successful seed production; have established a preliminary seed-conditioning plant in Meet Bera (1980); and have carried out several demonstrations for farmers.

In the near future, POC plans to increase the capacity of the seed-conditioning plant to 4 000 tonnes and to reach a capacity of 8 000 tonnes by 1987 (the overall capacity can be doubled by running the plant in two shifts). It also plans to set up more than a hundred demonstration plots in order to transfer knowledge and experience to farmers and to promote the merits of the new hybrids.

The commercial activities will be performed with Misr Pioneer Seed Company, which was established in June 1985 with an investment of 2.5 million L.E., and which now has an investment of 5 million L.E..

The cultivable area of Egypt is 2.5%, of which 0.8% is cultivated with maize every year. Although it might be possible to increase the total maize area, this will not be enough to meet the rising need. Only an increase in production per unit area can meet this rising need and lead to self-sufficiency in maize (Figure 1).

Although we expect to cover 25% of the maize area with hybrids in 1986 the deficit between production and need will still remain high. During 1987 we plan to cover 50% of the total area with high-yielding hybrids and 75% by 1988. We expect to have hybrids producing 25 ardabs/feddan (approx. 8 t/ha), achieving not only self-sufficiency but surplus production. Under Egyptian conditions and with good varieties and high-quality seed, it is possible to achieve these goals. We expect to be able to maintain adequate production by introducing new single-cross and/or modified single-cross hybrids in Egypt.

Misr Pioneer Seed Co. is also developing a system of distribution designed to reach every farmer in a timely fashion. The network will enable us to supply seed two months before the planting season. We also aim to provide a continuous flow of technical know-how throughout the entire growing season.

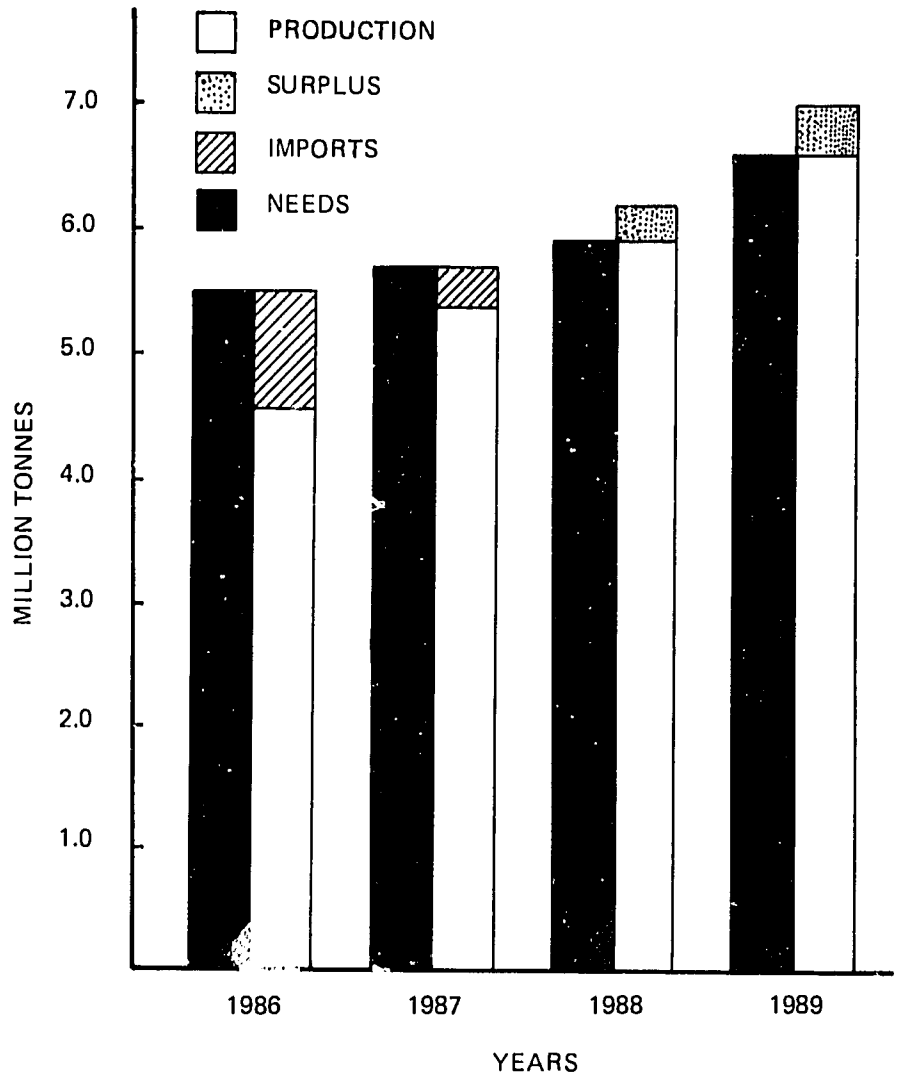

Figure 1. Estimated production, consumption, and imports of maize in Egypt (1986 – 1989).

AVAILABLE VARIETIES

Our available material includes maize and other crops. We have two white maize hybrids, KARNAK and 2E187, and a yellow maize hybrid 3147 for newly reclaimed land. In addition, several new white and yellow hybrids are expected to be released soon.

Sorghum sudangrass hybrid 988, a multi-cut hybrid, adopted worldwide, can yield (under optimum conditions) up to 100 tonnes of green forage/feddan (approx. 240 t/ha) in four cuts. This hybrid is under production in Egypt, and we hope to be able to provide Egypt's total seed requirements next year.

Grain sorghum, suitable for newly reclaimed land, was also introduced, and excellent yields can be obtained under good management. In the delta area at our research station, we have obtained over 25 ardabs/feddan (approx. 8 t/ha), a yield that might be reduced to some extent in newly reclaimed land. Two hybrids ZS002 and ZS003 have been released for commercial cultivation.

We also have hybrid sunflower and alfalfa, and at present this material is being multiplied in the country.

POC in USA agreed to expand our research activities, and we have decided to have a full breeding station for maize in the delta, one in Minia for grain and forage sorghum, and one in Nubaria for sunflower and alfalfa.

SUMMARY

In summary, we will benefit from Pioneer's 60 years of experience in the seed business and from the use of Pioneer's germplasm, and we hope to play an important role in bringing self-sufficiency to Egypt.