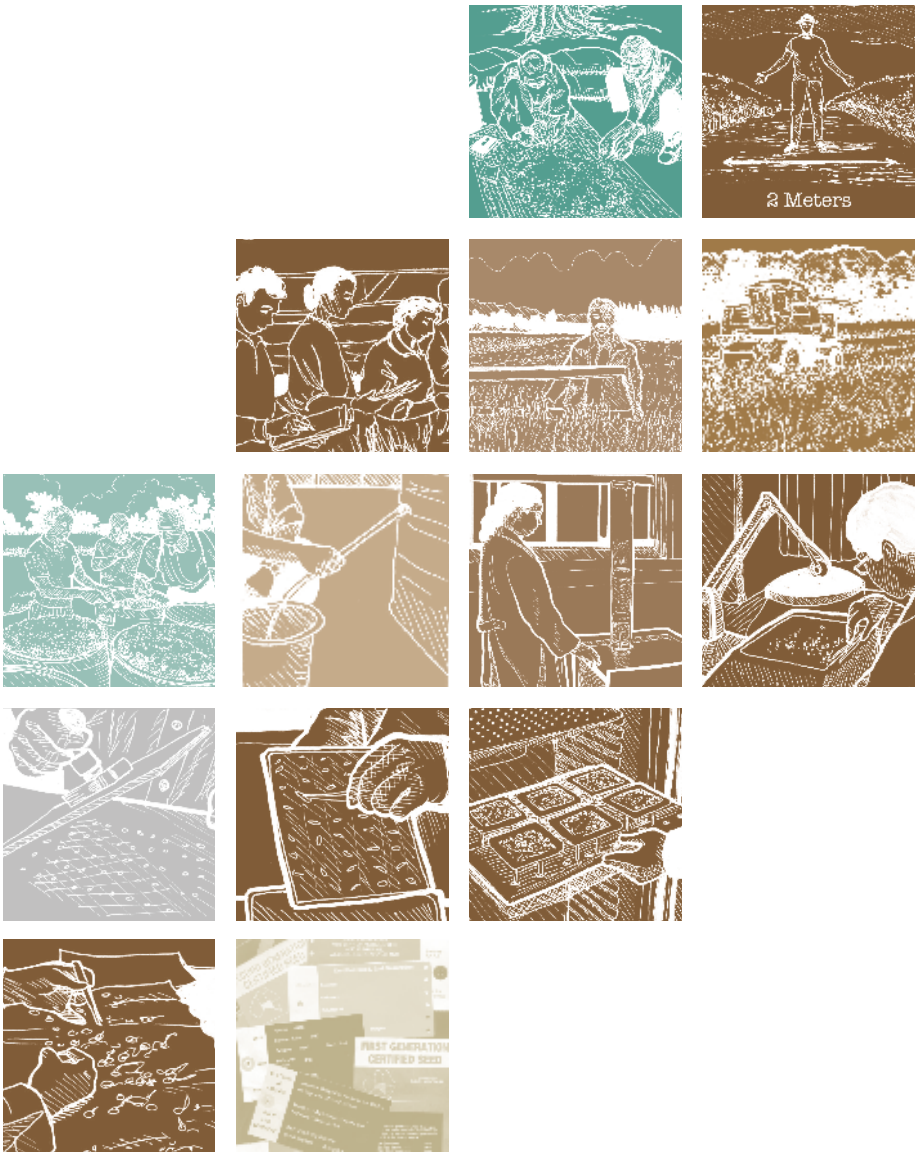
Food and Agriculture Organization of the United Nations

AfricaSeeds

SEEDS TOOLKIT

Module 3: Seed quality assurance



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Module 3: Seed quality assurance

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This assists seed practitioners and other stakeholders in meeting the set quality standards for seeds and in implementing procedures for certification. The topics covered include field inspections and seed conditioning, packaging and tagging, storage, sampling/testing, and distribution.

Contents

Foreword

The global community, through the Sustainable Development Goals, has committed to achieving a world free of hunger by 2030. This will require the sustained production of about 60 percent more food than at present, food that is both nutritious and safe, and produced in ways that do not damage the environment. Under most scenarios, there are no surplus land or water resources to deploy to increase agricultural production. In fact, the most sustainable path to this goal is through enhanced productivity in a sustainable way. That means producing more yield with fewer external inputs. To support this, farmers need to use well-adapted crop varieties.

FAO and partners work with countries to increase farmers' use of quality seed and planting material of well-adapted varieties, particularly for the rural dwelling resource poor small-scale and family farmers who produce most of the food consumed in vulnerable communities of developing countries.

A country's seed delivery system is best conceived as a value chain composed of interrelated components – from the development of well-adapted and nutritious crop varieties and their adoption by farmers, through the production and distribution, including sales, of quality seeds and planting materials, to on-farm utilization of these inputs by farmers. The effective functioning of the value chain, enabled by the applicable national seed laws, policies, strategies, action plans and regulations, depends largely on the extent to which the stakeholders are able to put into practical use the relevant knowledge and skills required for producing quality seeds and planting materials.

This Seeds Toolkit has been developed to support practitioners along the entire seed value chain to acquire the knowledge and skills they need in order to deliver quality seeds and planting materials of well-adapted crop varieties to farmers. The Toolkit is designed primarily for capacity building activities, especially for small-scale farmers and small and medium-scale entrepreneurs, and contains six interrelated modules. These modules address: the setting up of small-scale seed enterprises; the processing of seeds; quality control; and the storage and marketing of seeds. There is also a module on seed regulatory matters. These easy-to read modules of the Toolkit should also be useful for policy-makers and other practitioners interested in better understanding the workings of effective seed delivery systems.

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Director Plant Protection and Production Division

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Hamza Bahri and Diana Gutiérrez Méndez (FAO) coordinated the language editing, illustrations and layout. Ruth Duffy edited the document, Shalis Stevens drew the illustrations and Davide Moretti (Art&Design) undertook the overall design and layout of the publication.

Abbreviations and acronyms

AOSA	Association of Official Seed Analysts
AOSCA	Association of Official Seed Certifying Agencies
DUS	Distinctness, Uniformity and Stability
EC	Electrical Conductivity
ELISA	Enzyme-linked immunosorbent assay
EU	European Union
FAO	Food and Agriculture Organization of the United Nations
ISTA	International Seed Testing Association
NGO	Non-Governmental Organisation
OECD	Organisation for Economic Co-operation and Development
PCR	Polymerase Chain Reaction
PLS	Pure Live Seed
QDPM	Quality Declared Planting Material
QDS	Quality Declared Seed
TSW	Thousand Seed Weight
UPOV	International Union for the Protection of New Varieties of Plants
VCU	Value for Cultivation and Use

Introduction

Quality seed is the fuel for agricultural development, and availability of quality seeds of a wide range of adapted crop varieties is the key to attaining food security. Seed produced under a certification and quality control system is superior in terms of improved variety, varietal purity, freedom from admixtures of weeds and other crop seeds, high germination and vigour and seed health.

This module of the Seeds Training Toolkit is designed to guide and assist technicians, seed producers and other stakeholders involved in developing and implementing quality management programmes. It explains the principles and key elements of seed quality assurance and certification, and is based on guidelines from international organizations involved in seed certification and related activities, such as the Organisation for Economic Co-operation and Development (OECD), Association of Official Seed Certifying Agencies (AOSCA), International Seed Testing Association (ISTA) and Food and Agriculture Organization of the United Nations (FAO).

The module comprises six chapters. Each chapter is supplemented by exercises designed to promote discussion and brainstorming during the training sessions.

Chapter 1 explains what "quality seed" means, and the role of seed quality in crop production. It also explains the main quality attributes and the factors affecting the quality of seed.

Chapter 2 discusses sampling procedures for a seed lot in the warehouse and how to obtain working samples in the seed laboratory.

Chapter 3 details the measurements of seed quality attributes, related to (i) purity test, (ii) germination test, (iii) determination of moisture content, (iv) viability test, (v) vigour test, (vi) seed health testing and (vii) variety verification.

Chapter 4 outlines the purpose and organization of seed quality assurance and control. It explains the seed certification process, the Seed Certification Agency and its activities, the national variety list and the technical requirements for producing certified seed. Topics covered include site selection, land preparation, planting stock, sowing, roguing, harvest management, drying, processing, transportation and storage.

Chapter 5 describes the seed certification process and the necessary procedures for monitoring seed quality during the multiplication process. There is a special focus on the two main procedures – control plots and field inspection – designed to check the integrity of a variety at different stages in the seed production process.

Chapter 6 covers important management aspects and international considerations of seed certification, with attention to different aspects of seed quality assurance and control systems, including compulsory and voluntary certification and truthful labelling. The OECD and AOSCA seed schemes, the FAO quality declared seed (QDS) system and the role of ISTA are presented.

① Seed quality

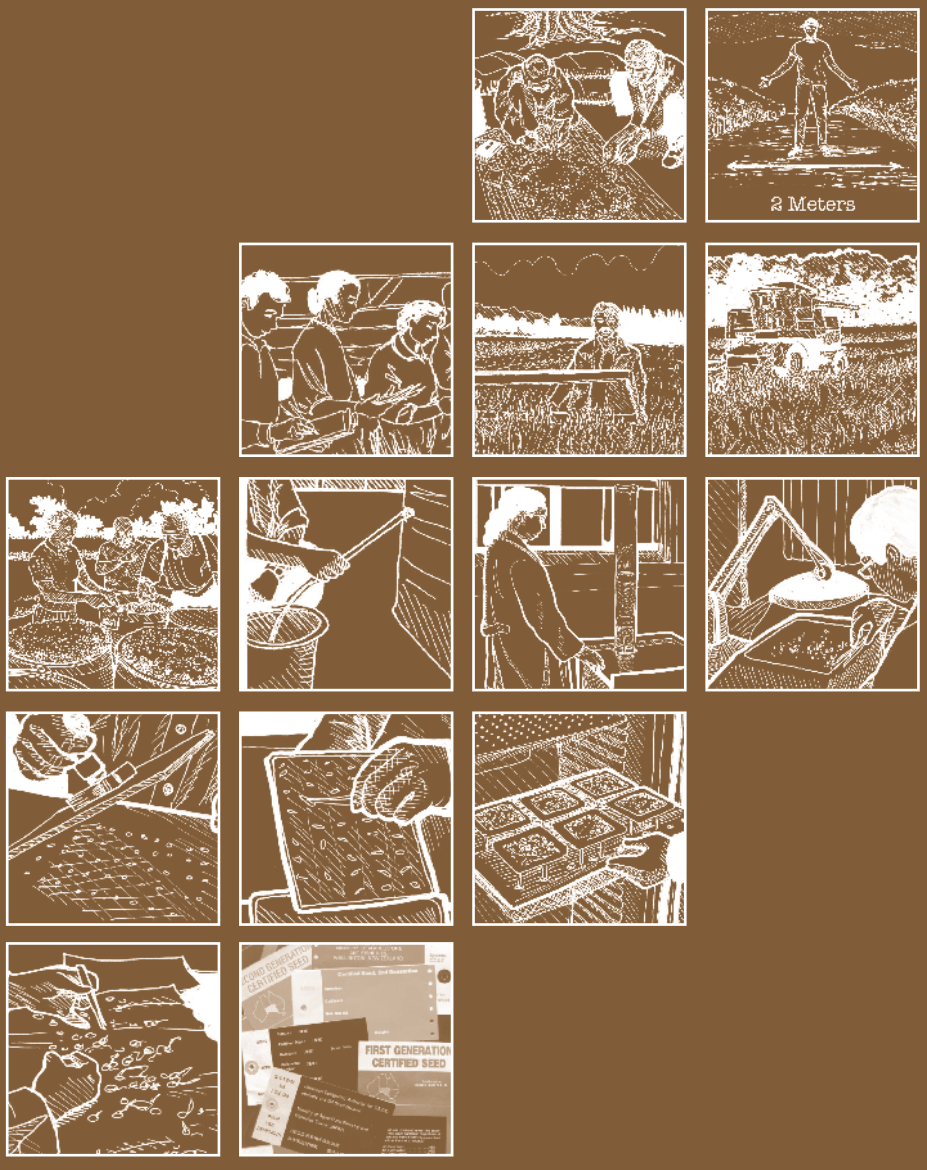

Figure 1.1 *Farmer selecting the seed*

Seed quality

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Seed quality means different things to different people depending on their interpretation of "quality". It is critical to understand the differences between "seed quality", "crop variety" and "quality seed". For new varieties to reach their optimum potential in the field, it is essential to follow **recommended farming practices**, including the timely use of **quality seed**. The adoption and spread of new varieties depend on the quality of seed made available to farmers. High yield cannot be obtained from a marvellous variety by planting low quality seed of that variety: it is the quality of the seed that ultimately determines the plant density in the field and the number of plants established per hectare.

WHAT IS SEED QUALITY?

Seed quality is a **concept**: it expresses the extent to which a given seed lot meets the standards set for certain attributes determining the quality status of seeds.

A **seed lot** can be defined as an identifiable quantity of seed of one variety, of known origin and history, and recorded under a single reference number in a seed quality assurance scheme.

Parameters of seed quality attributes:

- **Genetic** – relating to the specific genetic characteristics of the seed variety (genetic purity).
- **Physical** – relating to the condition of the seed in the specific seed lot (physical purity, presence of other seeds and moisture content).
- **Physiological** – referring to seed performance (germination, viability and vigour).
- **Health** – relative to the presence of diseases and pests within a seed lot.

Seed quality attributes:

- **Genetic purity** – the true-to-type nature of the seeds and whether they come from a distinct variety. Genetic purity has a direct effect on final yield. Trueness-to-type is usually determined by checking the seed source records to verify the origin and history of the seed. Alternatively, direct inspections may be carried out in the field with the guidance of control plots.
- **Physical purity** – the cleanliness of the seeds in terms of physical composition once divided into pure seed, inert matter, weeds and other crop seeds. The pure seed component, combined with the germination capacity, determine the planting value.
- **Germination capacity** – an indication of the proportion of live seeds capable of producing normal seedlings.

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*Both seed physical purity and seed germination have a profound effect on yield and determine the **planting value** of the seed. Planting value (percentage of pure live seed) defines the true value of a seed lot for crop cultivation. Only **pure live seed produces plants**, and it should therefore be calculated in order to accurately adjust the seeding rate, as necessary.*

Pure live seed (%) = Pure seed (%) x Germination (%)

Example: If a seed bag tag indicates germination of 80% and purity of 95%,

Pure live seed = (80 x 95) / 100 = 76%

Therefore, the seed lot contains 76 kg actual live seed for every 100 kg.

- **Moisture content** – the moisture level of the seeds. Drying the seed to a safe moisture content is critical to maintain seed germination and viability during storage.
- **Seed vigour** – defined by ISTA (1995) 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". In any seed lot, loss of seed vigour relates to a reduction in the ability of seeds to carry out the physiological functions that allow them to perform.
- **Seed health** – an indication of whether seeds are free from moulds, other seed-borne diseases and insect pests.

Seed quality is the sum of these attributes. It conditions just how acceptable the seed is to buyers and determines the price they are willing to pay for it. The standards set for these attributes determine whether a given seed lot can be considered of high or low quality. High quality seed has:

- high genetic purity;
- high germination percentage;
- minimum presence of inert matter, weeds and other crop seeds; and
- absence of diseases.

High quality seed is expected to produce normal seedlings that will emerge well in the field, give the farmer a uniform crop stand and produce a high yield.

What is quality seed?

Quality seed is genetically pure, characterized by a high germination percentage and appropriate moisture content; it is free from diseases, and has a high content of pure seeds and no weed seeds.

Quality seed is important in both the formal and the informal sector. The **formal sector** encompasses specific activities to make available new varieties and maintain their purity; and to certify seed and distribute it to farmers through recognized seed channels. Quality seed is produced under supervised conditions, which may vary depending on the specific seed class or category.

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The **informal sector** – also known as the traditional or farmer seed system – lacks public sector regulation. Seed is exchanged and bartered among farmers or sold on the local market. According to Cromwell, Friis-Hansen, and Turner (1992), five key features distinguish the informal system: it is based on tradition, is semi-structured, operates at individual community level, uses a wide range of exchange mechanisms and usually deals with small quantities of seeds as widely demanded by farmers. This traditional system has maintained local varieties and landraces for hundreds of years.

Factors affecting the production of good quality seed

Genetic factors

Genetic make-up determines characteristics, such as seed size and bulk density, which can influence seed quality.

Production practices

Good production practices are essential:

- **Planting conditions.** Production of high-quality seed can fail under adverse conditions causing too much stress.

Figure 1.2 Taking a seed sample to check the quality after harvest

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- **Use of chemicals.** Physical damage to plants as a result of chemical application can produce a crop unfit for field inspection. Moreover, chemicals may be retained in the seed with adverse effects on seed germination.
- **Timing and methods of harvesting.** Too early or too late harvesting may reduce the seed quality. It is crucial to harvest seed as soon as the moisture content reaches a safe level for storage (unless drying facilities are available).
- **Threshing, drying and processing**. Failure to clean the seed results in poor quality.Cleaning eliminates or reduces undesirable contaminants (e.g. diseased and immature crop seed, weed seed, inert matter, broken or split seed, or other crop seed). Drying at too high temperature – typically when trying to dry seed quickly – can adversely affect seed germination.

- **Seed storage**. Inappropriate conditions can increase the rate of deterioration. Prolonged storage under less than optimum conditions (in terms of temperature and humidity) leads to physiological, biochemical and cytological changes in seeds, resulting in deterioration of quality.

Environmental factors

Growing conditions at the time of planting and during seed development and maturation affect the production of quality seed. Fluctuations in environmental factors affect the physiological process and thereby seed quality. Extreme climatic conditions, such as excess rain or drought during flowering, affect the seed-set and cause low yields.

ROLE OF SEED QUALITY IN CROP PRODUCTION

Seed quality is fundamental in crop production. High quality seed is essential for good crop yields (and therefore good returns) and it minimizes the likelihood of crop failure. On the contrary, seed from unknown sources may result in poor stand establishment, unsatisfactory field performance and low yield. Moreover, if seed is contaminated with undesirable species or infected with pathogens, farmers may have to resort to the use of extra herbicides or pesticides.

The **objective** of seed quality evaluation is to allow a reasonable prediction of performance in the field in order to determine its value for planting. At planting, information about the seed vigour is useful for management decisions, especially under adverse conditions.

At each new planting season, farmers ask themselves whether buying certified seed or high-quality seed from a recognized source is a good **investment**. The answer is: compared with poor quality seeds, high quality seeds are generally more vigorous, germinate better and faster, and produce more uniform, vigorous stand establishment under diverse field conditions, resulting ultimately in **higher yields**.

In addition, the knowledge that the plants will display the agronomic characteristics of the variety selected is useful to farmers for the production process. This same knowledge may be key for selling the seed to a specific quality

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market, when the variety grown has the desired quality characteristics (suitable for malting, bread-making, oil production etc.).

Exploitation of the genetic potential of a variety, obtaining a high return per unit area, is the principle advantage of using good quality seeds.

Other benefits include:
- increased productivity;
- nutrient- and water-use efficiency;
- increased resistance to insect pests and diseases;
- greater tolerance to environmental factors (drought, flood, frost etc.); and
- improved nutritional value.

In summary, farmers who use quality seed can realize the full potential of modern high-yielding varieties.

MEASURING SEED QUALITY ATTRIBUTES

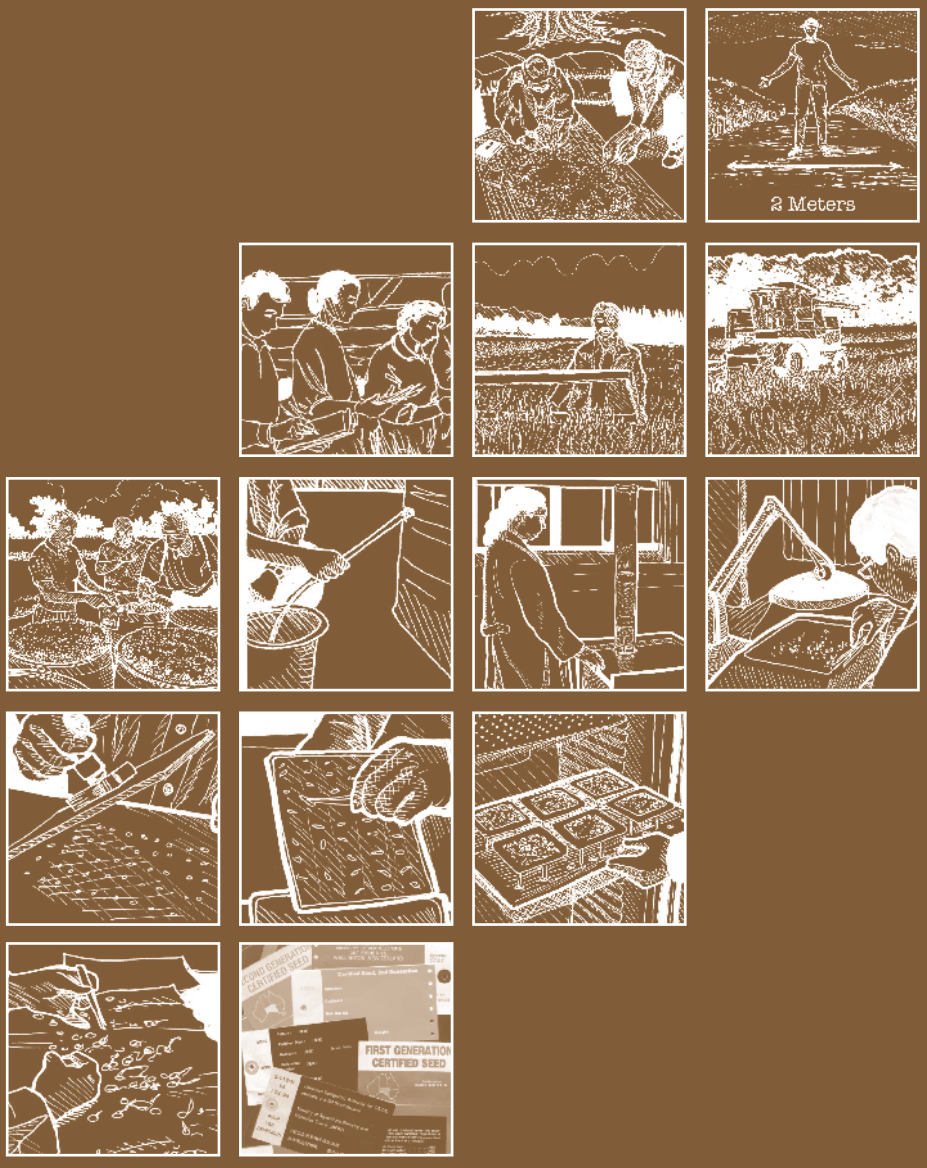
The minimum standards or requirements for quality seed are usually set by national law according to seed norms and regulations. Minimum seed standards (see Chapter 4) can exist independently from the certification scheme.

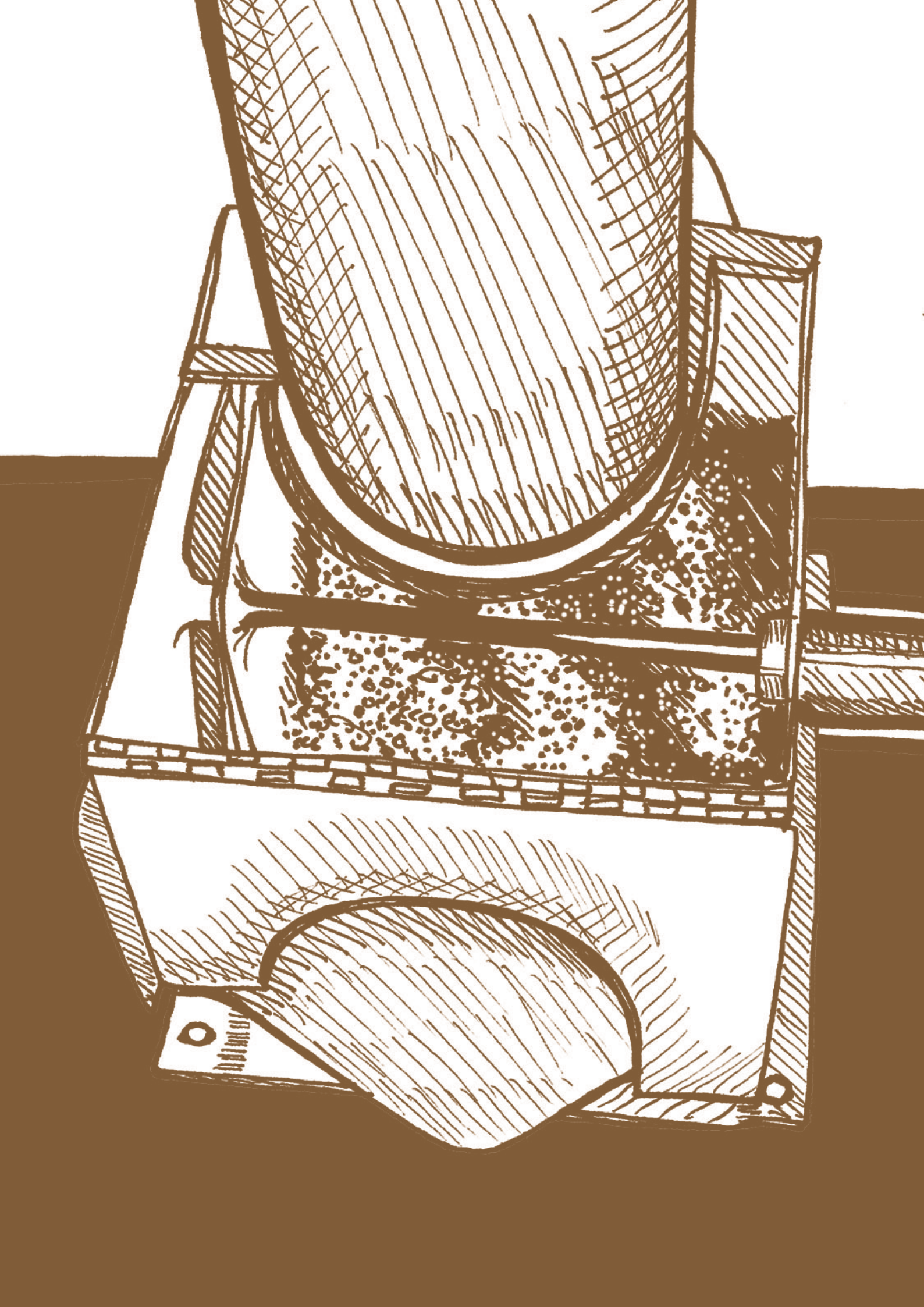
Standardized seed-testing methods of the International Seed Testing Association (ISTA) are generally used to measure the attributes of seed quality (see Chapter 3).

EXERCISES AND DISCUSSION POINTS

1. What are seed quality attributes?
2. What is planting value? You have purchased seeds of a given crop with labels indicating 75% germination and 85% purity; if the seeding rate is 80 kg/ha, calculate the quantity of seeds to be sown in 1 ha (adjusted seeding rate).
3. What are the main factors affecting the production of good quality seed?
4. What is the main objective when evaluating seed quality?

② Seed sampling





Seed sampling

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The purpose of seed sampling is to obtain a representative sample of a seed lot. This sample size must be such that laboratory tests can determine the probability of occurrence of different constituents in the seed lot. Seed sampling requires in-depth knowledge of the rules and methods. A properly trained seed sampler must take a good sample that represents as accurately as possible the quality of the seed lot.

SEED LOT SAMPLING PROCEDURES

Seed testing is based on lots, i.e. precise quantities of seed. Seed lots should be uniform and harvested from a specific seed field so that analysis results can be related to particular fields. The size of the seed lot depends on the size of the seed. In general, the bigger the seed, the bigger the seed lot. The ISTA Rules specify that maximum lot sizes must comply with the following general pattern:

Species or type of species	Maximum size of a seed
Maize	40 000 kg
Cereal and crops with seed larger than cereal seed	30 000 kg
Crops with seed the size of cereal seed (other than cereal)	20 000 kg
Crops with seed smaller that cereal seed	10 000 kg

The seed lot is represented by a very small quantity of seed (the sample). No matter how accurately the laboratory tests are carried out, the results only show the **quality of the sample** submitted for analysis.

For example, in the **ISTA test**:

- A 30 000 kg of rice (*Oryza sativa* L.) seed lot may contain 1 200 000 000 seeds (1 000-seed weight = 25 g), of which:
  - 2 800 (1 : 357 000) seeds are examined in the 70 g for purity analysis ((70 x1000) ÷25 = 2800);
  - 28 000 (1 : 35 700) seeds are examined in the 700 g for other seed count; and
  - 400 (1 : 2 500 000) are tested for germination.

Therefore, the **seed sampler must**:

- ensure that the sample sent to the seed testing laboratory accurately represents the seed lot in question; and
- verify that the seed lot is as uniform as possible (homogeneous) by inspecting all package units.

Two **international organizations** aim to guarantee uniformity in seed testing:

- International Seed Testing Association (ISTA) – present in 80 countries worldwide, it has approximately 218 member laboratories and 127 accredited laboratories (1 January 2015).

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- Association of Official Seed Analysts (AOSA) – organization of member laboratories in the United States and Canada.

Both organizations develop, adopt and publish standard procedures for sampling and testing seeds and issue seed quality certificates. These guidelines makes reference to **ISTA** procedures and standards (Figure 2.1).

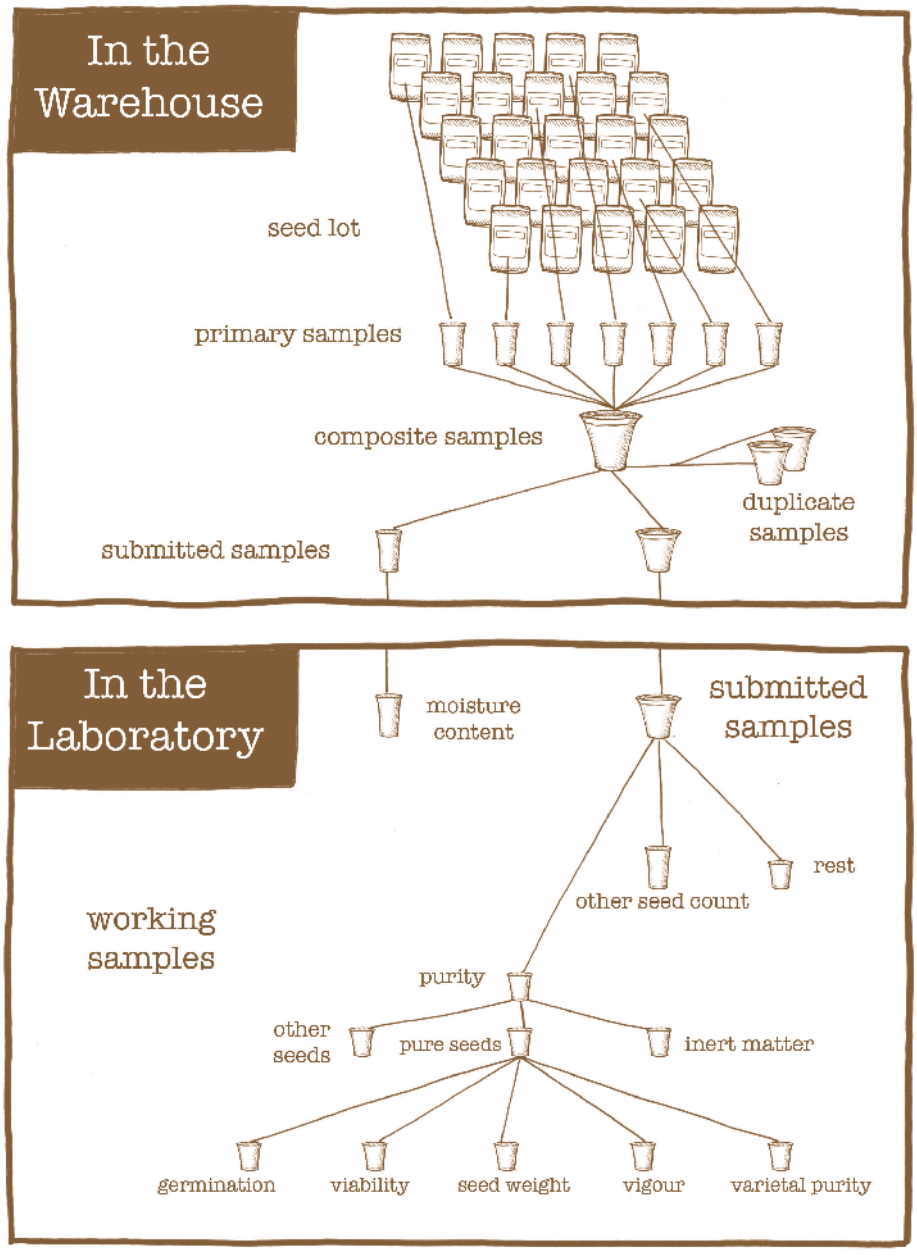

Figure 2.1 *ISTA sampling scheme in the warehouse and the laboratory*

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Collecting a primary sample

A primary sample is a portion taken from the seed lot in the warehouse in a single sampling action. In order to meet statistical requirements, ISTA defines the minimum number of primary samples for three different container types (Table 2.1):

- < 15 kg
- 15-100 kg
- > 100 kg (or streams of seed entering containers)

Table 2.1 Minimum sampling intensity for seed lots in containers

Weight of individual container in the seed lot	Weight of lot (kg or number of containers)	Number of primary sample
> 100 kg	≤ 500 kg	≥ 5
	501–3 000 kg	1 for each 300 kg (but ≥ 5)
	3 001–20 000 kg	1 for each 500 kg (but ≥ 10)
	20 001 kg	> 1 for each 700 kg (but ≥ 40)
15–100 kg	1–4 containers	3 from each container
	5–8 containers	2 from each container
	9–15 containers	1 from each container
	16–30 containers	15 from the seed lot
	31–59 containers	20 from the seed lot
	≥ 60 containers	30 from the seed lot
Containers < 15 kg	• Containers shall be combined into smaller units ≤ 100 kg (20 containers of 5 kg, 33 containers of 3 kg or 100 containers of 1 kg) • For sampling purposes, each sampling unit is regarded as "one container" • Sampling intensity is as defined for containers for 15-100 kg	

notes

Instruments for taking samples

Sampling by hand

This method is appropriate for all species. Moreover, it is potentially the most suitable method for seed that could get damaged using triers, seeds with wings, seeds with low moisture content, seed tapes and seed mats (Figure 2.2).

Figure 2.2 Sampling by hand

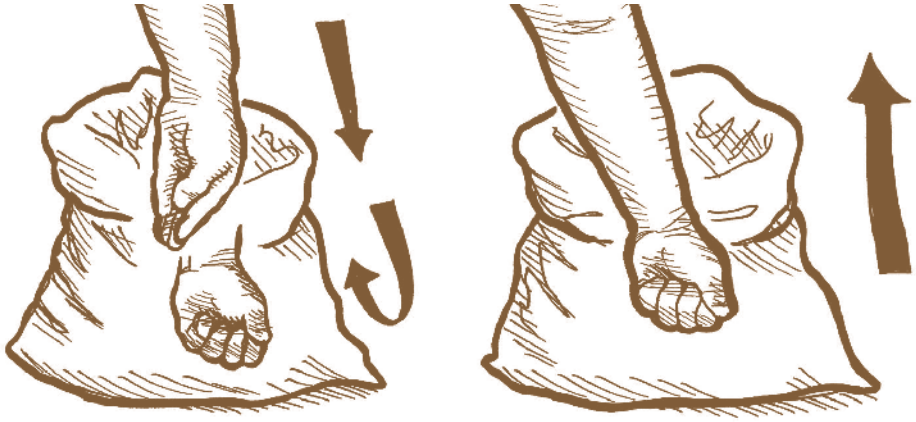
A) Push open hand into the container,

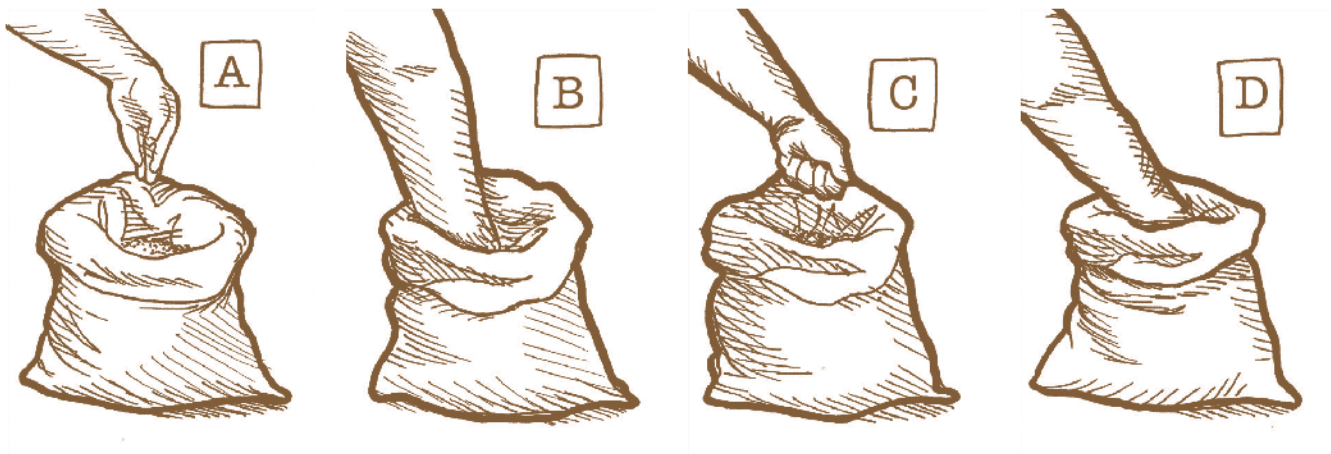
B) Close hand with seeds inside,

C) Withdraw hand, taking great care that fingers remain tightly closed around the seeds to prevent escape,

D) In the case of treated seeds, use appropriate gloves

(ISTA, 2005)





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Nobbe trier

The Nobbe trier – or dynamic spear – is a pointed tube with an opening near the pointed end. Seed passes through the tube and is collected in a container.

Dimensions of the hole:

- Width ≥ 2 times the maximum diameter of the seed
- Length 2–5 times the width of the hole

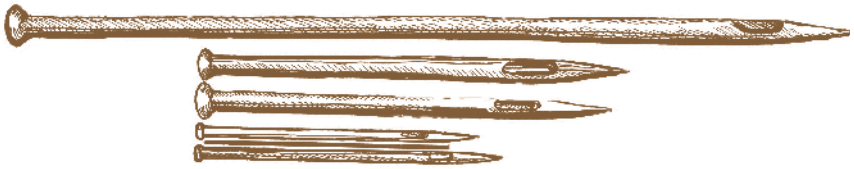

Figure 2.3 Nobbe triers

Procedure with Nobbe trier:

- Insert at an angle of about 30° to the horizontal plane with the opening facing down.
- Push until it reaches the required position and turn 180°.
- Withdraw with decreasing speed from the container.
- Gently agitate the trier to maintain an even flow of seed.
- Collect the seed sample from the trier in a suitable container.

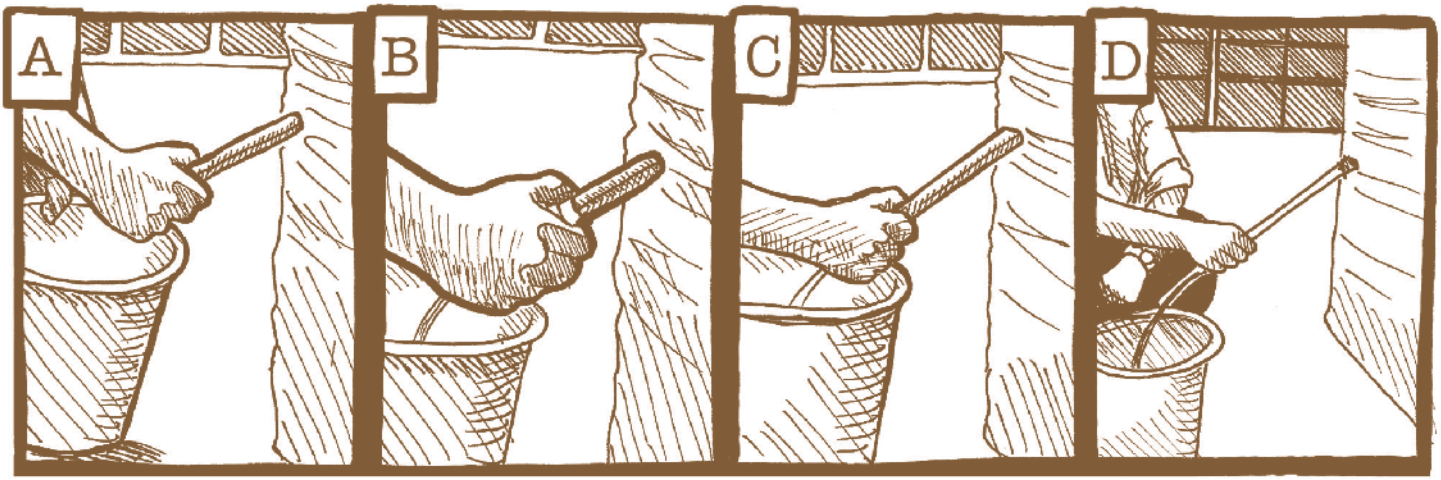

Figure 2.4 Using a Nobbe trier
A) Push trier into bag with opening pointing downwards,
B), C), and D) Turn trier and withdraw from bag (ISTA, 2005)

notes

Sleeve-type trier

The sleeve-type trier – stick trier or sampling stick – consists of an inner and an outer tube. Some models have partitions, others have only one cavity. The ISTA Rules stipulate that a stick without partitions can only be used horizontally.

Automatic sampling from a seed stream

Automatic sampling devices are available. It is important to ensure that:

- a uniform sample is taken from the whole cross-section of the seed stream; and
- material entering the sampler does not bounce out again.

Operation can be either **manual** or **automatic**. The intervals between taking primary samples should be constant; however, samples may also be taken at random intervals.

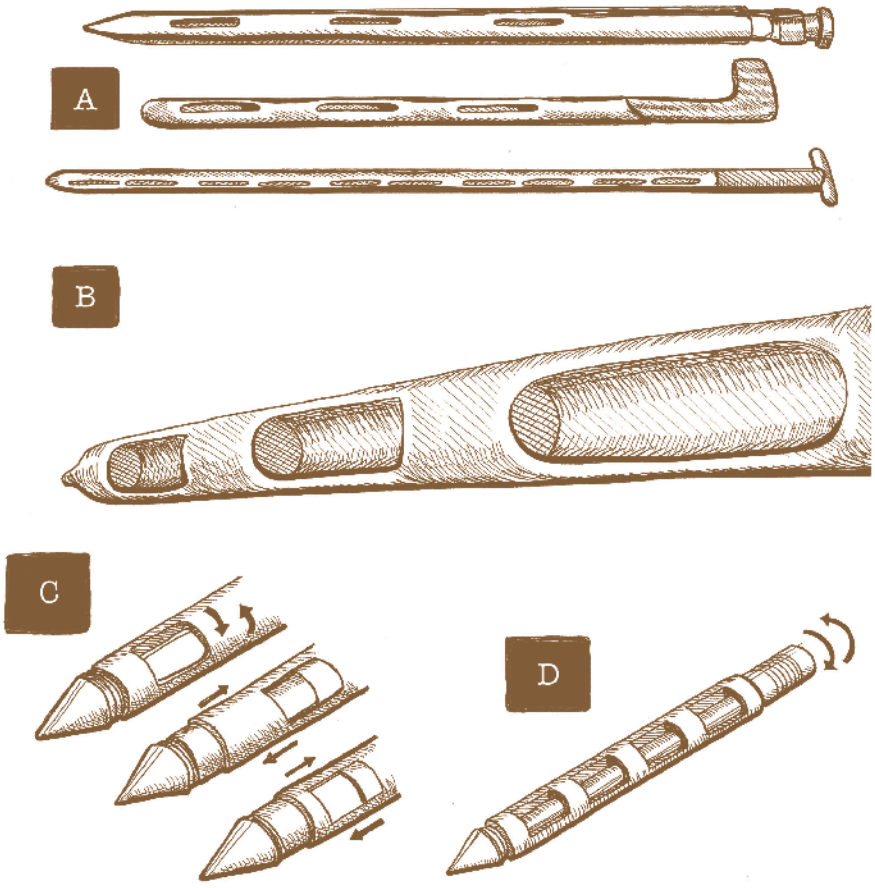

Figure 2.5 Stick triers
A) Different types,
B) Stick trier with compartments for vertical use,
C) Different ways of opening and closing the chamber,
D) Whole stick opened and closed by twisting the tubes (ISTA, 2005)

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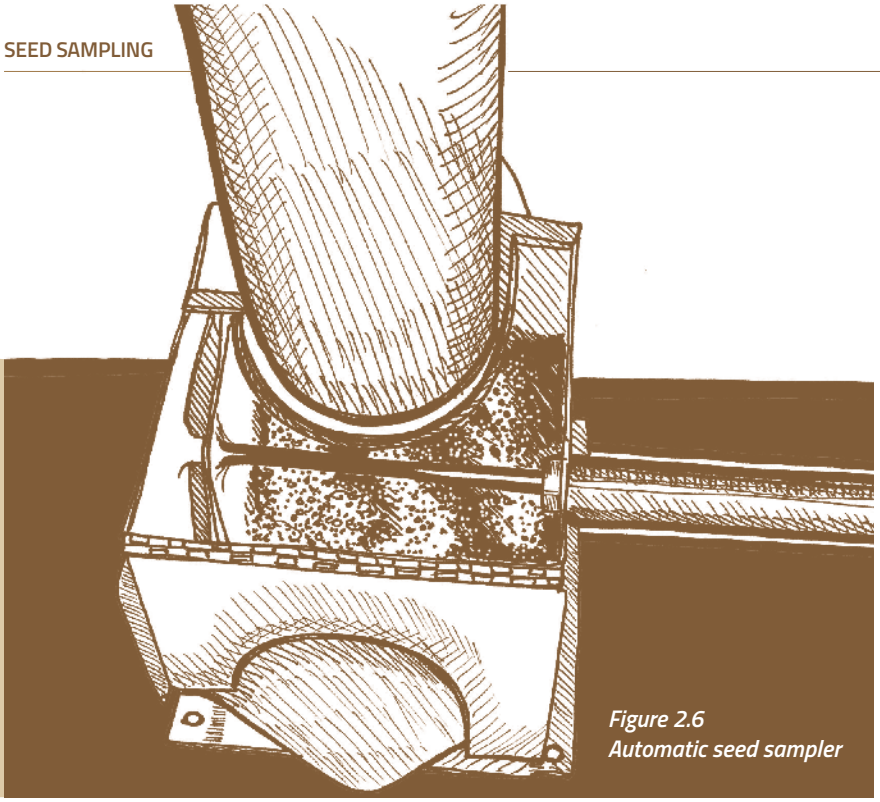

Figure 2.6
Automatic seed sampler

OBTAINING A COMPOSITE SAMPLE

To obtain a composite sample, it is necessary to combine and **mix all the primary samples** taken from the seed lot. During sampling, primary samples are compared to check for homogeneity. If the primary samples appear **uniform**, they are combined to form the composite sample. Otherwise, the sampling procedure is interrupted. Primary samples are sometimes collected directly in one container. The content of this container may be regarded as the composite sample only if uniform. Otherwise, do not use as a submitted sample.

OBTAINING A SUBMITTED SAMPLE

A submitted sample is a **sample sent to the testing laboratory**. It may comprise the entire composite sample or a subsample obtained using one or more ISTA reduction methods as for the working sample (see below).

The **packaging** depends on the specific test requirements. Suitable containers include an unused clean cloth, a paper bag or good quality manila envelope. When the sample is to be tested for moisture content, a moisture-proof container must be used. Samples should never be left unprotected or exposed to moisture, heat or direct sunlight.

Containers are sealed to discourage tampering and labels are attached both inside and outside the bag. To ensure that the sample is connected to the original seed lot, labels must provide all the necessary **information**, including:

- lot number;
- lot quantity;
- number and size of containers sampled;
- species and variety names;
- class of seed;
- producer;
- seed-processing plant (name and address);
- test requested;
- date and site of sampling; and
- name of sampler.

notes

There is a fixed minimum weight for submitted samples depending on the species and according to the tests requested (Table 2.2). It is important to forward the submitted sample to the seed-testing laboratory in a safe and timely manner, together with the sampler report. The sampler must always keep a copy of the sampling report.

OBTAINING A WORKING SAMPLE

A working sample is obtained in the laboratory from the submitted sample using an appropriate **reduction** method (Figures 2.7 and 2.8). It is the working sample that actually **undergoes seed testing**.

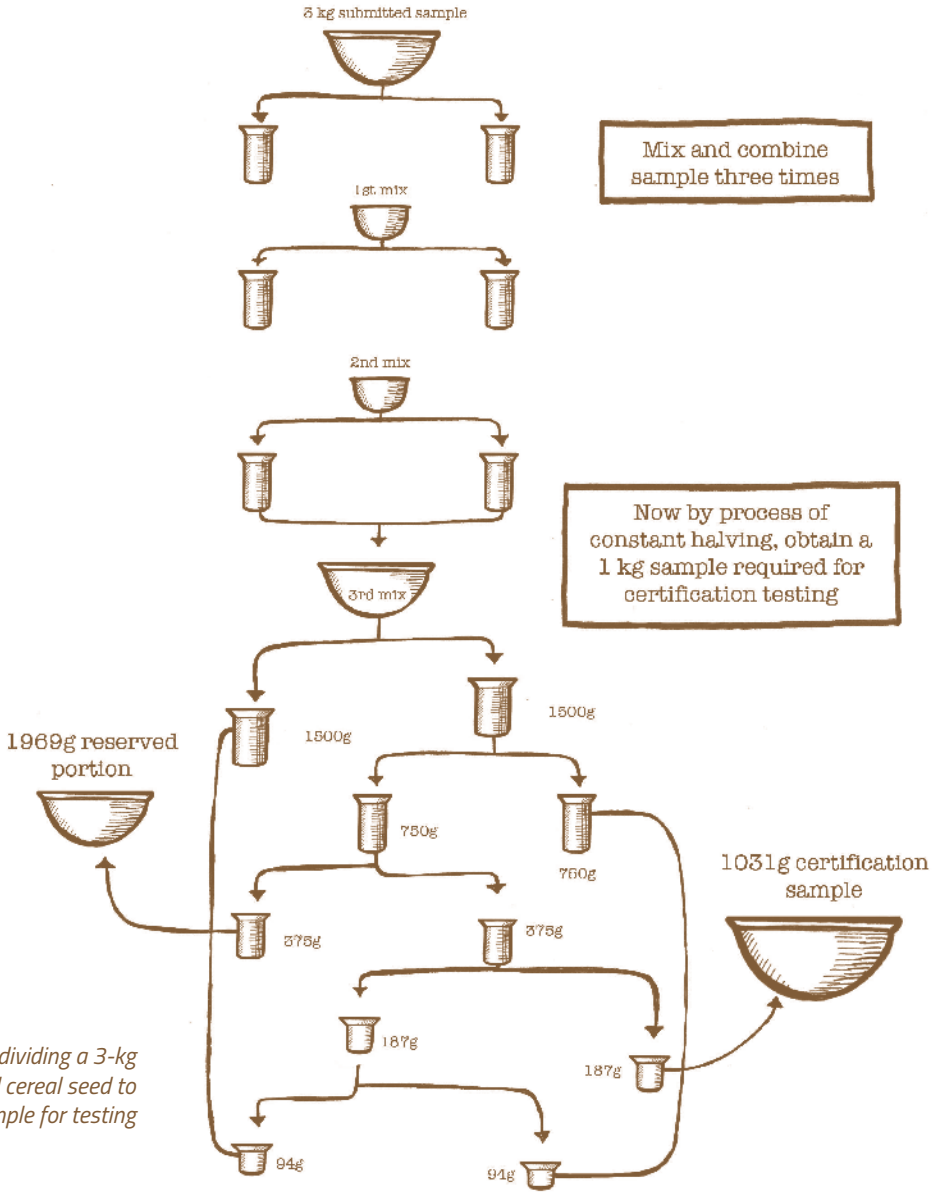

Figure 2.7 Mixing and dividing a 3-kg submitted sample of certified cereal seed to give a 1-kg working sample for testing

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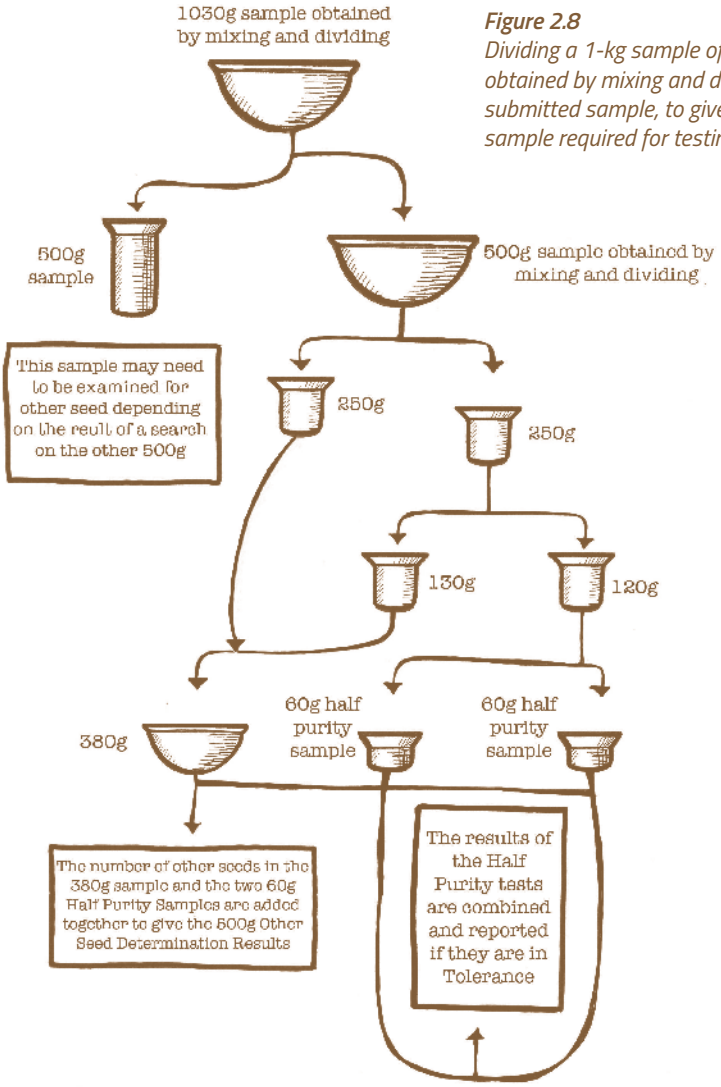


Figure 2.8
Dividing a 1-kg sample of certified seed, obtained by mixing and dividing a larger submitted sample, to give a working sample required for testing

notes

Minimum weight of working sample

The minimum weight of the working samples (i.e. the seeds to be analysed) is stipulated by ISTA and depends on the species and the types of test performed (Table 2.2).

Table 2.2. Lot sizes and sample sizes for some crop seeds

	weight of lot (kg)	submitted sample (g)	samples (g)	
			Purity analysis	Other seeds by number
Barley – *Hordeum vulgare* L.	30 000	1 000	120	1 000
Cowpea – *Vigna unguiculata* (L.) Walp.	30 000	1 000	400	1 000
Groundnut – *Arachis hypogaea* L.	30 000	1 000	1 000	1 000
Maize – *Zea mays* L.	40 000	1 000	900	1 000
Oats – *Avena sativa* L.	30 000	1 000	120	1 000
Pearl millet – *Pennisetum glaucum* (L.) R.Br.	10 000	150	15	150
Rice – *Oryza sativa* L.	30 000	700	70	700
Ryegrass – *Lolium multiflorum* Lam.	10 000	60	6	60
Sorghum – *Sorghum bicolor* (L.) Moench	30 000	900	90	900
Wheat – *Triticum aestivum* L.	30 000	1 000	120	1 000

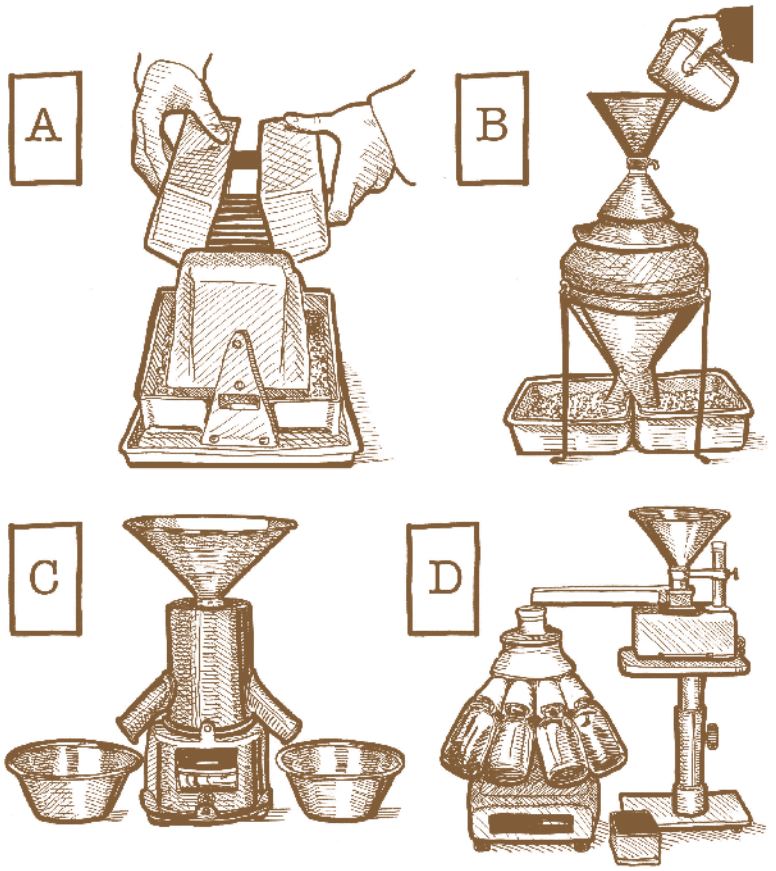
notes

Methods for obtaining working sample

The working sample must be **representative** of the submitted sample. Mix thoroughly the submitted sample before dividing it mechanically or manually. Each method has **advantages** and **disadvantages**; select the most appropriate according to the seed and the means available.

Mechanical methods (not appropriate for seed health testing)

- Soil divider (or Riffle divider) – suitable for most crop seeds. Comparatively cheap and easy to use, clean and move.
- Centrifugal divider – suitable for slightly chaffy species. Requires electricity and not easily transported.
- Conical divider - very effective, but difficult to clean, especially the cone, channels and spaces.
- Rotary divider – suitable for small seed species, in particular chaffy species (e.g. grasses, flowers or herbs). Sophisticated, but dividing procedure takes a long time. Requires electricity and expensive. Cleaning the chute and bottles is time consuming.
- Variable divider - allows variation of the dividing ratio; reduces a sample of known size to a predetermined subsample size in one operation; no mixing necessary before sample reduction. Expensive and requires electricity.



Different types of sample dividers:
(A) Soil divider
(B) Conical divider
(C) Centrifugal divider
(D) Rotary divider

2

notes

Manual methods

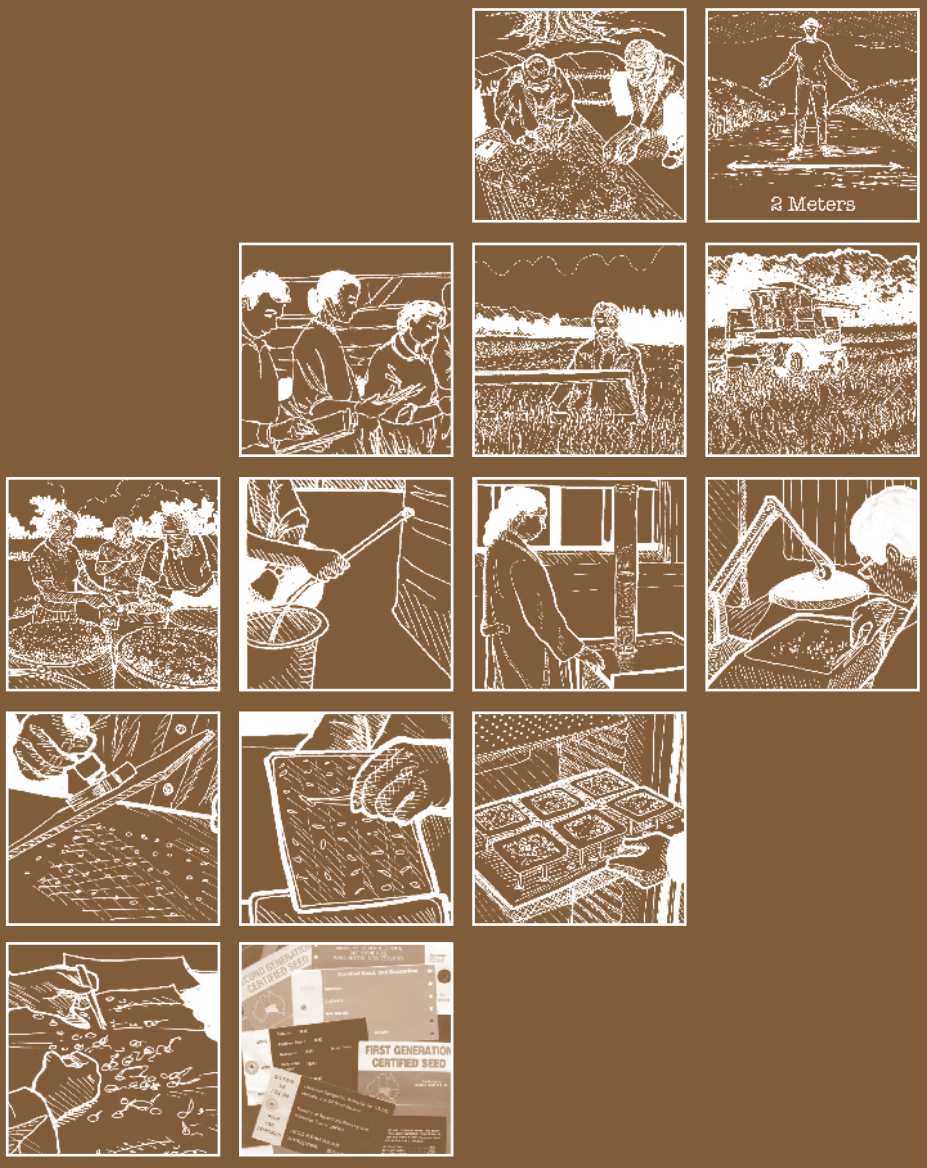
- Spoon method – comprising a tray, a flat-edged spatula and a flat spoon with vertical sides. Appropriate for species smaller than wheat.
- Modified halving – comprising a tray fitted with a grid of cubical cells that are alternately open at both ends or closed at the bottom. Allows halving of the sample, but no other division.
- Hand halving method – comprising a flat edged spatula and a straight-edged instrument (e.g. knife or ruler). Appropriate for chaffy seed species, as listed in the ISTA Rules.

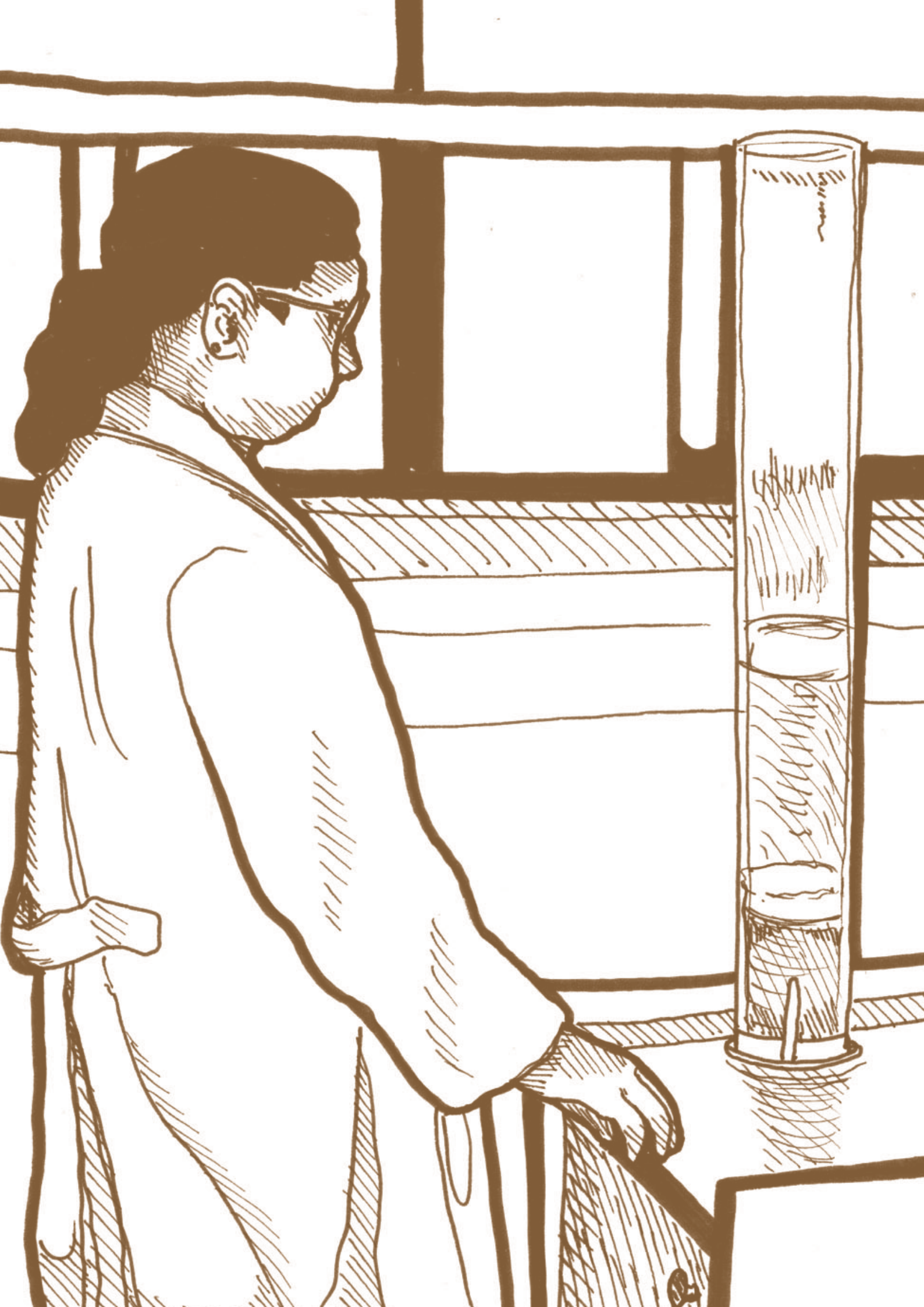
Whenever possible, ISTA recommends using mechanical reduction methods, being more effective and free from human intervention. However, in specific situations (very chaffy seed, unprocessed seed, seed health testing), hand reduction methods are more suitable.

EXERCISES AND DISCUSSION POINTS

1. How many individual bags (primary samples) would you obtain from a seed lot containing 16 bags? 41 bags? 312 bags? (Bag weight = 50 kg)
2. Explain how a composite sample is obtained.
3. What methods are adopted in the laboratory to obtain a working sample?
4. Explain the differences between the various kinds of equipment used in mechanical sample reduction. In your opinion, which is the most suitable method? Why?

3 Seed testing





Seed testing

3

notes

The quality of seed cannot be assessed by visual observation; instead, objective methods have been developed. Evaluation of the seed quality is vital in order to **predict its performance** in the field and **determine its value** for planting. Seed analysis laboratories are, therefore, now widespread. They adopt standardized methods to eliminate poor quality seed lots and ensure improved results for farmers at harvest.

WHY SEED TESTING IS IMPORTANT

Seed testing is an analysis of physical parameters and physiological qualities of a seed lot, based on a small representative sample. "Quality" – i.e. **physiological quality**, not genetic quality – is a measure of potential performance under optimal conditions. Seed testing is, therefore, an important tool for ensuring that farmers get the quality of seed they want. Testing is also used in seed law enforcement to protect buyers from fraudulent sales and to provide technical professional opinions in cases of litigation arising from differences between the information on certification labels and actual results.

For farmers, **seed testing**:

- guarantees that seeds meet minimum quality standards in terms of physical purity and germination percentage;
- minimizes the risk of crop failure; and
- avoids problems resulting from use of seed contaminated with noxious weeds, seed infested with disease or insects, and seed having a low viability level.

Seed scientists and technologists have developed standard testing procedures to extract detailed information on those quality characteristics that determine the value of seed. It is important that evaluation methods and test results are consistent and uniform. For this reason, 1924 saw the establishment of the International Seed Testing Association (ISTA)[1].

ROLE OF SEED-TESTING LABORATORY

The seed-testing laboratory is central to the seed certification process; it must meet the standards set by seed legislation. A seed laboratory **does not improve the quality** of seeds produced and distributed in the country; rather, based on the results of tests on samples, it **provides information** to avoid – or at least mitigate – the adverse effects of using poor quality seed.

1 *As indicated in Chapter 4, this guideline refers to ISTA Rules.*

notes

Technical sections of the laboratory

The seed-testing laboratory comprises specialized, interdependent technical sections responsible for different areas:

- Analytical purity – measurement of purity and other related areas (e.g. moisture content, content of seeds of other species, weight, hectolitre weight and 1 000-seed weight [TSW]).
- Varietal purity – determination and verification of identity and purity of species and cultivar (e.g. morphological characteristics of the seed or seedling, chemical properties and cytological aspects). In addition to the laboratory, testing may require use of growth chambers, greenhouses or field plots to cultivate control plots).
- Germination – evaluation of germination percentage and other tests (e.g. biochemical viability and vigour testing).
- Seed health – all tests related to seed health.

Laboratory equipment, calibration and maintenance

The laboratory must have all the equipment necessary for the correct performance of tests and sampling according to the ISTA Rules and it should be identifiable with a unique numbering system. The maximum care must be applied:

- Allow trained personnel only to use equipment.
- Make available and distribute laboratory procedures and manufacturer's literature on the use, maintenance and control of equipment.
- Control and calibrate equipment influencing test quality before commissioning and periodically thereafter. Attach a label indicating the date of the last and the next scheduled inspection/calibration.
- Assign laboratory staff to carry out checks according to the technical procedures of the laboratory; alternatively, revert to an external specialist company.
- Decommission, and clearly mark or isolate any equipment that is subject to mishandling, proven defective or which gives suspect results. In addition, evaluate the possible influence on previous test results.

Laboratory work documents

- Sampling sheets
- Records of samples submitted in order of arrival
- Purity analysis sheets
- Moisture content test sheets
- Germination test sheets
- Seed health sheets

The results of a sample testing are recorded on analysis sheets, according to the prescribed rules. When appropriate, a certificate is issued by the laboratory.

3

PROCEDURES FOR LABORATORY SEED TESTING

notes

Sample reception and registration

When submitted samples arrive at the testing laboratory, but **before registration**, check the following:

- Samples are sealed.
- Two samples are provided (one for use as a working sample, the other as a control kept in a cold room and possibly for use in the post-control test).
- Samples are accompanied by sampling reports/forms.
- There are no traces of insects (samples with live insects are rejected).
- Sample bags are neither wet nor torn.
- Labels both inside and outside contain all the required information (see Chapter 2 "Obtaining a submitted sample" for full details).

Register each sample received including:

- label details;
- information in the sampling report;
- test identification number;
- sample reception date;
- test completion date; and
- reference and nature of documents issued to the customer.

Computerized information systems are widely used in laboratories to facilitate data management and print all related documents and certificates.

Assign a **code** to identify the sample and all samples taken from it for analysis throughout the laboratory testing process. The simplest method is to give consecutive serial numbers, for example:

0004 = the fourth sample received at the laboratory; or
08003 = the third sample received in 2008.

Prepare a **test sheet** including the following information:

- Registration number (code)
- Reception date
- Species, variety and seed class
- Requested test

Following registration, it is possible to identify a given sample easily and to obtain information on the progress of analysis and test results at any time.
To proceed with testing, it is necessary to obtain a working sample by reducing the submitted sample in the laboratory using appropriate methods (see Chapter 2 "Obtaining a working sample").

notes

Physical purity analysis

Objectives:

- Determine percentage composition by weight of the sample being tested (and by inference the composition of the seed lot).
- Identify the various species of seeds and inert particles constituting the sample.

It is essential to follow all the general requirements established in the regulations. The working sample is divided into three components:

- Pure seed
- Other seeds
- Inert matter

Identify all species of seed and each kind of inert matter present, and then determine the percentage of each part by weight.

- **Pure seed** – the species stated by the applicant, or that found to predominate in the test, and including all botanical varieties and cultivars of that species. The pure seed fraction comprises also:
  - mature undamaged seeds of the species; and
  - pieces of broken seeds that are more than half the original size.
- **Other seeds** – seed units of any plant species other than that of pure seed.
- **Inert matter** – seed units and all other matter and structures not defined by ISTA as pure seed or other seed, for example:
  - broken pieces of pure seed and crop seed species that are half or less their original size;
  - soil particles, sand, stones, chaff, stems, leaves, flowers; and
  - smut balls, ergots and nematode galls.

Apparatus:

- Purity board – the main instrument.
- Hand lenses and binocular microscopes – often used for accurate identification and separation of small seed units and fragments.
- Seed blowers – mechanical devices used to separate lightweight material (e.g. chaff and empty florets) from heavier seeds. Several types of seed blower have been developed (Figure 3.2).
- Sieves – used to separate components of different sizes into sized fractions. Examine each fraction and classify the particles (pure seed, other seed or inert matter). Note that the sizing of the fractions may shorten the time required to perform the purity test.
- Analytical balance, forceps and fine needles.

3

Procedure:

- Identify the seed.
- Determine the correct weight of the working sample (≥ 2 500 seeds with a maximum weight of 1 000 g). The ISTA Rules stipulate that the analysis can be done on one working sample of this weight or on two subsamples of at least half this weight, each independently drawn.
- Weigh the working sample (or each subsample) in grams to the minimum number of decimal places necessary to calculate the percentage of its component parts to one decimal place, as indicated in the table below:

Weight of working sample or subsample (g)	Minimum number of decimal places	Example
< 1.000	4	0.7056
1.000–9.999	3	7.056
10.00–99.99	2	70.56
100.0–999.9	1	705.6
≥ 1 000	0	7 056

- Divide the working sample on the working board into three components (pure seed, other seed and inert matter).
- Weigh the individual fractions independently using an analytical balance. For example:
  - Pure seed = X (g)
  - Other seeds = Y (g)
  - Inert matter = Z (g)

notes

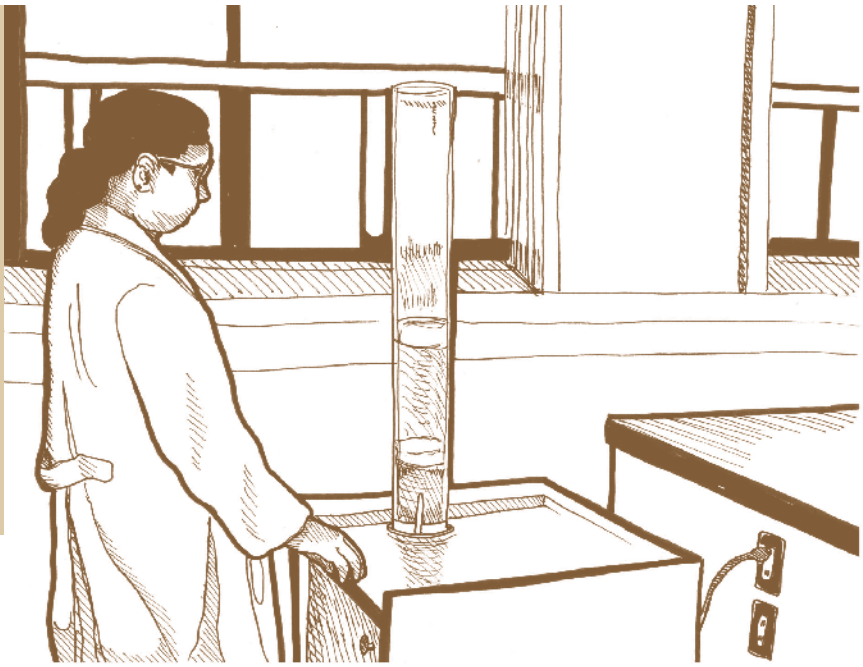


Figure 3.1 Separating sample into components parts by seed blower

notes

Results are expressed as a percentage with two decimals. The third decimal place is round down if 4 or less (98.384 will read 98.38), and up if 5 or more (98.386 will read 98.39).

Components	Weight (g)	Percentage	Example Example (rice)	
			Weight (g)	%
Pure seed	Pure seed	[X × 100] ÷ W	X = 68.88	98.4
Other seeds	Other seeds	(Y × 100) ÷ W	Y = 0.14	0.2
Inert matter	Inert matter	(Z × 100) ÷ W	Z = 0.98	1.4
Total	Total	100	W = 70	100.0

- Pure seed = 98.4%
- Other seeds = 0.2%
- Inert matter = 1.4%

Laboratory reports of purity analysis should include the following information:

- Name and address of issuing laboratory
- Name of responsible individual
- Laboratory test or sample number
- Date of issue of analysis report
- Applicant information (e.g. seed type, cultivar, lot number, lot size, certification number, treatment)
- Pure seed type by common name
- Weight of working sample
- Percentage by weight of pure seed, other crop seed, inert matter and weed seed (to two decimal places)
- Scientific name or common name – or both – of all other crop or weed seed (including noxious weeds) found, if any (if none, specify)

Determination of other seeds by number

"Other seeds" – i.e. species specified by the applicant (besides those tested) – may refer to:

- a general group (e.g. all other species);
- one category of seeds (e.g. species registered as noxious); or
- a specific species (e.g. *Elytrigia repens*).

For example, in Morocco, for certified seed (R1) of cereals, the maximum number of other seeds allowed in 1 kg is 20, of which ≤ 12 of other cereal species, ≤ 1 of wild oat and ≤ 4 of noxious weeds *(Emex spinosa, Galium tricornitum, Vaccaria pyramida* and *Astragalus* sp.)

The seeds are counted and the figure is expressed as the number of seeds found in the quantity examined. When it is not possible to identify with certainty at species level, the genus name only is reported.

3

notes

In **international trade**, this test is particularly useful for determining the presence of seeds of **noxious or undesirable species**.

Apparatus: Sieves, blowers and various other mechanical devices.

Procedure:

- Obtain a working sample of a weight estimated to contain ≥ 25 000 seed units or of the weight prescribed by the Rules. If a species indicated by the applicant is difficult to identify, use a minimum of one-fifth of the ISTA prescribed working sample weight.
- Examine the working sample for seeds of all other species (or of certain stated species only, as requested by the applicant).
- Count the number of seeds found of each indicated species.
- Keep seeds of the other species found and store for reference until sample disposal.

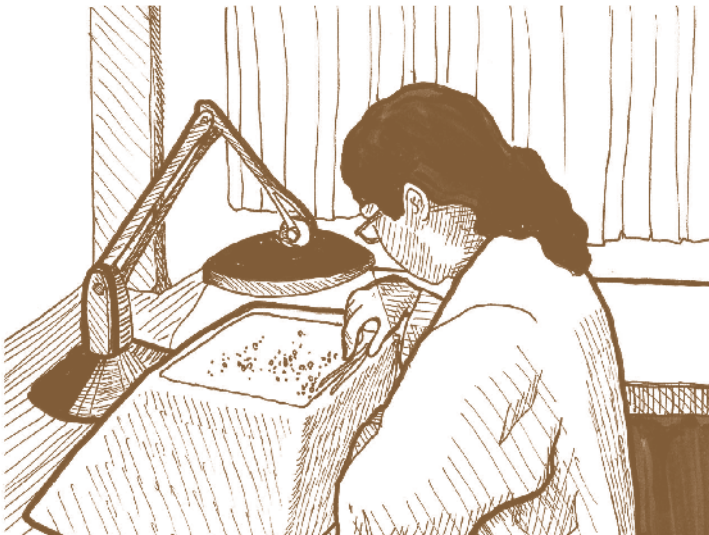
The determination of other seeds is reported using one of the tests described below:

- **Complete test** – the whole working sample is searched, according to the ISTA Rules, for all other seeds present, with the exception of dust-like seeds (e.g. *Orobanche* and *Striga* species). Testing for *Orobanche* spp. is only carried out if specifically requested.
- **Limited test** – the search is restricted to stated species in the whole working sample as prescribed.
- **Reduced test** – only part of the working sample is examined as prescribed.
- **Reduced-limited test** – less than the prescribed weight of seed for a working sample is examined for stated species only as prescribed.

Laboratory reports of determination of other seeds should include the following information:

- Actual weight of seed examined to the minimum number of decimal places.
- Scientific name and number of seeds of each species sought and found.
- Genus name only if the seed characteristics are insufficient for more precise identification (e.g. *Astragalus* sp.).

Figure 3.2 Determination of other seeds by number



notes

Germination test

Germination is the emergence and development of the seedling to a stage at which the appearance of its essential structures indicates whether it can develop further into a satisfactory plant under favourable conditions in the field.

Objective: Determine the **germination potential** of a seed lot, which is vital to compare the quality of different lots and estimate the field planting value.

Testing under field conditions does not give reliable results as conditions tend to vary when a test is repeated.

In **laboratory testing**, on the other hand, **external conditions are controlled** in order to obtain the most regular, rapid and complete germination for the majority of samples of a particular species. Moreover, **conditions are standardized** so that test results can be reproduced within limits as close as possible to the limits of random sample variation.

Germination tests are performed on seed taken either from the pure seed fraction extracted in a purity test or from a representative fraction of the submitted sample.

The prescribed **number of seeds** for germination tests is 400, which can be divided into four replicates of 100 seeds. They are tested under favourable moisture conditions and in accordance with the methods prescribed.

The seeds are spread apart on the substratum to prevent seedlings from coming into contact with one another before they are counted and removed. At the end of the specified germination period, the replicates are examined; two counts are usually made of the seedlings and seeds in each category undergoing testing.

Table 3.1 Methods for germination tests for some species *(ISTA, 2016)*

Species	Substrate	temperature (°C)	First count (d)	Final count (d)	Recommendations for breaking dormancy
Barley - *Hordeum vulgare* L.	BP; S	20	4	7	Preheat at 30-35°C; GA_3; KNO_3; prechill
Cowpea - *Vigna unguiculata* (L.) Walp.	BP; S	20 <=> 30; 25	5	8	-
Groundnut -*Arachis hypogaea* L.	BP; S	20 <=> 30; 25	5	10	Remove shells, Preheat at 40±2°C;
Maize - *Zea mays* L.	BP; TPS; S	20 <=> 30; 30; 25	4	7	-
Oats - *Avena sativa* L.	BP; S	20	5	10	Preheat at 30-35°C; prechill
Pearl millet – *Pennisetum glaucum* (L.)R.Br.	TP; BP	20 <=> 35; 20 <=> 30	3	7	-
Rice – *Oryza sativa* L.	TP; BP; S	20 <=> 30; 25	5	14	Preheat at 50±2°C; soak in water or HNO_3 for 24 h
Ryegrass – *Lolium multiflorum* Lam.	TP	20 <=> 30; 15 <=> 25; 20	5	10	KNO_3; prechill
Sorghum – *Sorghum bicolor* (L.) Moench	TP; BP	20 <=> 30; 25	4	10	Prechill
Wheat – *Triticum aestivum* L.	TP; BP; S	20	4	8	Preheat at 30-35°C; GA_3; prechill

** The symbol "<=>" indicate alternating temperature regimes. 1st temperature: 16 h; 2nd temperature: 8 h*
BP= between paper, S = Sand, TP = Top of paper, TPS = top of paper or sand. Preheat at 30-35°C; prechill

3

notes

The **germination percentage** reported on the certificate issued indicates the proportion by number of seeds that have produced "normal" seedlings under the conditions and within the period specified by the Rules.

Essential seedling structures

A seedling, depending on the species tested, consists of a specific combination of some of the following structures essential for its development into a satisfactory plant:

- Root system (primary root; in certain cases seminal roots)
- Shoot axis (hypocotyl; epicotyl; in certain *Poaceae* mesocotyl; terminal bud)
- Cotyledons (one or more)
- Coleoptile (in all *Poaceae*)

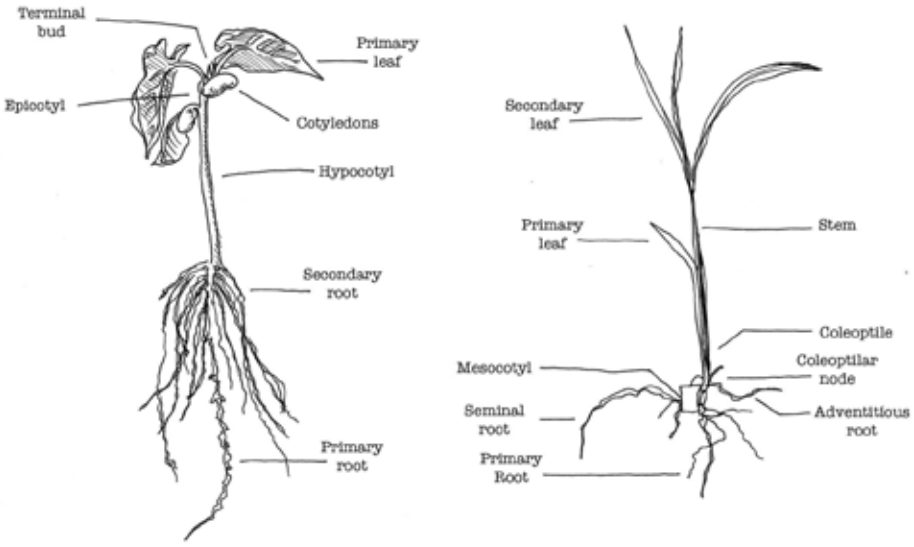


Figure 3.3 Seedling structures: bean (left) and rice (right)

The 50 % rule

The 50% rule is used to evaluate cotyledons and primary leaves.

Cotyledon tissue:

- Seedlings are "normal" when at least half the total cotyledon tissue is functional.
- Seedlings are "abnormal" when more than half the cotyledon tissue is missing, necrotic, decayed or discoloured.

Primary leaves (evaluated in species such as *Phaseolus*):

- Seedlings are "normal" when at least half the primary leaf tissue is functional.
- Seedlings are "abnormal" when more than half the primary leaf tissue is missing, necrotic, decayed or discoloured.

notes

Growing media

Growing media must provide sufficient pore space for air and water, growth of the root system and contact with solutions (water) necessary for plant growth. The prescribed media are **sand** and **paper** and each has **advantages** and **disadvantages**. Sand provides a more natural environment for seedling growth. The contact between the seed and sand is good, the shoots grow upwards and emerge from the media, and the seedling is exposed to light which allows improved development of essential structures. However, it requires more space in germination chambers than paper substrata, it is heavy to move during testing and at disposal, and it requires significant storage space. The laboratory can be designed to minimize these concerns. Sand is often the preferred media when retesting due to fungal infection, or because of any condition rendering seedling evaluation difficult in a paper substrate. In these cases, it may be necessary to sterilize the sand. Sand used as growing media must have ≥ 90% of the particles able to pass through a sieve with holes 2.0 mm wide.

Paper growing media:

- **Top of paper (TP)** – seeds germinate on top of one or more layers of paper.
- **Between paper (BP)** – seeds germinate between two layers of paper.
- **Pleated paper (PP)** – seeds are placed in a pleated, accordion-like paper strip with 50 pleats, usually two seeds to each pleat. This method is an alternative to TP and BP.

Sand growing media and organic growing media:

- **Top of sand (TS), top of organic growing medium (TO)** – seeds are pressed into the surface of the sand or the organic growing medium.
- **Sand (S), organic growing medium (O)** – seeds are planted on a level layer of moist sand or organic growing medium and covered with 10–20 mm of uncompressed substrate, depending on the size of the seed.

Figure 3.4 Germination test on paper substrate
TP (top) , BP (middle), PP (bottom)

Apparatus:

- Bell jar or Jacobsen apparatus (Copenhagen tank) – a germination plate on which are placed filter paper substrates with seeds. The substrate is kept continuously moist by means of a wick, which passes through slits or holes in the germination plate into the underlying water bath.
- Germination incubator and room germinator – used for germinating seeds in darkness or light, or for providing seeds with pre-treatments to break dormancy (e.g. pre-chilling). They are well insulated and are equipped with both heating and cooling systems to ensure the maintenance of required temperatures.
- Petri dishes, forceps, covering net, water, blotting paper, sand.

Procedure (TP):

- Take a sample of 400 seeds at random from well-mixed pure seed. It is important to **not select seeds**, as this would give biased results.
- Use four replicates of 100 seeds to ensure adequate spacing. Split replicates of 50 seeds (or even 25, particularly where there are seed-borne pathogens or saprophytes present) to minimize the effect of adjacent seeds on seedling development.

3

- Place seeds uniformly and sufficiently apart on the moist substrate on the Petri dish. If seeds grown on paper substrates are heavily infected, at an intermediate count, transfer remaining seeds and seedlings to fresh media.
- Place Petri dishes in the germination apparatus; record the number of seeds set and the date.
- Make two counts of seedlings. Schedule the first and final countings according to the ISTA Rules.
- Keep the seed moist throughout the test period.

The **germination percentage** is expressed as follows:

$$\textit{Germination}\ (\%) = \frac{\textit{Number of normal seedlings}}{\textit{Number of seeds set for germination}} \times 100$$

Seedlings are **evaluated** and categorized as follows:

- **Normal seedlings** – with potential to develop into satisfactory plants when grown in good quality soil and under favourable conditions of moisture, temperature and light. To be classified normal, a seedling must conform to one of the following categories:
  - **Intact** – seedlings with all essential structures well developed, complete, in proportion and healthy.
  - **With slight defects** – seedlings with slight defects in essential structures, but with otherwise satisfactory and balanced development comparable to that of intact seedlings of the same test.
  - **With secondary infection** – seedlings that would clearly have conformed to one of the above categories, but affected by fungi or bacteria from sources other than the parent seed.

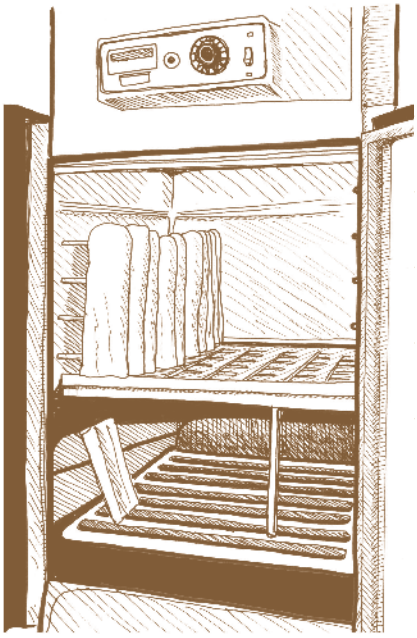
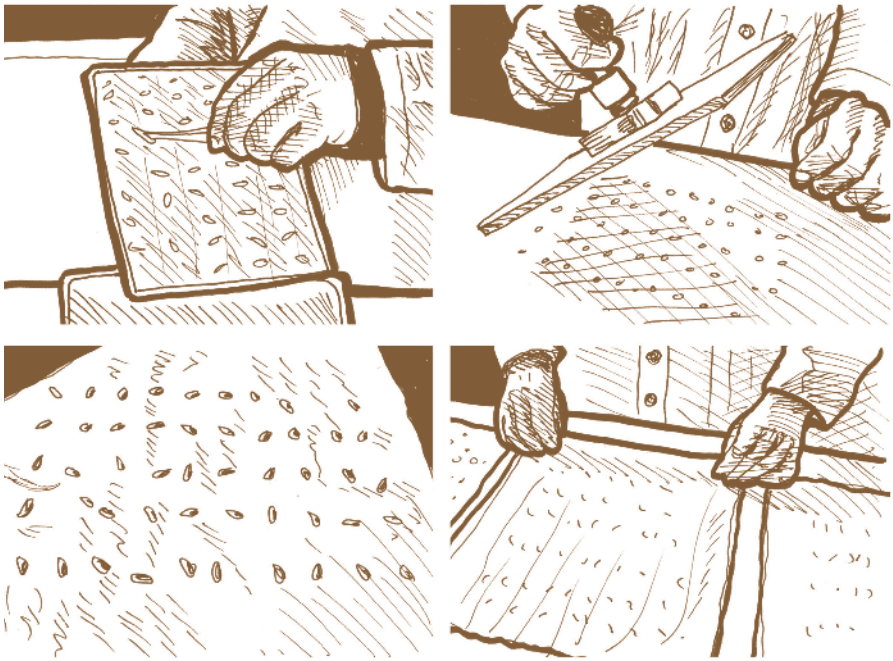


Figure 3.5 Germination incubator

Figure 3.6 Preparing a germination test



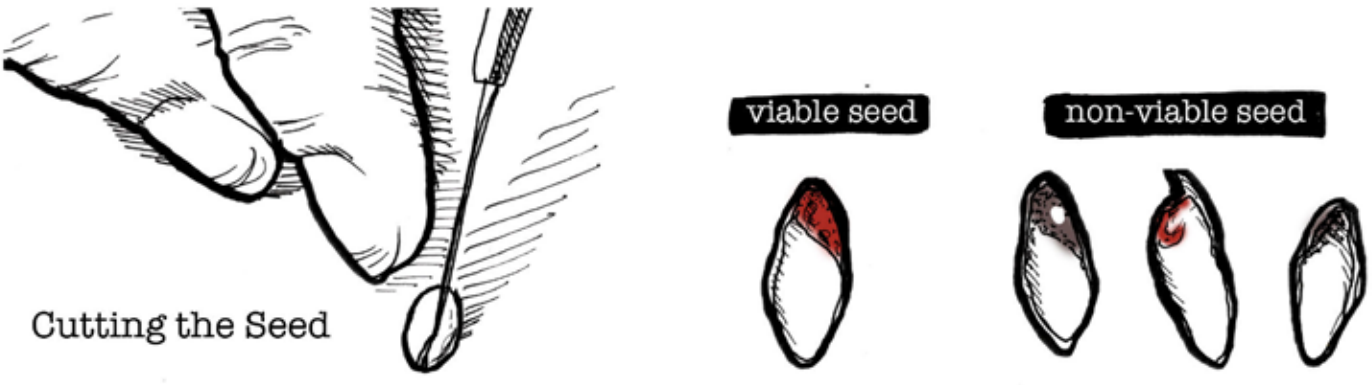
notes

- **Abnormal seedlings** – no potential to develop into a normal plant when grown in good quality soil and under favourable conditions of moisture, temperature and light. The following seedlings are classified as abnormal:
  - **Damaged** – seedlings with any of the essential structures either missing or so badly and irreparably damaged that balanced development cannot be expected.
  - **Deformed or unbalanced** – seedlings with weak development or physiological disturbances, or with essential structures deformed or out of proportion.
  - **Decayed** – seedlings with any of the essential structures so diseased or decayed as a result of primary infection that normal development is prevented.

- **Ungerminated seeds** – not germinated by the end of the test period. Classification is as follows:
  - **Hard** – seeds that remain hard at the end of the test period, because they have not absorbed water. Hardness in seeds is a form of dormancy. It is common in many Fabaceae species, but can also occur in other families.
  - **Fresh** – seeds (other than hard seeds) that have failed to germinate under the conditions of the germination test because of dormancy, but which remain clean and firm and have the potential to develop into a normal seedling. They are able to imbibe water under the conditions set out in the ISTA Rules, but the germination process is blocked.
  - **Dead** – seeds that are neither hard nor fresh and have produced no part of a seedling by the end of the test period. Dead seeds absorb water, are usually soft or discoloured and frequently mouldy. They show no sign of seedling development.
  - **Other** – in some circumstances, empty and ungerminated seeds may be further categorized according to the ISTA Rules.

The result of the germination test is expressed as a percentage by number of normal and abnormal seedlings and hard, fresh and dead seeds. The percentages are rounded to the nearest whole number. For example, 75.00 and 75.25 are rounded to 75%; 75.50 and 75.75 are rounded to 76%. The sum of the percentages of normal and abnormal seedlings and ungerminated seeds must be 100.

Figure 3.7 Evaluating a germination test



3

Tetrazolium test for viability

notes

Viability is the capability of the seed to germinate and produce a normal seedling. It indicates that a seed contains the structures and substances required to germinate under favourable conditions in the absence of dormancy. External physical appearance alone cannot determine whether a seed is alive or dead. Seed viability testing is therefore carried out to determine the percentage of viable seed in a given lot. The test is valid for all species for which a method is described in the ISTA Rules.

Objective: Make a **rapid assessment** of seed viability and seed vigour in the following circumstances:

- Seeds need to be sown shortly after harvest.
- Seeds have deep dormancy or show slow germination.
- A very quick estimate of germination potential is required (e.g. when a seed lot is received at a processing plant).
- A solution is required to problems encountered in a germination test (e.g. reasons for abnormals are not clear or treatment with pesticides is suspected).

Tetrazolium solution is an indicator and produces a substance called formazan in living cells. Formazan is red, stable and non-diffusible and turns living tissues red; they can thus be distinguished from colourless dead tissues.

A viable seed shows staining in all those tissues whose viability is necessary for normal seedling development. Seeds can then be classified into viable and non-viable seed classes.

Apparatus: Petri dishes, filter paper, magnifying glass, dropper and bottle, solution of tetrazolium, dissecting needles, forceps.

Procedure:

- Draw four replicates of 100 pure seeds at random, either from the pure seed fraction of a purity test carried out or from a representative fraction of the submitted sample.
- Mix the pure seed fraction thoroughly taking care to not select seeds causing biased results.
- Soak seeds in water overnight to soften the embryo and endosperm and activate the enzyme system.
- Make a cut or completely remove the seed-coat (depending on the species) – to expose the embryo and facilitate contact with the tetrazolium solution.
- Immerse the prepared seeds or embryos in tetrazolium salt solution. Avoid exposure to direct light, as it would cause a reduction of the tetrazolium salt. Refer to the ISTA Rules for optimum temperatures and staining times.
- Wash seeds repeatedly with distilled water.
- Examine seeds under a magnifying glass.

notes

Example: For maize, the seeds are soaked for 18 hours in water at 20 °C, then cut longitudinally through the embryo and ¾ of the endosperm before staining in 1% tetrazolium solution for 2 hours at 30 °C. The seeds are then halved and the cut surfaces observed.

Seeds are **classified** as follows:
- Living – red or purple embryo.
- Dead – no colour in the embryo. Even when the embryo is not stained but red colour develops on other parts, the seed is still classified as dead.

The percentage of viable seed is calculated as follows:

$$\textit{Viable seed}\,(\%) = \frac{\textit{Number of living seeds}}{\textit{Number of seeds set for viability test}} \times 100$$

Vigour test

The germination test does not detect quality differences among seed lots with similar germination percentages. A vigour test is more sensitive and able to detect such differences.

Objectives:
- Assess the extent of seed lot deterioration and/or physical damage that has occurred during handling and storage.
- Distinguish important differences in physiological potential among seed lots of commercial value (in particular those of similar germination percentage).

There are several **definitions** of seed vigour, including:
- Seed properties that determine the potential for rapid uniform emergence and development of normal seedlings under a wide range of field conditions (AOSA, 1983).
- Sum total of properties of seeds that determine the activity and performance of seed lots of acceptable germination in a wide range of environments (ISTA, 1995).

Seed vigour is not a single measurable property. It is a concept describing **several seed characteristics** associated with aspects of performance in the field, including:
- rate and uniformity of seed germination and seedling growth;
- ability of seeds to emerge under unfavourable environmental conditions; and
- performance after storage, particularly retention of the ability to germinate.

It is possible to identify lots more likely to perform well under non-optimal environmental conditions. Indeed, germination tests take place under optimal germination conditions and the results express the germination potential. This figure may be quite different from actual performance under stressed field conditions.

For example, two seed lots may have similar germination potential (> 90%), but significant differences in seed vigour (Table 3.2). An efficient vigour test must

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pinpoint differences in physiological potential not detected by viability tests and rank lots according to performance potential.

Table 3.2 Example of germination and emergence in two seed lots

Seed lot	Germination (%)	Seedling emergence (%)	
		Field 1 (near ideal conditions)	Field 2 (unfavourable conditions)
A (high vigour)	90	88	75
B (low vigour)	90	87	50

- Field 1 – the stands of both high (A) and low (B) vigour seed lots are similar to their germination.
- Field 2 – the low vigour seed lot (B) has poor seedling emergence compared with the high vigour seed lot (A). In addition, despite seed lot A's superior vigour, emergence in Field 2 is lower than the germination percentage; therefore, stand may be unacceptable if conditions are stressful.

Seed vigour tests

Objective: Obtain information about the **planting value** in a wide range of environments and the **storage potential** of the seed lot.

Since seed vigour describes several characteristics associated with seed performance – rather than a single measurable character – there is no single adopted standard procedure to measure vigour. The various vigour test methods are described in detail in the AOSA (2002) and ISTA (1995) handbooks. Some tests measure a direct aspect of the deterioration processes (e.g. cell membrane integrity test, conductivity test), others a consequence of the deterioration process (e.g. reduced tolerance to environmental stresses test, cold test, accelerated ageing test). There are three categories of vigour testing methods:

- Stress tests – cold, accelerated ageing and controlled deterioration tests
- Biochemical tests – conductivity and tetrazolium tests
- Seedling growth and evaluation tests

Cold test

The cold test was developed in the United States to evaluate the seed vigour of **maize** (corn). In the United States, when corn is planted in late spring, the soil is humid and cold, and weak seeds do not germinate and establish. The cold test replicates field conditions at the time of corn planting. The test aims to differentiate between weak and vigorous seed lots by subjecting them to a combination of low temperature, high substrate water content and, if possible, presence of pathogens.

The test has also been used for other species, including barley (*Hordeum vulgare* L.), carrot (*Daucus carota* L.), cotton, eggplant (*Solanum melongena* L.), field beans, lettuce (*Lactuca sativa* L.), onion (*Allium cepa* L.), rice (*Oryza sativa* L.), sorghum (*Sorghum bicolor* L.) and soybean.

notes

The cold test places the seed under the influence of **two stress factors**:

- low temperature; and
- presence of pathogens.

To guarantee the presence of certain pathogens, soil from the previous year's plot is used as substrate. This usage of different soil types means that there is no standardized cold test. Modified cold test methods exist with a mixture of soil and sand, or only sand. In such cases, the seed is exposed only to low temperature and the effect of pathogens is completely ignored.

Apparatus: Aluminium tray, field soil, sand, germinator.

Procedure:

- Ground and sieve the soil.
- Put the soil in the tray to a depth of 2 cm.
- Place 50 seeds on the soil/sand mixture and cover with a 2-cm thick layer of soil.
- Compact the soil and add water (at 10 °C) until the soil reaches about 70% of its water-holding capacity.
- Cover the trays with polythene bags, place in the refrigerator and maintain at 10 °C for 7 days.
- Remove the trays and place in the germinator at 25 °C.
- Calculate the germination percentage by counting the number of normal seedlings (as in the germination test). The higher the germination percentage, the greater the vigour.

Many different cold test procedures have been developed by different seed-testing laboratories, using a range of containers from plastic boxes and trays to rolled towels (Figure 3.8).

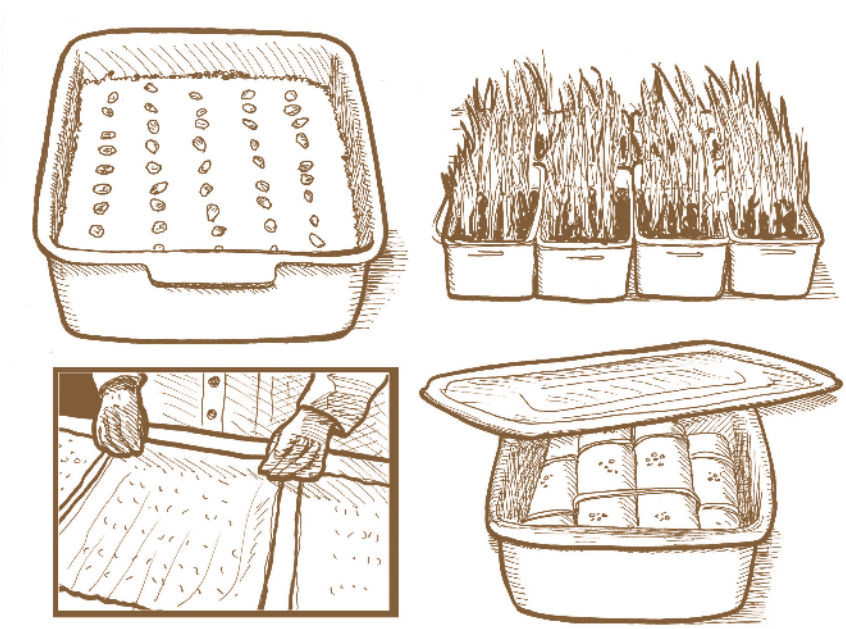

Figure 3.18Cold test: plastic trays with sand (top) and rolled paper (bottom)

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Accelerated ageing test

The accelerated ageing test was developed initially to determine storage potential. It is now used to predict the seedling field emergence potential of seed lots and is widely adopted for **soybean** (*Glycine max*). The ageing process is accelerated by subjecting the seeds to high temperature (40–45 °C) and high relative humidity (around 95%) in the ageing chamber for 72 hours. Seeds are then subjected to a germination test.

During the test, the seeds absorb moisture from the humid environment; the increased seed moisture content, combined with the high temperature, causes rapid seed ageing. Seed lots that show high germination in the accelerated ageing test have high vigour and are expected to maintain high viability during ambient storage.

Apparatus: Accelerated ageing chamber, equipment for germination test, plastic accelerated ageing boxes with wire mesh, distilled water.

Procedure:

- Use two boxes with 42 g of seed (100 seeds) in each.
- Place seeds on a dry wire mesh (screen) tray in a plastic accelerated ageing box containing 40 ml of distilled water. Take care not to splash water on the screen.
- Close the containers and place in the ageing chamber at 41 ± 0.3 °C for 72 hours. Stable temperature is important to ensure the validity of the results of repeated tests.

Remove the seeds from the containers and conduct a standard germination test using four replications of 50 seeds each.

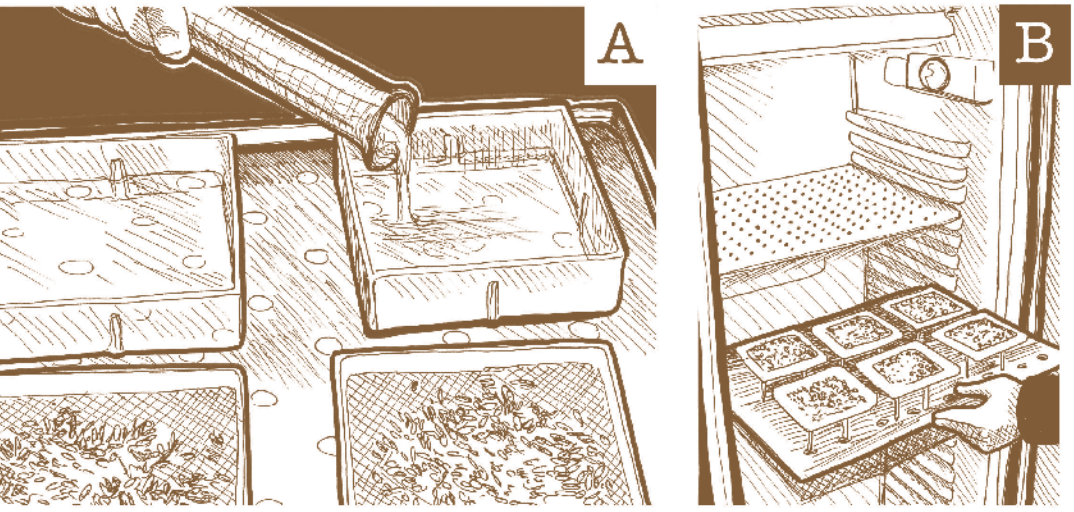

Figure 3.9 Accelerated ageing test: *A) Ageing containers with water and seeds over wire mesh, B) Placing the containers in the ageing chamber*

notes

Conductivity test

The electrical conductivity (EC) test is based on the assumption that cell membranes disintegrate during seed deterioration. The test is used for **garden pea** (*Pisum sativum*). The principle of the EC test is that less vigorous or more deteriorated seeds have a slower rate of cell membrane repair during seed water uptake for germination, and therefore release greater amounts of solutes to the external environment. The test evaluates the amount of ion leakage. Under field conditions, leakage of exudates after sowing, reflecting the loss of cell membrane organization and selective permeability, can stimulate the growth of pathogenic microorganisms and impair seedling emergence.

Since high vigour seeds can repair damage and reorganize their membranes more rapidly (compared with low vigour seeds), electrolyte leakage is an indication of vigour. Low conductivity indicates low electrolyte leakage and thus high vigour; high conductivity indicates low vigour (ISTA, 1995).

Apparatus: Conductivity meter, beaker, 0.1% mercuric chloride, distilled water, seed sample, wash bottle, tissue paper.

Procedure:

- Use 4 replicates of 50 seeds and weigh each replicate to two decimal places (0.01 g).
- Fill four containers of the same size with 250 ml of deionized water, cover to prevent contamination and maintain at 20 ± 2 °C for 24 h.
- Put the seeds to soak in the containers and re-cover to avoid pollution and evaporation. Place in a germinator at 20 ± 2 °C for 24 h.
- Use two other containers containing only de-ionized water as control for each test run.
- At the end of the incubation period, stir the seeds and measure the electrical specific conductivity – either between seeds or after the seeds have been removed from the water.
- Measure the conductivity of the control containers and subtract the mean value from the readings for the seed samples. Between readings, rinse the dip cell in deionized water.

Conductivity is expressed in $\mu S\ cm^{-1}\ g^{-1}$ and is calculated as follows:

$$\textit{Conductivity} = \frac{\textit{Conductivity reading - Mean value of the conductivity of the control}}{\textit{Weight of replicate (g)}}$$

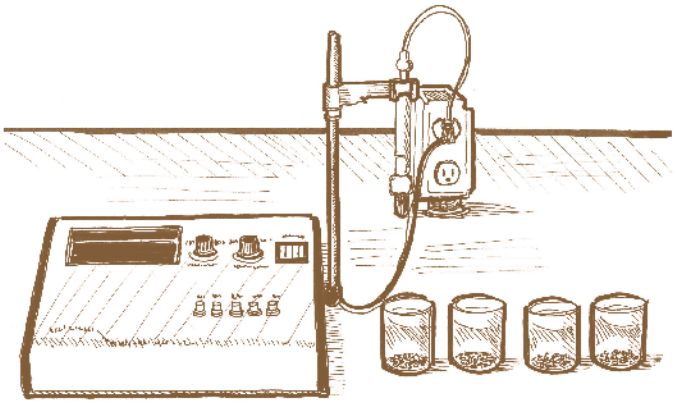

Figure 3.10 Conductivity test for peas

Tetrazolium test

The tetrazolium test has been used for many years to obtain a rapid general estimation of seed viability, particularly in species with dormancy when the germination test would last too long. To determine seed lot vigour, the procedure is as for the viability test, but **classification** is more precise:

- High vigour - staining uniform and even, tissue firm and bright.
- Medium vigour - embryo completely stained or embryonic axis stained in dicots. Extremities may be unstained, while some areas may be more or less stained.
- Low vigour - large areas of non-essential structures unstained. Only one root may be stained (monocots) or the extreme tip of radicle unstained (dicots). Tissue is milky and over-stained.

For reliable results, an experienced tetrazolium analyst must evaluate the test and the method must be accurately followed. The test is widely adopted for **cereal** crops and used successfully with **field pea**. It is also applied to soybean, cotton, corn, and large-seeded legumes.

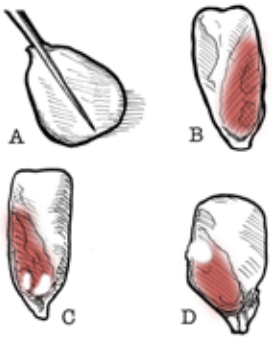

Figure 3.11 Tetrazolium test
A) Seed preparation,
B) Vigorous seed,
C) Seed viable not vigorous,
D) Seed not viable

Seedling growth and evaluation tests

Several tests based on seedling performance are used to evaluate seed vigour:

- First count of germination test.
- Speed of germination - one of the oldest manifestations of seed vigour. Rapid germination is important, because it usually corresponds to rapid seedling emergence in the field.
- Uniform seedling emergence - evaluation of seedling length or seedling dry weight.
- Rate of primary root emergence.

Tests on seedlings are simple to perform and do not usually require special equipment. Seedling tests are particularly useful for evaluating seed vigour in species where there is a lack of information about other seed vigour tests.

Moreover, for the evaluation of seedling length, new technologies, including scanners and specific computer programs, allow accurate measurement.

notes

Determination of moisture content

Moisture content is crucial for preserving quality of stored seed and maintaining viability. Seeds with the correct moisture content can be stored longer and are relatively resistant to damage by insects.

The moisture content of a sample is derived from the loss in weight when the seed is dried in accordance with ISTA methods. It is expressed as a percentage of the weight of the original sample.

The ISTA Rules differentiate between **direct** and **indirect** methods to determine moisture content. Direct methods involve oven drying, desiccation and other physicochemical approaches. Note that some species require grinding before testing.

Objectives:

- Determine the appropriate drying conditions for optimum preservation during storage.
- Verify whether seed complies with the maximum moisture content specified in the seed regulations.

Constant temperature oven method

A **direct method**, it reduces oxidation, decomposition and loss of other volatile substances, but ensures the removal of as much moisture as possible. The temperature (high/low) depends on the species.
Note that pre-drying may be necessary (see Table 3.3).

Apparatus: Grinding mill, electrically heated oven, containers, thermometer, desiccator, suitable desiccant (e.g. silica gel), analytical balance, sieves, cutting tool.

Procedure:

- Distribute the working sample evenly over the surface of the container.
- Weigh the container and its cover before and after filling.
- Quickly place the container on top of or next to its cover, in an oven.
- At the end of the prescribed period, cover the container, place in a desiccator (containing desiccant) and leave to cool at ambient temperature.
- Once cooled, weigh the container with its cover and contents.

The moisture content as a percentage by weight is calculated to three decimal places for each replicate using the following formula:

$$MC\,(\%) = \frac{\text{Loss of weight}}{\text{Initial weight}} \times 100 = \frac{M2 - M3}{M2 - M1} \times 100$$

Where:

- M1 = weight (g) of container and cover
- M2 = weight (g) of container, cover and contents before drying
- M3 = weight (g) of container, cover and contents after drying

3

Figure 3.12 Moisture test. Drying the seeds in the oven (left) and placing the seed to cool in a desiccator (right)

Table 3.3 Example of germination and emergence in two seed lots

Species	Grinding / cutting	Method to be used (temperature)	Drying at high temperature (h)	Pre-drying requirement
Red beet - *Beta vulgaris* L.	No	High	1	-
Cowpea - *Vigna unguiculata* (L.) Walp.	Coarse	High	1	≤ 17% moisture content
Groundnuts -*Arachis hypogaea* L.	Cut	Low	–	≤ 17% moisture content
Maize - *Zea mays* L.	Fine	High	4	≤ 17% moisture content
Rice – *Oryza sativa* L.	Fine	High	2	≤ 13% moisture content
Sorghum – *Sorghum bicolor* (L.) Moench	Fine	High	2	≤ 17% moisture content
Wheat – *Triticum aestivum* L.	Fine	High	2	≤ 17% moisture content

Moisture meter method

An **indirect method**, any type of moisture meter can be used, as long it meets the calibration and determination requirements. The moisture content measured is calibrated against the moisture content obtained using the oven method.

Meters are very practical and particularly useful when a rapid result is required, for example, when seed arrives at the processing plant after harvest and it is necessary to decide whether further drying is required.

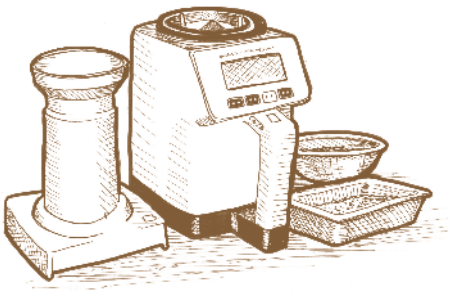

Figure 3.13 Portable moisture meter

notes

Seed health testing

It is important to understand the distinction between seed pathology and seed health.

Seed pathology – the study of seed-borne diseases, including the infection mechanism; seed transmission; role of seed-borne inoculum in disease development; techniques for detection of seed-borne pathogens; seed certification standards; deterioration due to storage fungi, mycotoxins and mycotoxicoses; and control of seed-borne inoculum.

Seed health – the presence or absence of disease-causing organisms (e.g. fungi, bacteria and viruses) and animal pests (e.g. nematodes and insects).

Objectives:

- Prescribe seed treatment.
- Enable seed certification.
- Determine the need for plant quarantine.
- Conserve seeds in gene banks.

Methods

There are various ways of detecting the presence or absence of seed-borne organisms:

- Inspection of dry seed (described in detail below)
- Seed washing for suspension (described in detail below)
- Whole embryo count method
- Blotter method (described in detail below)
- Agar plate method
- Water agar plate method
- Freezing method
- Seedling symptom method
- Serological test
- Growing on test
- Enzyme-linked immunosorbent assay (ELISA)
- Molecular biology methods (PCR)
- Field trials
- Inspection of seed crops

Inspection of dry seed

The seed sample is examined with the naked eye or hand lens stereo-microscope; the presence of fungi, if any, is observed and recorded. Fungi affects the **physical appearance** of the seeds:

- Fruiting structures of fungi are visible as *acervuli* or *pycnidia*; seeds are partly or completely smutted or bunted.
- Whole or broken ergot sclerotia are mixed with the seed.

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- Spores or spore masses of fungi are visible on the seed surface (rusts, smuts, downy mildews, spores of other fungi – e.g. *Drechslera, Alternaria, Nigrospora, Curvularia*).
- Nematode galls are present.

Inspection also reveals **physical abnormalities** (e.g. shrivelling of seed-coat, reduced or increased seed size, discoloration of or spots on seeds)

Apparatus: Purity box, stereo-binocular microscope, compound microscope, Petri dishes, watch glass, balance, sodium hydroxide (NaOH).

Procedure:

- Take a sample – the same size as that used for a purity test.
- Put seeds on the purity box and separate into pure seeds, inert matter and seeds of other crops.
- Weigh the three components and record details in the seed health report.
- Examine the pure seeds with the naked eye and then under a stereo-binocular microscope.
- Pick out isolated spores using a thin brush or wet needle. Alternatively, dip the seed on the slide in a drop of water causing some spores to be released. This can be done under a stereo-binocular microscope.
- Record observations in the seed health report.

notes

Washing test

Seeds are washed and the suspension is examined. This test is used principally to detect fungi whose inoculum is present on the seed surface – e.g. teliospores of bunts and smuts, oospores of downy mildew, chlamydospores of *Protomyces macrosporus*, rust of sugar beet (*Uromyces betae*) and safflower (*Puccinia calcitrapae*).

Apparatus: Compound microscope, balance, shaker, centrifuge, centrifuge tubes, capillary tubes, conical flasks, beakers, measuring cylinder, glass slides and cover slips, test tube racks, cheesecloth, Tween 20, mounting solution, haemocytometer.

Procedure:

- Take a working sample.
- Transfer seeds into a flask and add water until the seeds are submerged.
- Add 1–2 drops of Tween 20 (Polysorbate-type non-ionic surfactant).
- Place seeds on shaker for 5-10 minutes.
- Filter contents into a beaker through muslin or cheesecloth.
- Transfer contents into a centrifuge tube; put water in another centrifuge tube for control.
- Centrifuge contents at 1 500–3 000 for 2–10 minutes.
- Decant upper liquid and add 1 ml of water or mounting solution to the centrifuge tube.
- Mix contents with a needle.
- Insert a capillary tube; suck out a few drops and place on slides.
- Place cover slip over drops.
- Examine slide under a compound microscope.
- Pour contents into a Petri dish directly and examine the washings directly under a stereo-binocular microscope at 50X.
- Pick spores using capillary tubes and place on slide for compound microscope examination. This is useful when only a small number of seeds are available for testing (e.g. germplasm samples in quarantine clearance).
- Record results in the seed health report.

This method is used to test for pathogens in various crops:

- Soybean – downy mildew
- Pearl millet – downy mildew, smut
- Wheat – bunt, dwarf bunt, karnal bunt
- Rice – bunt

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Blotter method

This is an **incubation method** (seeds are placed on moist blotters) with seeds incubated for 7 days at 22 °C under alternating cycles of light and dark. After incubation, the fungi developed are observed under a stereo-binocular microscope and identified based on the habit characteristics and morphology of the spores. Fruiting bodies are observed under a compound microscope. Normally 400 seeds are tested in the blotter method. It is recommended that one analyst examines 200 seeds and another analyst examines the other 200.

Apparatus:

- Incubation room/incubator with racks equipped with blacklight tubes (for near ultraviolet light) fitted with an automatic timer for 12-h light/dark and a deep-freezer (-20 °C).
- Eye protection glasses (for NUV lights), plastic disposable gloves and masks.
- Compound and stereo-binocular microscopes.
- Petri dishes, filter paper discs, trays (30 × 60 cm) for holding plates, trays and spoons of different sizes for sampling, container for water, glass slides and cover slips.
- Sodium hypochlorite, distilled water, measuring cylinders (25 ml, 250 ml), refrigerator, toolbox and cheesecloth.

Procedure:

- Prepare required number of Petri dishes.
- Disinfect surface of the plates.
- Place 5–50 seeds per plate on three wet blotter papers in circular pattern.
- Incubate dishes at the selected temperature (20–25 °C) – e.g. 22 °C for 7 days in alternating 12-h cycles of light and darkness.
- Examine fungi on seed under stereo-microscope.
- Observe growth characters and identify fungi.
- Count various fungi in each Petri dish and calculate the percentage of infected seed.

The blotter method is the most commonly used seed health testing method and it also provides information on seed germination and vigour. It is used to detect pathogenic and saprophytic fungi and is applicable for seeds of almost all crops.

During examination, the analyst makes the following observations:

- Seed rotting
- Symptoms in roots (discoloration, rotting)
- Symptoms in cotyledons, coleoptiles, hypocotyls and leaves
- Death of seedlings
- Presence and frequency of saprophytes.

notes

Selection of pathogen testing method

The analyst needs to know the exact **location of the pathogen** (i.e. in/on individual seeds or among the seed as separate bodies), and whether there is one or more **types of inoculum**.

Methods:

- Naked eye - to identify bunts, as partially or completely bunted grains are easily visible on dry seed.
- Stereo-microscope and washing test - to identify loose spores on the seed surface.
- Seedling symptom test - to observe fungi-producing symptoms on young seedlings within a short period or causing loss of germination. Note: this should be an additional test, not the only test.
- Enzyme-linked immunosorbent assays (ELISA) – to detect soybean mosaic virus, bean pod mottle and other viruses. An antibody to a specific protein (antigen) in the pathogen is added to a sample and the reaction between them reflected in a colour change indicating infection.

Some crops require several tests to obtain the full picture of seed-borne pathogens, for example, with **wheat**:

- dry inspection for ergot;
- washing test for *Tilletia* spp.;
- embryo count method for loose smut;
- blotter and deep-freezing blotter method for *Alternari* spp., *Bipolaris sorokiniana*, *Fusarium* spp. and *Stagonospora nodorum*; and
- agar plate method for quick screening for *B. sorokiniana*.

Figure 3.14 Blotter test
A) Placing seeds in plates,
B) Placing plates in incubator,
C) Plates after incubation

notes

Varietal purity testing

Varietal or species purity is tested in the laboratory, in the greenhouse, and in field plots. However, variety identification in the laboratory is not standard practice, because most species have insufficient morphological features for accurate identification. The best way to ensure varietal purity is **field inspection** (as part of the certification process) and **post-control plots** (see Chapter 5 "Post-control").

Traditional varietal purity tests in the laboratory (e.g. visual examination of seeds and seedlings and chemical tests) are the first step towards identifying a variety or narrowing down the range of possibilities. The morphological and physiological characteristics of seeds, seedlings and plants are examined. In all tests, authentic samples of the species/variety should be available for comparison.

An **authentic sample** is defined by ISTA as a seed sample of a known species or variety or a sample with a known specific trait. The sizes of submitted samples are shown in Table 3.4.

Table 3.4 Sample sizes for the species and variety test

Species	Laboratory only (g)	Field plot and laboratory (g)
Glycine, Lupinus, Phaseolus, Pisum, Vicia, Zea and species of other genera with seeds of similar size	1 000	2 000
Avena, Hordeum, Secale, Triticum and species of other genera with seeds of similar size	500	1 000
Beta and species of other genera with seeds of similar size	250	500
All smaller-seeded species	100	250

Examination of seeds

It is possible to differentiate between cultivars on the basis of colour, morphological characters and chemical characteristics. Various testing methods are available.

Examination of phenotypic characters

A working sample of ≥ 400 seeds is analysed using replicates of ≤ 100 seeds. Direct visual examination or suitable magnification are adopted to identify **morphological** characters. To identify **colour** characters, seeds can be examined in daylight or under ultraviolet light. Identifying characters include:

- Wheat – colour, shape and size of caryopsis; frequency and length of bristles at the end of the caryopsis (brush).
- Rice – shape, size and colour of grain; size and colour of caryopsis.

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- Barley – shape of grain, base of lemma, colour, hairs in the ventral crease, opening of the ventral crease, rachilla hairs, dentation of the lateral dorsal nerves, wrinkling of the lemma and palea, shape and hairiness of the lodicules.
- Oat – grain colour (white, yellowish grey or black).
- Pea – colour, size and shape.

Chemical tests

Various chemical tests are available to differentiate between varieties of several species:

- Phenol test – distinguishes between cultivars of wheat, barley, oat and ryegrass.
- Peroxidase test – separates soybean cultivars into high and low seed-coat peroxidase activity.
- Cooper sulphate-ammonia test – separates yellow sweet clover (*Melilotus officinalis*) from white sweet clover (M. *alba*).
- Sodium hydroxide (NaOH) test – distinguishes white wheat from red wheat.

Phenol test procedure:

- Prepare 1% phenol solution by weighing 8 g of phenol crystals and dissolving in 800 ml of distilled water. Heat until crystals liquefy (avoid skin contact and prepare under fume hoods to prevent inhalation).
- Soak the seed in distilled water overnight for 16 hours.
- Drain and place in Petri dishes on filter paper moistened with the 1% phenol solution.
- Evaluate staining after 1 hour (or as soon as differences appear) – light staining seeds will continue to develop colour, so the timing of evaluation can be critical.
- Test a known control of the variety as a reference point for staining evaluation.

Figure 3.15 Wheat varieties develop a characteristic brown colour varying from pale to very dark under the phenol test

notes

Fluorescence test

The sample is examined under ultraviolet light and the fluorescence is observed. It is important to use safety eyewear and to avoid looking directly at the ultraviolet light. This test is useful for differentiating between species of ryegrass and between varieties of oats. **Identifying characters** include:

- Oat - lemma and palea of the seed. A sample of 75 g of pure seed is placed on a black work surface and examined under ultraviolet light for off-type or variant fluorescence.
- Ryegrass - roots of seedlings. The test is used to differentiate between annual (*Lolium multiflorum*) and perennial (*Lolium perenne*) seeds.

Electrophoresis

Electricity is used to separate molecules (protein or DNA) based on their charge and/or size. Specific stains are observed and the pattern is compared with known standards. ISTA recommends the following standard techniques for certain crops:

- **Polyacrylamide gel electrophoresis (PAGE)** – barley (*Hordeum*), pea (*Pisum*) and ryegrass (*Lolium*). The pattern of protein bands observed on the gel is characteristic of a specific variety.
  - *Hordeum* - alcohol-soluble proteins (hordeins) are extracted from the seeds and separated by PAGE at pH 3.2.
  - *Pisum* and *Lolium* - seed proteins are extracted from individual *Pisum* seeds or from a meal of *Lolium* seeds, treated with sodium dodecyl sulphate (SDS) and separated using a discontinuous SDS-PAGE procedure.

- **Isoelectric focusing (IEF)** - maize (*Zea mays*). The standard reference method for measuring hybrid purity and verifying varieties in maize is ultrathin-layer isoelectric focusing (UTLIEF). Alcohol-soluble proteins (zeins) or water-soluble proteins are extracted from individual maize seeds and separated by IEF in ultrathin-layer gels. The pattern of protein bands found on the gel is characteristic of a specific variety or an inbred line. It is usually possible to estimate the purity of hybrid samples by identifying one or more zein bands in the male parent that are lacking in the female parent (and present in the hybrid).

Examination of seedlings

Cereal

Some varieties can be distinguished by the colour of their coleoptiles, which varies from purple to green and is determined when the seedlings reach a suitable stage of development.

Procedure (to intensify the colour): moisten the filter paper (substrate) with a 1% solution of NaCl or HCl; alternatively, place the seedlings under UV light for 1–2 hours before examination.

notes

Brassica

White-fleshed cultivars are distinguished from yellow-fleshed cultivars by the colour of the cotyledons of germs in turnip: lemon for white-fleshed cultivars and orange for yellow-fleshed cultivars.

Procedure:

germinate 400 seeds in the dark at 20–30 °C; after 5 days, place cotyledons in Petri dishes containing alcohol (85–96%); place dishes on a white surface; determine the colour of the cotyledons after 4 hours.

Lolium

Ryegrass species can be identified using the fluorescence test on seedlings. Root traces in the majority of *Lolium multiflorum* cultivars exhibit fluorescence while in *Lolium perenne* they do not.

Procedure:

- Place the seed on non-fluorescent white filter paper moistened with distilled water for germination under the prescribed conditions (Table 3.1).
- After 14–18 days, when roots are well-developed, examine seedlings under ultraviolet light from a lamp transmitting 360–370 nm radiations.
- Record the number of fluorescent seedlings and non-fluorescent seedlings, as well as the number of normal seedlings, for each repetition.

Storage of samples

It is essential to perform tests as soon as possible after receipt of the sample.

Do not delay testing:

- Moisture content can dramatically increase or decrease during storage, depending on the temperature and humidity of the storage room.
- Dormancy may be altered and – in the case of *Fabaceae* (*Leguminosae*) species – the number of hard seeds can increase.

After analysis, the samples should be kept for ≥ 1 year to allow for audit retesting. Samples must be stored in a room with controlled temperature and humidity and protected against insects and rodents to minimize changes in seed quality. Samples should be placed on appropriate shelves in a clear and orderly manner. High-value samples (e.g. pre-basic seed, seed for research, hybrids, certain vegetable seeds and seeds from a germplasm collection) must be stored under stricter conditions. The moisture content of samples for long-term storage must be lowered to 7–8%. These samples are then placed in appropriate tins containing a desiccant agent and sealed with a watertight seal or stored in a freezer.

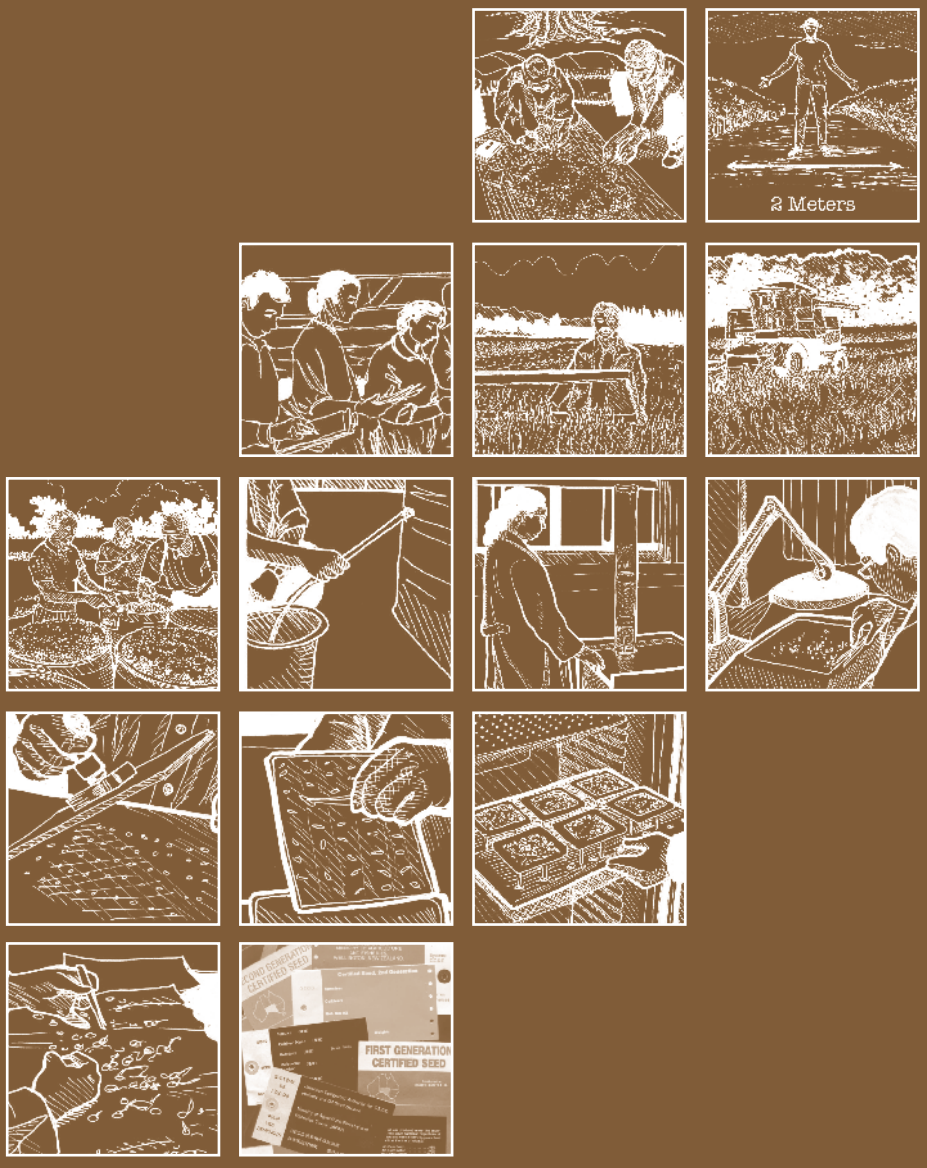
3

EXERCISES AND DISCUSSION POINTS

1. What are the components of a purity test?
2. If the weight of a working sample is 150 g, how many decimals should be used?
3. Why is a larger seed sample examined for other seeds and noxious weeds than for purity analysis?
4. What are the essential structures of a seedling?
5. For what kind of structures is the 50% rule used? Explain.
6. How is a germination test evaluated?
7. How is moisture content calculated in a constant temperature oven method determination?
8. What is the difference between a germination test and a viability test (tetrazolium)?
9. What are the objectives of seed health testing?

notes

4 Purpose and organization of seed quality assurance and control



Purpose and organization of seed quality assurance and control

4

notes

The **economic importance** of genetically and physically pure seed of high-yielding varieties is increasingly recognized in developing countries. Good quality seed offers excellent production potential and a continuous supply is essential for **food security**. To assure the quality of seed sold to farmers, most countries have adopted specific legislative measures.

This chapter discusses seed certification, its organization, regulation and requirements.

WHAT IS SEED QUALITY ASSURANCE?

Seed quality assurance is a programme for suppliers of varieties and brands of seed. It is a **systematic and planned process** designed to ensure the genetic, physical and physiological integrity of the seed delivered to farmers. It includes field inspections, laboratory testing, audits of production records, and onsite evaluations of conditioning and treatment facilities.

Seed quality assurance guarantees that the certified seed sold to farmers meets **high standards**, enabling a seed enterprise to produce and market seed according to sound **quality management practices**.

Objectives:

- Ensure that the best quality seeds are produced and sold to farmers.
- Prevent the spread of weeds, pests and diseases, particularly invasive types.
- Meet consumer demands for specified qualities.
- Cater for the needs of specialized farming.
- Comply with mechanization of agriculture.
- Encourage healthy competition among seed traders.

WHAT IS SEED CERTIFICATION?

Seed certification is a **regulatory process** designed to maintain and make available to farmers high quality seeds and propagating materials of superior crop varieties, grown and distributed to ensure **genetic identity** and **genetic purity** (International Crop Improvement Association, 1968). It also ensures other factors, including absence of weeds and diseases, analytical purity and viability.

The seed certification authorities adopt predetermined **standards and systems** for the production, multiplication and marketing of seed.

notes

REGISTRATION OF VARIETIES

Objectives:
- Establish the identity of the variety.
- Set performance standards.

In most countries, for a variety to be eligible for certification, it must be listed in the "national variety list" or "national variety catalogue". A national listing procedure is a potentially useful tool in the agricultural industry: only one name is associated with a variety; and beneficial attributes (high yield, resistance to drought and disease) increase over time as a result of agronomic performance trials.

Once a variety is added to the national list, it can be included in seed certification schemes for marketing. In many countries, a variety can also be granted **plant breeders' rights**, allowing the plant breeder to recover the costs of breeding activities and invest in the future. The introduction of plant breeders' rights has led to a move away from state breeding to private breeding.

one variety, one name, one description

In order to be included in the **national list**, testing must be done over at least two cropping seasons involving two series of **evaluations**:
- **DUS** testing - Distinctness, Uniformity and Stability
- **VCU** testing - Value for Cultivation and Use

The testing period varies among countries (see Table 4.1).

Table 4.1 Crop seasons required for evaluation and registration of cereal variety in selected countries

Species	Morocco (wheat)	Nepal (maize)	Spain (wheat)	Uganda (maize)	Ukraine (maize)
Number of crop seasons for DUS testing	2	2	2	2	3
Number of crop seasons for VCU testing	2	2	2	2	3
Applicant data accepted	No	Yes	Yes	Yes	No

Source: World Bank, 2015

4

notes

DUS testing

Objectives:

- Show that the variety has a unique taxonomic description, and is therefore distinct from all other varieties on the national list.
- Ensure that the variety is uniform – i.e. plants conform to the same description.
- Ensure that the variety is stable – i.e. plants do not change taxonomically from one generation to the next.
- Produce a detailed variety description to identify the variety during the certification process.

DUS testing is carried out by the national designated authority (in most countries, the variety registration/release committee) with appropriate technical expertise, particularly in countries not accepting applicant data (see Table 4.1). A combination of plant rows and plots are used to grow:

- seed supplied by the plant breeder;
- other candidate varieties;
- varieties already on the national list; and, sometimes
- varieties in "common knowledge" – typically, varieties that have recently been removed from the national list, but which are still being grown in commerce.

There is usually a period of grace – after a variety has been removed from the national list but before marketing has to stop – to give merchants and seed producers time to sell existing stock of that variety.

Plant **taxonomic characters** are recorded for each candidate variety. This creates a paper description of the variety. The official variety description is used for national listing purposes and also during the certification process once the variety is accepted on the list.

The list of characters is based on the UPOV technical guidelines[2], which also list:

- growth stage at which characters should be recorded;
- range for each character that can be used; and
- example varieties displaying the specific character state.

VCU testing

Objective: Show that the variety has an agronomic advantage over existing varieties.

2 *Available at http://www.upov.int/tgp/en/.*

notes

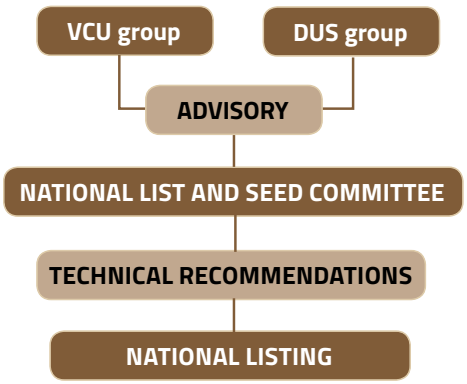
In most countries, this test is performed on **varieties destined for the domestic market**; in general, it is **not applied to vegetable species**.

The evaluation entails field trials of candidate varieties grown together with carefully selected varieties from the national list to act as controls and featuring a range of attributes (e.g. high yield and good disease resistance).

For example, in a cereal VCU trial, the seed is sown in plots with a harvest area 2 m wide and 10 m long. The plots are replicated in each trial, the number of replicates depending on the size of the trial and the number of trials carried out.

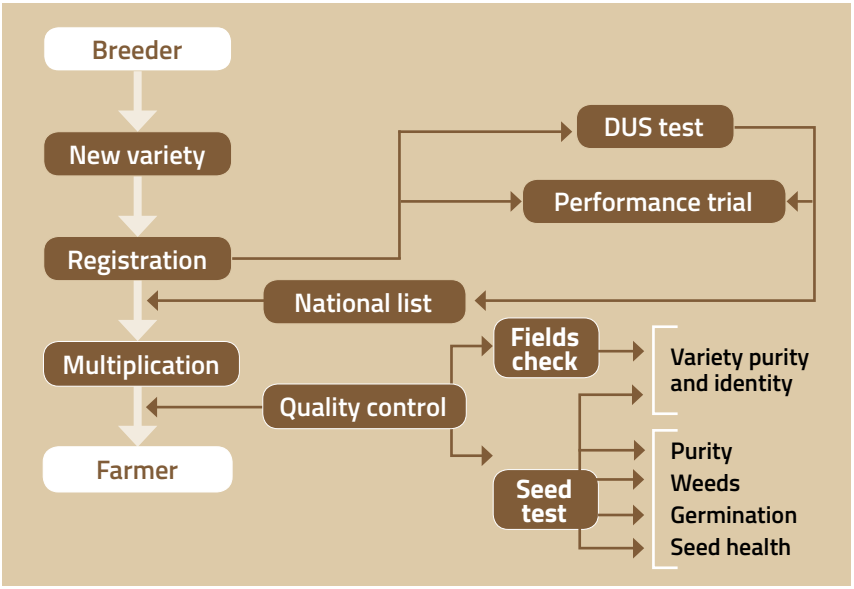
The official system for national listing is shown in Figure 4.1.

Figure 4.1 National list decision-making mechanism



An overview of the variety registration and certified seed production process is provided in Figure 4.2.

Figure 4.2 Diagram of variety registration and seed certification process



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SEED CERTIFICATION PROCESS

notes

Seed certification programmes have been in existence for over 100 years. They have effectively defined and monitored standards to **guarantee specific purity requirements** of the final product or seed.

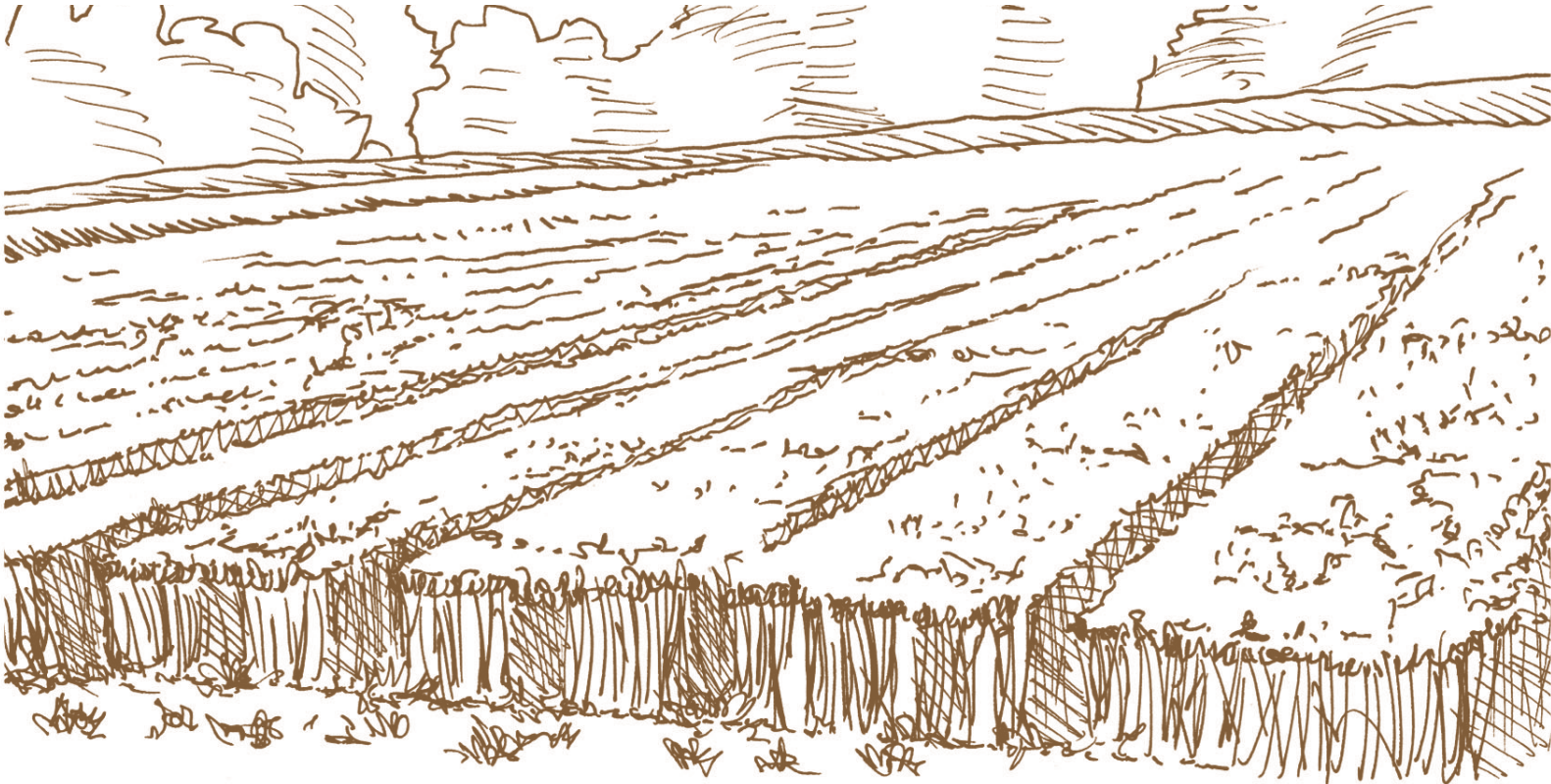
Certification means that you can buy seed with high physical and physiological quality standards, as close as possible to the genetic make-up of the variety selected by the breeder. The plant breeder invests time and effort in selecting a variety that performs better than the varieties available on the market. Farmers who choose to grow the certified variety have the benefits of quality seed.

For example, in the United Kingdom, there was a 33% increase in national average wheat yields - from 6.2 tonnes/ha in 1982 to 8.3 tonnes/ha in 2008 - around 90% of which is due to plant breeding (BSPB, 2010). Farmers can optimize this potential by buying seed of modern varieties with high varietal purity through a certification scheme.

Objectives:

- Establish and maintain reasonable standards of seed quality.
- Facilitate the production of seed of specified quality.
- Maintain the identity and purity of varieties.

Figure 4.3 Certified wheat seed field



notes

ORGANIZATION OF A SEED CERTIFICATION PROGRAMME

Regulations and procedures are necessary to ensure that the established minimum quality standards are maintained. Countries have developed certification schemes over time, adapting to local conditions, including the agricultural pattern and existing system of administration. For the international seed trade, countries adopt the certification scheme developed by the Organization for Economic Co-operation and Development (OECD) (see Chapter 6).

The organization of seed certification comprises **three main steps**:

1. Institute a seed certification agency.
2. Establish minimum seed certification standards.
3. Devise procedures for field inspection, processing, sampling and testing, labelling etc.

Seed certification agency

The seed certification agency is the competent authority – **independent from the industry** – responsible for implementing the certification scheme. The organization and the structure of a country's certifying authority may vary depending upon the development of the seed sector. In some countries, certification is under public authority and the agency is also responsible for the seed-testing laboratory.

Main activities of a seed certification agency:

- Registration of varieties and maintenance of the variety list for seed certification
- Establishment and review of seed certification standards
- Registration of seed growers
- Registration of processing plants for seed certification
- Field inspection
- Seed sampling
- Issue of official labels
- Laboratory testing
- Awarding of certificates
- Seed certification and seed testing training.

Classes of seeds

A certification scheme provides for different classes of certified seed. Certified seed production of registered varieties follows a generation system to ensure that all seeds marketed to farmers originate from a known source (seed produced by the breeder). Source material is also known as "nucleus seed" or "parental material". The more a variety is multiplied, the greater the possibility of contamination, crossing and variability. For this reason, it is important to limit the number of classes and generations.

4

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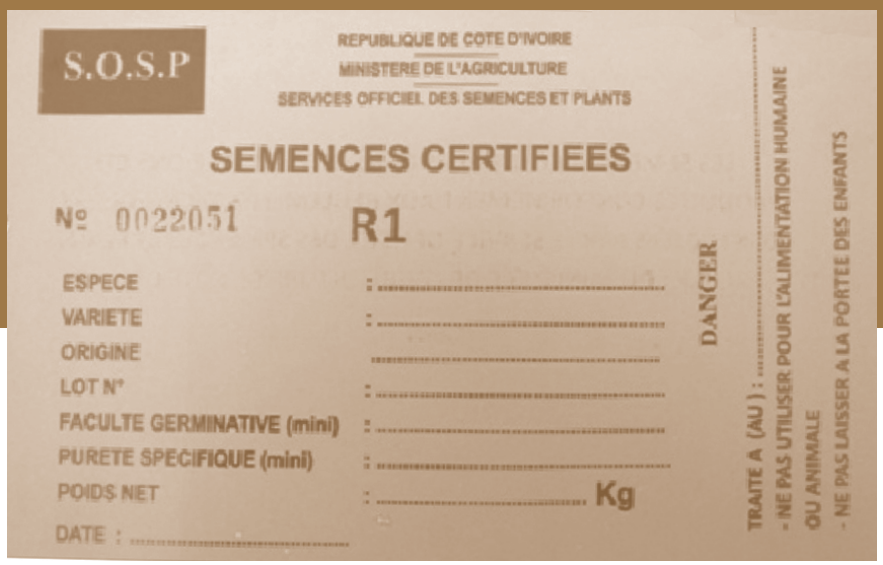
The **OECD** seed scheme (OECD, 2016) recognizes three classes of seeds:

- Pre-basic (PB) – seed material of any generation between the parental material (nucleus seed) and basic seed. It is produced by the breeder.
- Basic (B) – seed produced by or under the responsibility of the breeder and intended for the production of certified seed. It is called basic seed because it is the basis for certified seed and its production is the last stage that the breeder would normally be expected to closely supervise.
- Certified – the progeny of basic seed, produced under contract with selected seed growers under the supervision of a seed enterprise (public or private). Certified seed can be used to produce further generations of certified seed (certified 1, certified 2 etc.) depending on the country's regulations.



A seed store

Figure 4.4 Examples of seed labels from Côte d'Ivoire: basic seed G4 (4th generation) and certified seed R1 (1st multiplication in French reproduction 1)

notes

The **AOSCA** seed scheme recognizes four generations of seed:

- Breeder (equivalent of OECD pre-basic) – seed of a new variety with the highest purity. It is produced, developed, controlled and provided directly by breeders or their institution for further multiplication.
- Foundation (equivalent of OECD basic) – the progeny of breeder seed. It is produced by trained officers from an agricultural station in conformity with national standards and handled to maintain genetic purity and varietal identity.
- Registered – the progeny of foundation seed. It is grown by selected farmers, handled to maintain genetic purity and identity, and undergoes field and seed inspections to ensure conformity to standards.
- Certified – the progeny of foundation, registered or certified seeds. It is handled to maintain sufficient varietal identity and purity. It is grown by selected farmers under prescribed conditions of culture and isolation and is subjected to field and seed inspections prior to approval by the certifying agency. Harvest from this class is used for commercial planting.

Nucleus seed production is not monitored by the seed certification agency. Other classes of seed (pre-basic/breeder, basic/foundation, certified/registered and certified) all come under the seed certification scheme. The seed quality control agency verifies the quality – both in the field and in the laboratory – and certifies that the seed meets national standards.

Seed certification systems in different countries use different names for generations or seed classes depending on the seed scheme adopted (Table 4.2).

Figure 4.5 Nucleus seed production of cereals

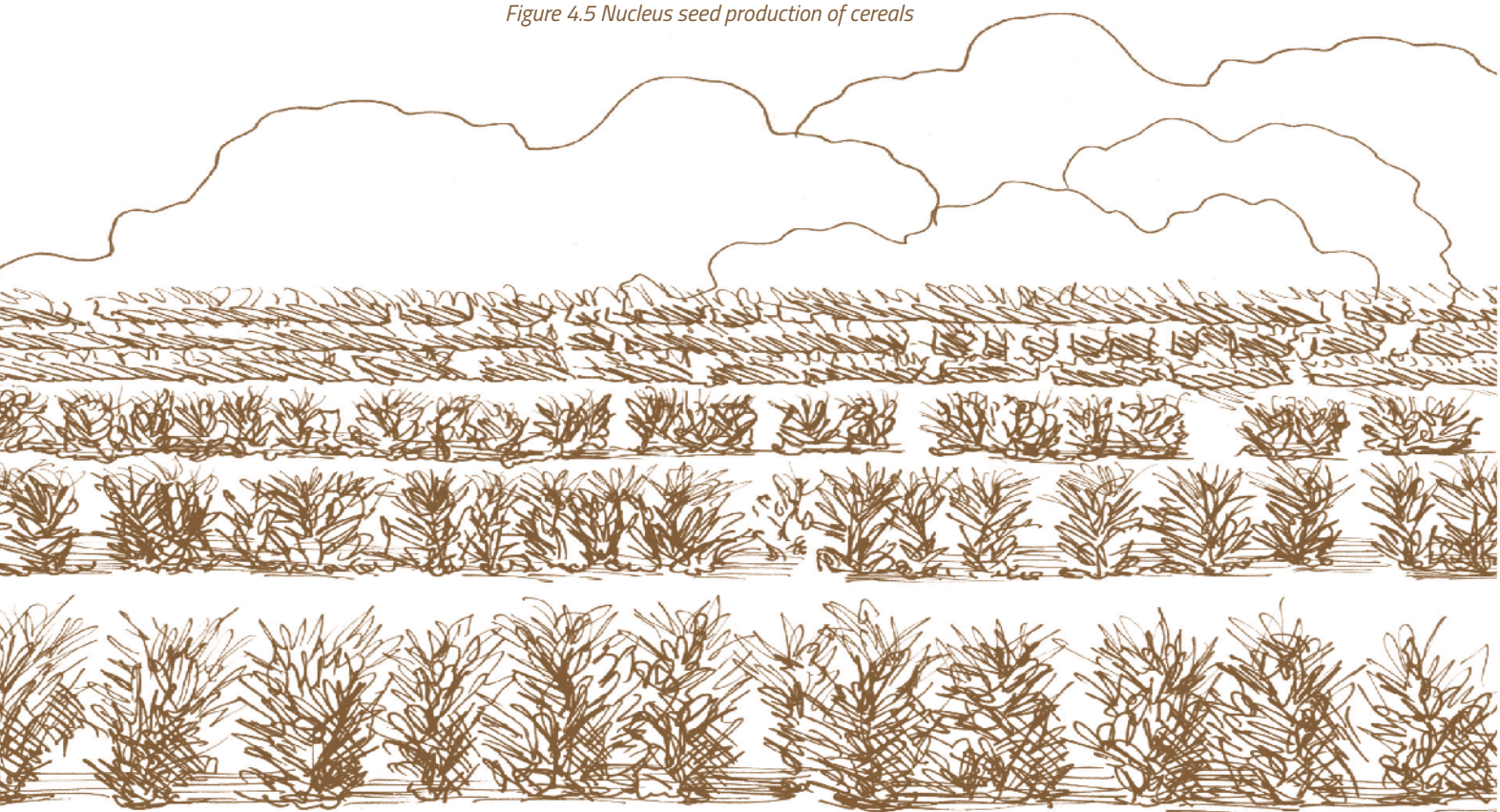


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Table 4.2 Designation of cereal seed classes in some countries

Country	Ethiopia	Egypt	Morocco	New Zealand	OECD	AOSCA
			Initial material			
	Nucleus	Nucleus	Head-rows	Nucleus	Nucleus	Nucleus
			Classes			
First	Breeder	Breeder	Pre-basic	Breeder	Pre-basic	Breeder
Second	Pre-basic	Foundation	Basic	Basic	Basic	Foundation
Third	Basic	Registered	Certified R1	Certified 1	Certified 1	Registered
Fourth	Certified 1	Certified	Certified R2	Certified 2	Certified 2	Certified
Fifth	Certified 2	-	-	-	-	-

Seed certification standards

Seed certification requirements vary according to local conditions and national laws and regulations. The aim is to provide the buyer with the best possible assurance of obtaining good quality seed of known purity and provenance. Technical seed certification requirements comprise **field (production) standards and seed standards** (see Table 4.3):

- Varietal purity, isolation, seed-borne diseases and weeds - controlled by field inspections and pre- and post-control tests.
- Analytical purity, germination, seed heath, vigour and moisture content and variety purity (insofar as possible) - controlled by seed quality testing.

Table 4.3 Field and seed standards for soft wheat in Morocco *(ONSSA, 2016)*

	Pre-basic	Basic	Certified (R1)	Certified (R2)
A. Field standards				
Isolation (m)	10	10	≥ 2	≥ 2
Maximum rate of other varieties (‰)	0.5	1	2	3
Maximum levels of specific impurities of winter cereals (barley, oat, durum wheat, rye and triticale)	1/15 000	1/10 000	1/8 000	1/2 000
Maximum rate of infected plants by seed-borne diseases: bunt, loose smut, leaf blight and blast disease	1/10 000	1/5 000	1/2 000	1/1 000
B. Seed standards				
Minimum varietal purity (%)	99.9	99.9	99.8	99.7
Minimum germination (%)	85	85	85	85
Minimum physical purity (% in weight)	99	99	98.5	98
Maximum content of other seeds (no. seeds per kg)	6: 1 for OC(*) 0 for WO (**) 2 for NW (***)	8: 3 for OC 0 for WO 3 for NW	20: 12 for OC 1 for WO 4 for NW	30: 15 for OC 1 for WO 8 for NW

(*) OC: Other cereal species (**) - WO: Wild oats (***) - NW: Noxious weeds

notes

Field standards

High quality seed production is an exacting task. Farmers must be highly skilled with a thorough knowledge of seed crops and their management from establishment through to harvest. They should take all necessary precautions to control factors potentially causing irreversible damage to genetic purity or seed health. Many seed-producing farmers work on a contract basis for a seed organization or company with specialized equipment and resources. In order to conform to seed certification standards, farmers must meet certain requirements in the field and during production in the following areas:

- Planting stock
- Site selection and isolation
- Sowing
- Weed control
- Harvest management
- Seed processing
- Seed packaging and labelling
- Storage of processed seed.

Planting stock

In most countries, to be eligible for certification, a variety must be included in the national variety list – a register comprising varieties both introduced from other countries and resulting from an in-country selection programme.
Seed must be from an approved source and its classification depends on the stage of seed multiplication:

- Pre-basic seed is planted to produce basic seed.
- Basic seed is planted to produce certified seed C1 (first generation).
- Certified seed C1 is planted to produce certified seed C2 (second generation).

Site selection and isolation

It is important to select a site with appropriate conditions for high seed yields. Fields used for growing certified seed must meet the **criteria defined in national seed regulations**, for example:

- **Crop history**. The field must not have been planted to another variety of the same crop for the period specified in the individual crop standards. However, a farmer may plant the same variety on the same field if he is producing the exact same variety of equal or lower class.
- **Isolation**. The field must be separated from other fields cultivated with the same variety in order to maintain genetic identity. The isolation distance depends on the mode of pollination. Isolation can be **spatial** (separated by a specific distance) or temporal (cultivated after a determined period). When time and space isolation are not possible, mechanical barriers can be created, such as a ditch, levee or roadway; alternatively, a barren strip may be left to preclude contamination through chance outcrossing or mixing during harvest. The width of the **isolation strip** depends on the species and seed class. For self-pollinated crops, 2–3 m around the edges of the field are sufficient to prevent contamination, but for cross-pollinated crops, a greater distance is required (e.g. for maize, 400–500 m).
- **Cleanliness**. The field must be clean and free from weeds, pests and diseases.

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notes

Sowing

Clean sowing machinery and seed-handling equipment before use to minimize the risk of contamination during sowing, harvesting and processing. Appropriate cleaning equipment includes a high pressure air hose and a high-powered vacuum cleaner. Keep all documentation received at purchase (seed labels and tags, bulk sales certificate, invoice etc.) to enable verification at any time that seed regulation standards have been met. Always follow recommendations for planting time and seeding rates.

Roguing

Roguing is the systematic removal from the seed production field of off-types, plants of another crop or variety and diseased plants.

Practise roguing at least once (but preferably twice – before and after flowering), and ensure that off-type plants are removed before they shed pollen. It is not always possible to identity an off-type until seed begins to form and a difference in grain colour becomes apparent. Therefore, inspect fields periodically for timely identification of off-types.

Characteristics determining varietal purity under field conditions include: plant height, pigmentation of plant parts, pubescence, awn characteristics and time of flowering.

Figure 4.6 Isolation distance for self-pollinated crops

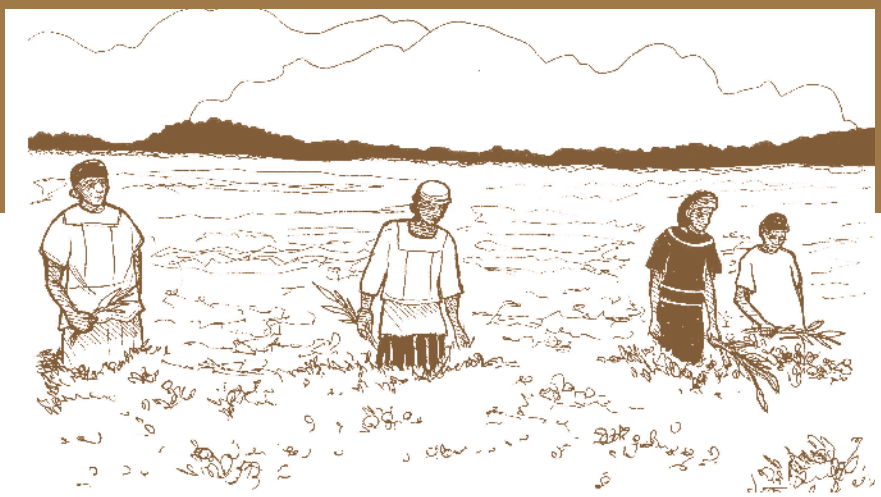

Figure 4.7 Roguing off-types from wheat field

notes

Harvest management

Always harvest seed at the proper stage of maturity; permission may be required from the field inspector. Avoid contamination by other varieties by cleaning thoroughly the harvest equipment (combines, trucks, tarps, augers, legs, conveyors and seed storage bins etc.). In some countries, harvested and threshed seed is packed in bags and sealed by the field inspector prior to transport to the seed-processing plant. The higher the quality of the seed, the greater the care required in harvesting and processing. Breeder seed should be hand-harvested or harvested using specialist plot equipment and threshed using a mechanical self-cleaning thresher.

Seed processing

- **Seed drying.** Seed loses viability and vigour during processing and storage, mainly because of high seed moisture content affecting longevity. Dry seed immediately after harvest to the prescribed moisture content (generally 10–14 %, depending on the species and on the conditions and duration of storage). Sun drying is the most popular method among small farmers, while mechanical drying is widely used in processing plants. Care must be taken with mechanical dryers to avoid "heat damage", which reduces germination.
- **Storing unprocessed seed on farm.** Store harvested seed in clean bins. Before the seed leaves the field, mark clearly (e.g. with an appropriate unprocessed seed label) to identify the field/crop from which the seed was harvested. Clean and label all on-farm storage containers.

Figure 4.8 Harvesting basic seeds

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notes

- **Transportation of unprocessed seed.** Label clearly each load of unprocessed seed delivered to the authorized seed processor and provide all the necessary documentation. Before loading, ensure that containers and truck bins used to transfer unprocessed seed are clean and free from contaminating material.
- **Seed cleaning and processing**. Seed must be processed by a seed processor approved by the certifying authority. Seed processing removes unwanted inert material (e.g. stones, straw and chaff), weed seed, other crop seed and small, less vigorous crop seed. Processing equipment must be easily accessible for cleaning and inspection, and must be cleaned between lots.
- **Storing unprocessed seed at the processing plant.** Once delivered to the authorized seed processor, unprocessed seed is stored in clean, numbered storage containers. It is important to keep a permanent record of storage containers and their contents (i.e. identity of the unprocessed seed lot) at all times for audit and tracking purposes. The seed processor needs to register with the appointed authority and must fulfil the requirements specified by the seed norms and regulations.
- **Seed packaging and labelling.** Processed seed for certification must be packed in new sacks or containers and appropriately labelled according to national seed regulations. Each seed lot is assigned a specific number so that it can be easily identified and its origin traced throughout storage and transit.
- **Storage of processed seed.** A processed lot of certified seed must be held under bond on the seed processor's premises until the seed lot is officially released (i.e. when all analytical testing is completed and the official seed certificate is issued). No seed lot held under bond may be moved to another location or re-cleaned without permission from the seed certification authority.

Seed standards

In order to conform to seed certification standards, seeds must meet certain prescribed requirements (see also Table 4.3):

- Minimum percentage of pure seeds and maximum permissible limits for inert matter.
- Maximum permissible limits for other crop seeds.
- Maximum permissible limits for objectionable weed seeds and seeds infected by seed-borne diseases to ensure good seed health.
- Minimum percentage of germination.
- Maximum permissible limits for moisture content for the safe storage of seeds.

Issuing official labels

All packages containing certified seed have a certification label issued by the official seed certification body. The certification body is responsible for printing, distributing and attaching labels; it may choose to delegate this responsibility to an authorized private organization.

notes

To guarantee inviolability, one certification label is affixed on the packaging and a second label is placed inside. Sealing and labelling take place after seed treatment.

Label information includes:

- species and variety names;
- origin and class of seed;
- date of testing; and
- lot number – vital for maintaining traceability.

The **lot number** makes it possible to verify the history of the seed production and handling process, tracing the seed back to the production field. (Figure 4.9).

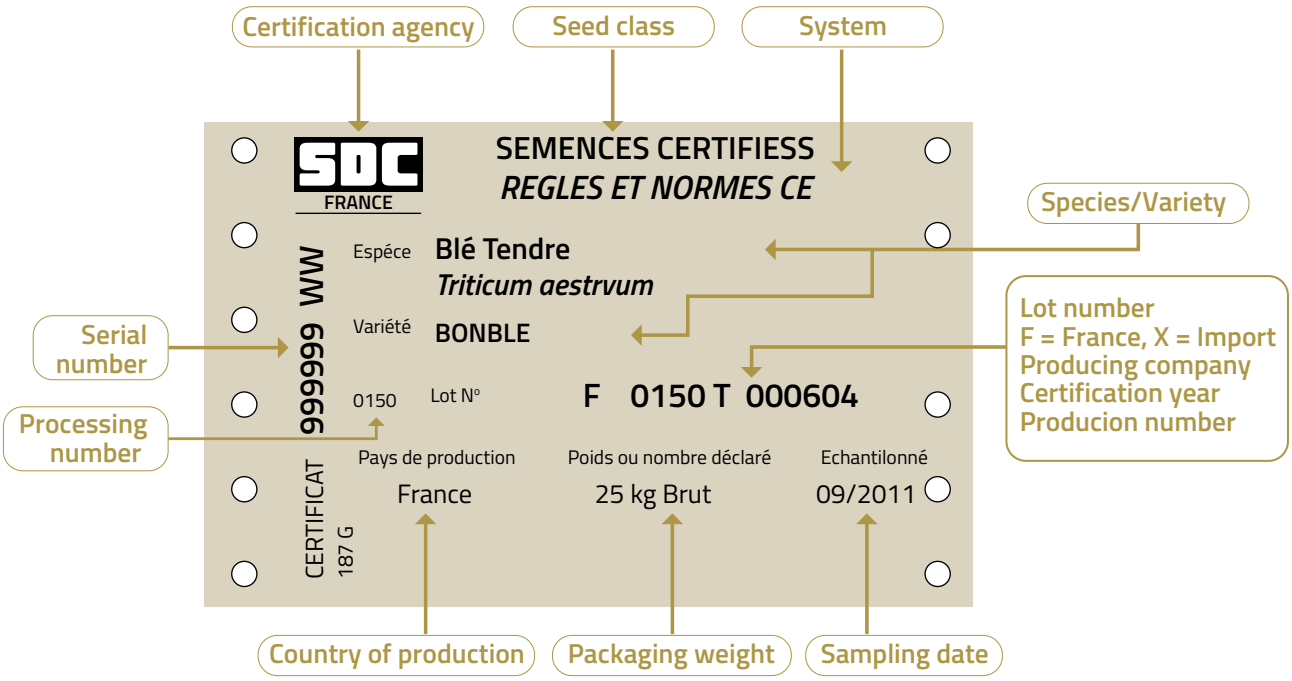
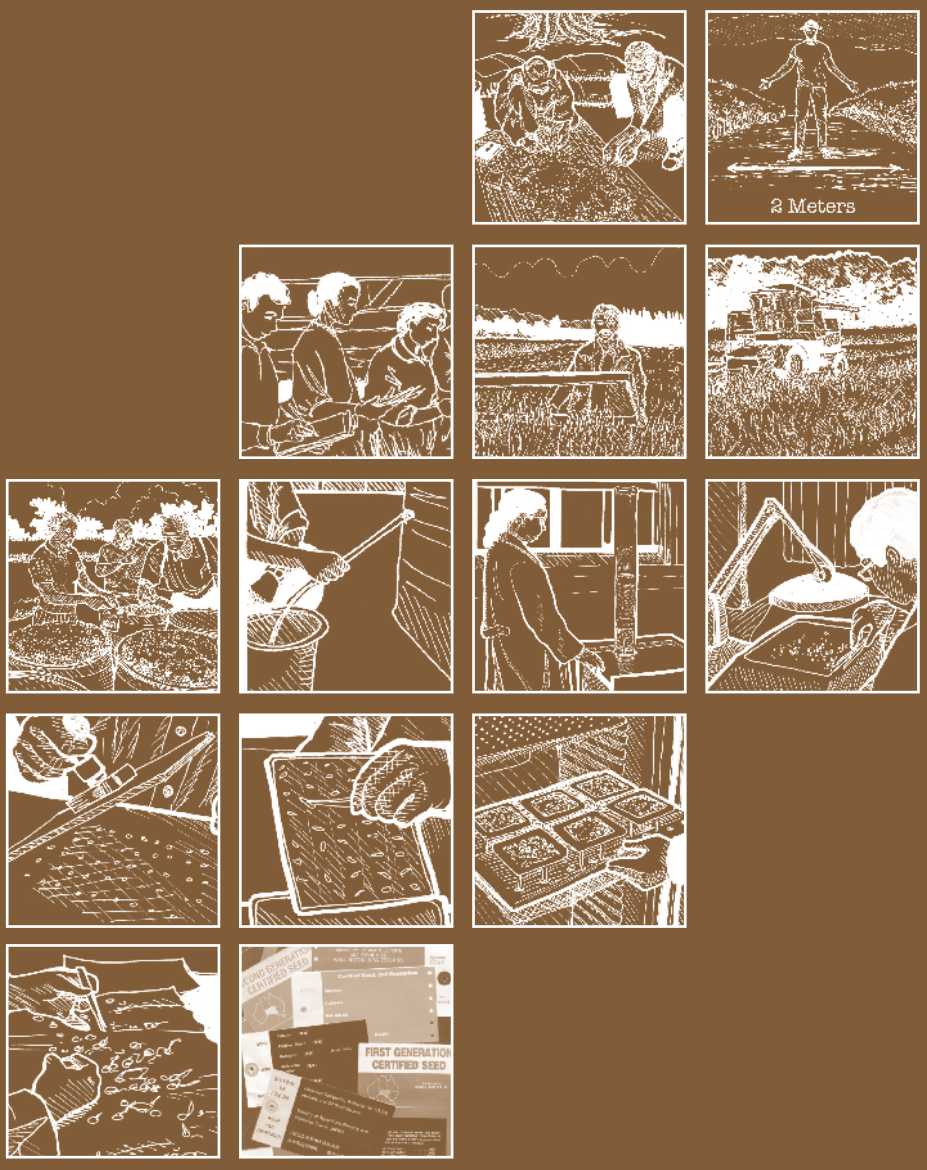


Figure 4.9 Seed certification label from France
(GNIS, France, available at http://www.gnis.fr/index/action/page/id/812/title/Tracabilite-et-qualite-au-service-du-consommateur)

EXERCISES AND DISCUSSION POINTS

1. What is the rationale of seed quality assurance?
2. Discuss the existing quality assurance/control systems.
3. What is the purpose of variety registration? What tests can be performed to register a variety?
4. What are the main requirements for seed certification in your country?

5 Seed certification processes and procedures



Seed certification processes and procedures

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notes

The **objective** of seed certification is to supply high quality seed to farmers and other growers. High quality seed is true to identity, high in purity and germination capacity, and free from certain pests and diseases.

It is important to maintain varietal purity and seed quality throughout the certification process, and the procedures in place aim to give continuity. There are **four important stages** in the certification process:

- Control seed in previous generations.
- Carry out field inspections during the multiplication process to ensure there is minimal contamination and that the variety is true to type.
- Test seed quality in laboratories.
- Grow samples in control plots of the known seed to ensure that the progeny conform to the characteristics of the variety

ELIGIBILITY FOR CERTIFICATION

To enrol a crop for certification, applicants must complete and submit the seed crop application form specifying the type of crop (annual or perennial) and the class of seed to be produced. Growers agree to abide by all rules and conditions governing certification and to pay all fees in a timely manner if applicable. In some developing countries where certification is in the public sector, seed producers do not pay fees – all costs are covered by the public budget or by the contracting company.

Details must be supplied in the **application form**, including:

- applicant's name;
- crop name/species;
- variety;
- category;
- crop location;
- previous cropping;
- field size; and
- seed lot used.

FIELD INSPECTORS

Seed certification inspectors constitute the **technical base** of the seed certification system. They should be well trained in the field of field inspection and must take periodic refresher training courses comprising theory and practical sessions. Field inspectors require the following **attributes**:

- Knowledge of and familiarity with varietal characteristics commonly used for national list purposes for the species they are to inspect.

notes

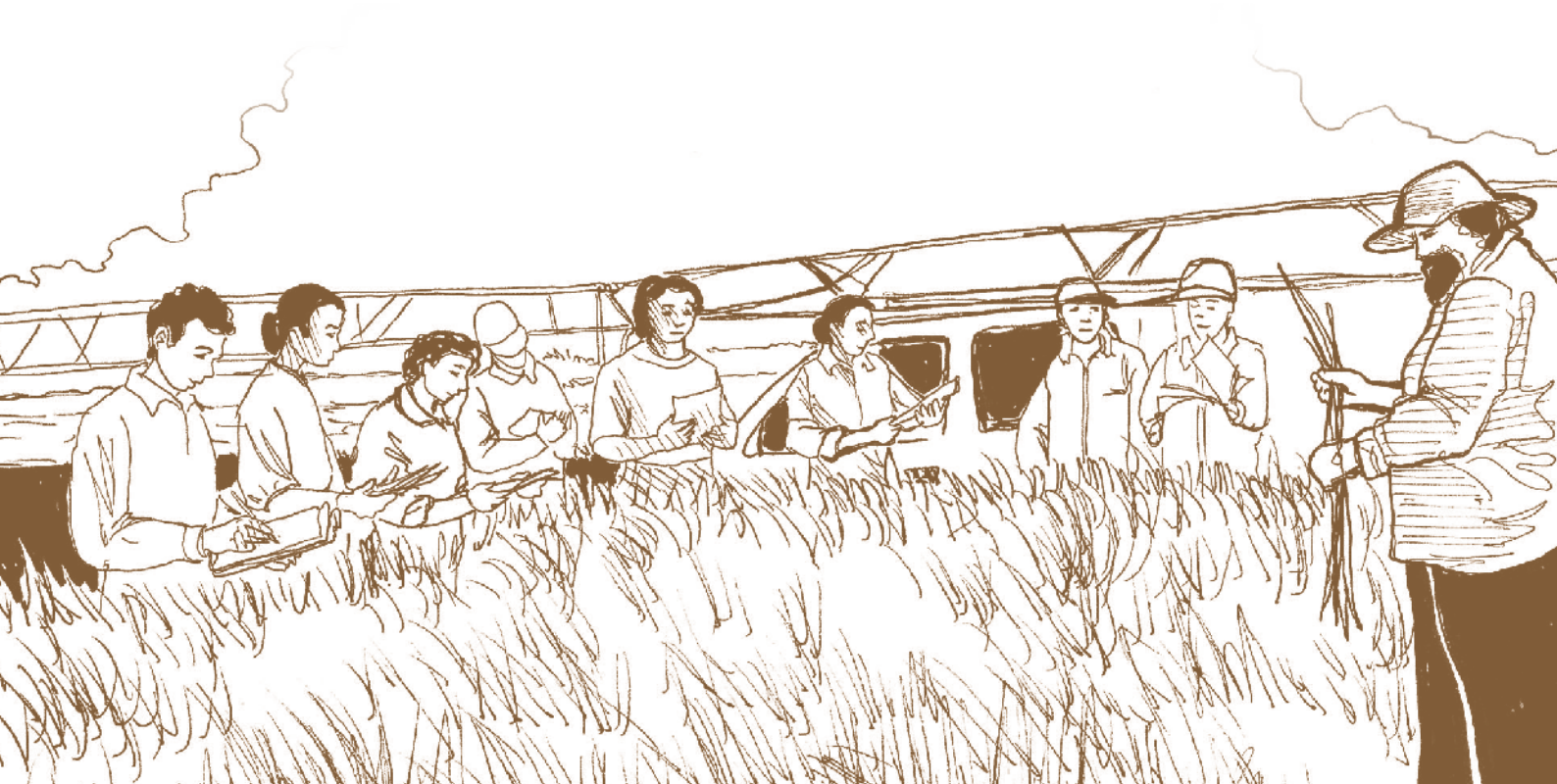
- Ability to record and observe morphological characteristics both systematically and accurately.
- Ability to use a botanical key to identify varieties.
- Ability to detect, identify and quantify varietal impurities and atypical plants at the growth stage at which field inspections would normally be carried out.
- Awareness of the principles of seed certification and the importance of field inspections as a component of a comprehensive certification system.
- Detailed knowledge of the procedures required to carry out a field inspection.
- Awareness of the standards required by crops entered for seed production.

Field inspectors are provided with all the necessary material by the certifying authority:

- A card/report form for each field inspection to be filled in by the field inspector with details, including: variety name; parent seed lot; location; field size; and category for which the crop is being inspected.
- Variety descriptions.
- A botanical key of varieties likely to be encountered during field inspection.
- Information on health and safety issues, for example:
  - lone working – another person must always know where you are in case of an accident); and
  - crop spraying – inspectors must not enter a field that has been recently sprayed.

In some cases, it might also be necessary to consider biosecurity measures (e.g. in the UK, these were introduced during the foot-and-mouth outbreak in 2000).

Figure 5.1 *Training of seed crop inspectors*



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CROP INSPECTION PROCEDURE

The most important functions of field inspection are to:
- check that the seed crop exhibits the characteristics of the variety which it claims to be (**varietal identity**); and
- ensure there are no circumstances that might be prejudicial to the quality of the seed to be harvested (**varietal purity**).

Objectives:
- Confirm the crop entry details and the correct location of the field.
- Authenticate the seed sown to produce the crop.
- Positively identify the variety as far as possible in the field.
- Collect information on the cropping history of the seed field and verify whether the seed field meets the prescribed land requirements.
- Detect and record any admixtures of other varieties of the same species.
- Assess noxious weed contamination.
- Check the isolation requirements.
- Assess the general condition of the crop including the amount of lodging and poor growth.
- Assess other species contamination.
- Check freedom from seed-borne diseases.

There must be at least one inspection when conditions are optimal for assessing varietal identity and purity, i.e. when varietal characteristics are most visible. Additional inspections may be necessary.

For wheat, barley and oats, it is normal practice to carry out a field inspection shortly after ear emergence. Re-inspections are done if remedial action is required (e.g. roguing after failing the first inspection). The inspector assesses the reason for failure, thoroughly checks the whole crop and - if necessary - may still fail the crop for a different reason.

METHOD OF INSPECTION

Authentication of seed sown

The inspector must check a label from the seed lot used to sow the crop. If the label is on the farm, the serial number should be noted on the inspection form. In particular, the inspector must verify that:
- the correct seed lot was sown in the stated field (or, where appropriate, seed lots);
- the details on the label match those provided by the farmer (variety name, seed lot reference number, category);
- the previous cropping details are correct; and
- the area details are correct.

notes

If the farmer cannot produce a label for the sown seed lot(s) or any other documents confirming purchase, the inspection may nevertheless continue. It is necessary to inform the certifying authority, and an alternative means of authentication may be accepted. Failure to confirm the authenticity of the seed lot will normally result in rejection of the crop.

General crop assessment

The inspector begins by walking round the outside of the crop to verify the isolation. The certifying authority establishes the isolation requirements, which may vary according to the species and the seed category.

In most countries, for self-pollinated crops (e.g. cereals), the minimum isolation distance is 2 m, but greater distances may be required depending on the crop and grade. A permanent hedge or fence is acceptable instead of a 2-m isolation gap. If the gap does not meet requirements, the inspector fails the crop – but nevertheless completes the inspection. The producer can then arrange for the farmer to cut the correct width and at a later date the crop can be re-inspected for isolation alone.

Example: Wheat field inspection

- Take ≥ 100 ears at random over a wide area of the crop and examine them to confirm the identity of the variety by checking against the varietal description.
- Roughly check the crop area.
- Assess the amount of lodging or tendency of the plants to fall over.
- Look for localized areas of contamination with other varieties, species or wild oats.
- Assess the number of wild oats per hectare.

On completion of the headland walk, the inspector should complete the isolation and lodging recommendations on the inspection card.

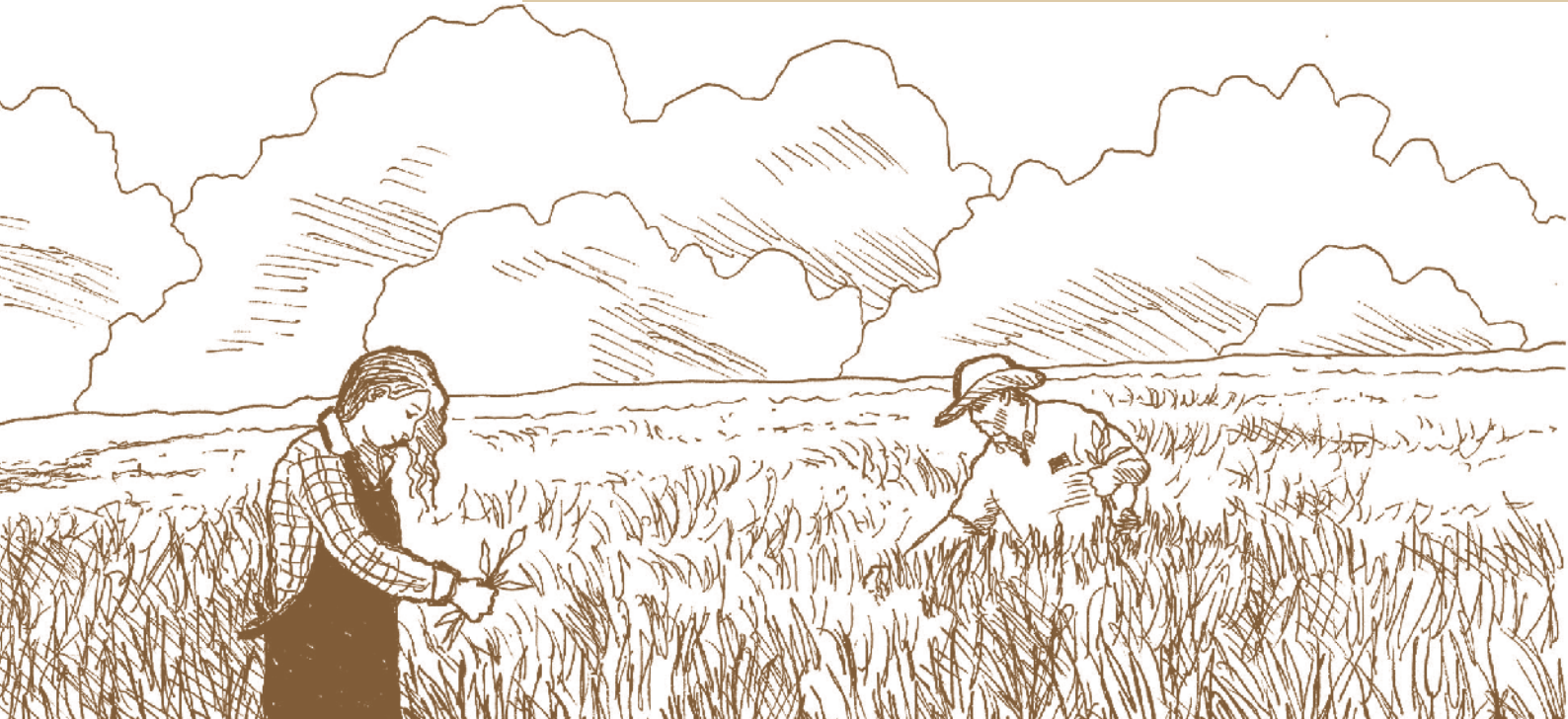

Figure 5.2 *Inspection of certified wheat field after ear emergence*

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Detailed crop assessment

Some assessments are too detailed to be applied to the crop as a whole – it is impossible to examine every spike/ear/plant in a crop. The inspector is therefore required to follow a sampling procedure to focus attention on small areas of the seed crop for detailed examination. These areas are referred to as "**quadrats**" and must meet the following criteria:

- Number and size depend on the specific minimum variety purity standards of the crop species produced as defined by the certifying authority.
- Location should be such that the whole field is effectively covered.
- Distribution should be random and widespread to represent the whole crop.
- No conscious selection of areas should take place (whether better or worse than average).
- Position should be in areas of standing crop, avoiding lodged areas.

Example: For wheat, barley, oats and triticale, each quadrat is a minimum of **1 m wide** and **10 m long**, taken at right angles to the direction of drilling.

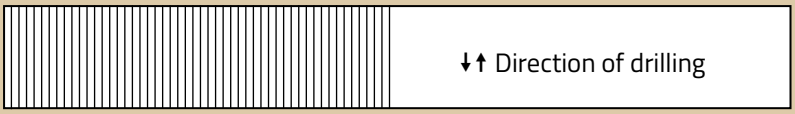
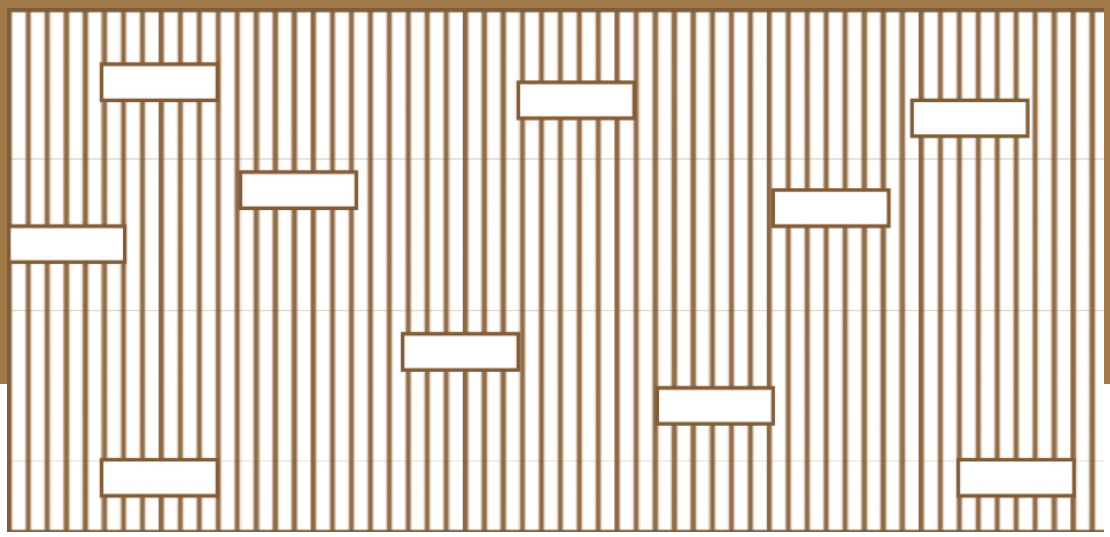


Figure 5.3 Distribution of quadrats throughout a crop



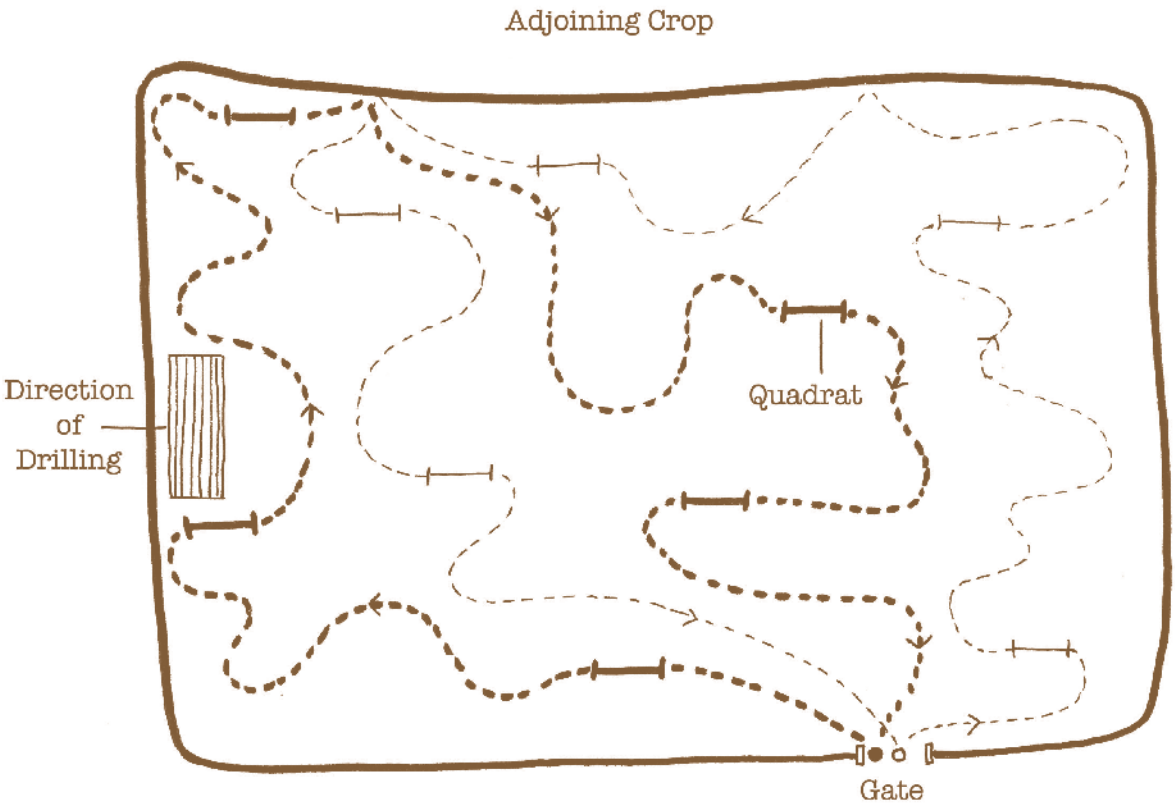


Figure 5.4 Suggested walking patterns for field inspection

Assessment procedure:

- Examine varietal purity (and species purity if required by the certifying authority) within the quadrat.
- Record any off-types together with a description of how they differ from the variety.
- Assess a smaller area (1 m or 1 m^2) – the spike/ear sample – within the quadrat, in order to assess the quadrat and crop population.
- Count all the ears in a 1-m row or 1-m^2 of plants.
- Examine the ear characters for all the plants in the 1-m row or 1 m^2.
- Detect and record all the varietal impurities in the quadrat.
- Each time a quadrat is completed, fill in the field inspection card under the appropriate column on the form (see Figure 5.5).

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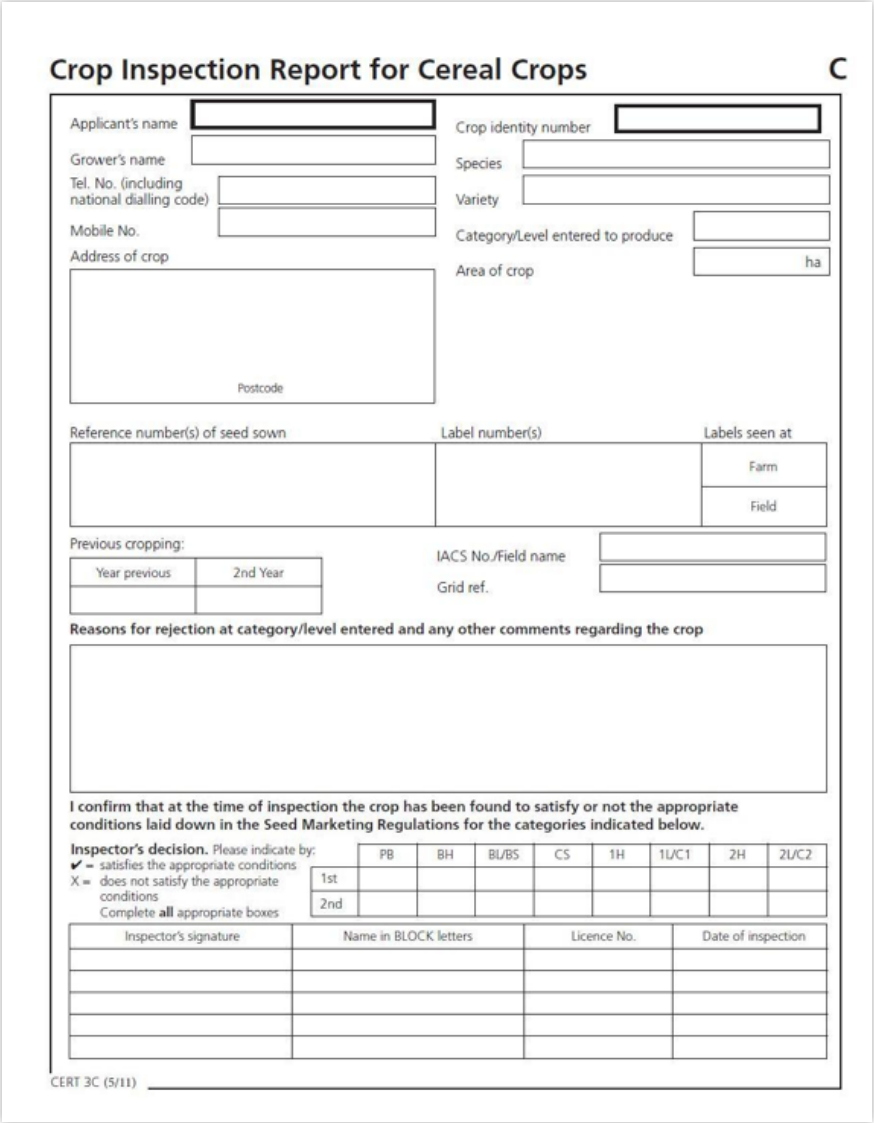


Crop Inspection Report for Cereal Crops C

Applicant's name

Grower's name

Tel. No. (including national dialling code)

Mobile No.

Address of crop

Postcode

Crop identity number

Species

Variety

Category/Level entered to produce

Area of crop ha

Reference number(s) of seed sown	Label number(s)	Labels seen at
		Farm
		Field

Previous cropping:

Year previous	2nd Year

IACS No./Field name

Grid ref.

Reasons for rejection at category/level entered and any other comments regarding the crop

I confirm that at the time of inspection the crop has been found to satisfy or not the appropriate conditions laid down in the Seed Marketing Regulations for the categories indicated below.

Inspector's decision. Please indicate by:
✔ = satisfies the appropriate conditions
X = does not satisfy the appropriate conditions
Complete **all** appropriate boxes

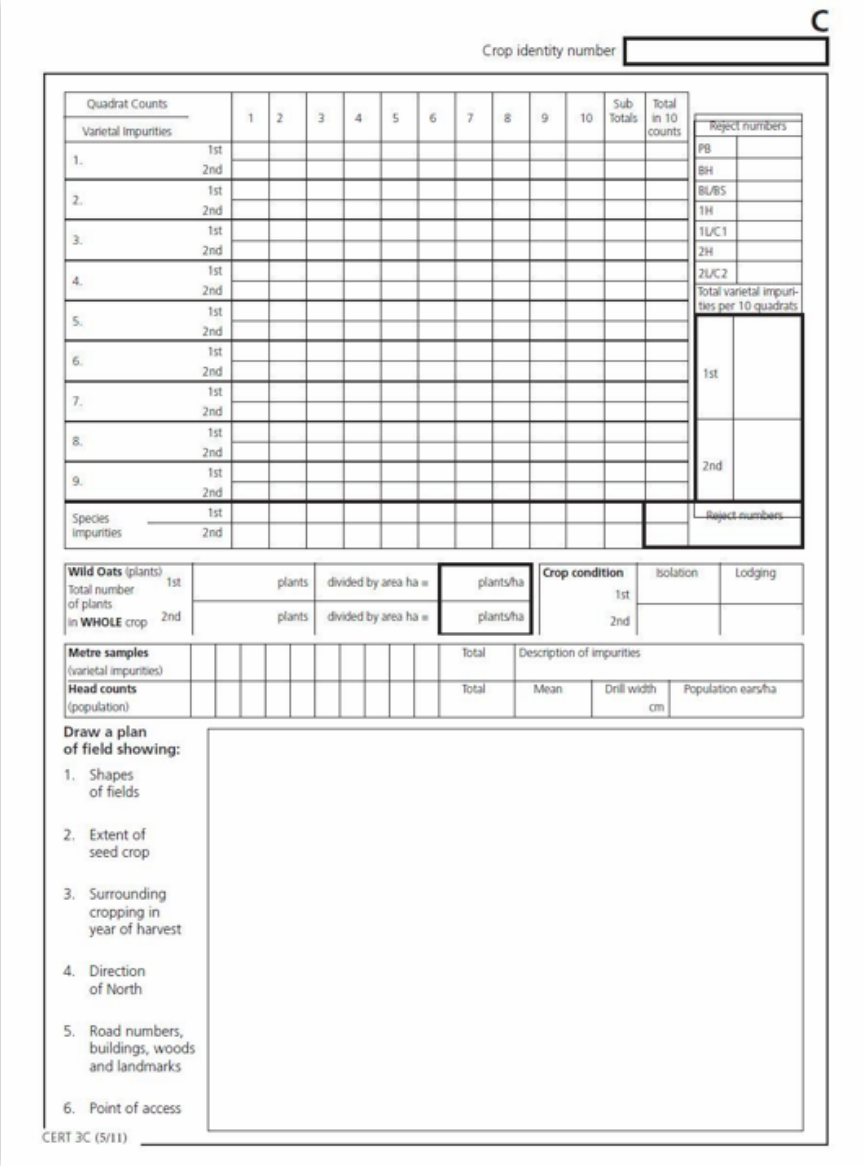
	PB	BH	BL/BS	CS	1H	1L/C1	2H	2L/C2
1st								
2nd								

Inspector's signature	Name in BLOCK letters	Licence No.	Date of inspection

CERT 3C (5/11)

Figure 5.5a *Front side of field inspection card, UK (https://www.gov.uk/government/publications/seed-crop-inspection-reports)*

notes



C

Crop identity number

Quadrat Counts / Varietal Impurities		1	2	3	4	5	6	7	8	9	10	Sub Totals	Total in 10 counts
1.	1st												
	2nd												
2.	1st												
	2nd												
3.	1st												
	2nd												
4.	1st												
	2nd												
5.	1st												
	2nd												
6.	1st												
	2nd												
7.	1st												
	2nd												
8.	1st												
	2nd												
9.	1st												
	2nd												
Species impurities	1st												
	2nd												

Reject numbers	
PB	
BH	
BL/BS	
1H	
1L/C1	
2H	
2L/C2	

Total varietal impurities per 10 quadrats

1st	
2nd	

Reject numbers

Wild Oats (plants) Total number of plants in **WHOLE** crop					
	1st	plants	divided by area ha =	plants/ha	
	2nd	plants	divided by area ha =	plants/ha	

Crop condition	Isolation	Lodging
1st		
2nd		

											Total	Description of impurities		
Metre samples (varietal impurities)														
Head counts (population)											Total	Mean	Drill width cm	Population ears/ha

Draw a plan of field showing:

1. Shapes of fields
2. Extent of seed crop
3. Surrounding cropping in year of harvest
4. Direction of North
5. Road numbers, buildings, woods and landmarks
6. Point of access

CERT 3C (5/11)

Figure 5.5b *Reverse side of field inspection card, UK (https://www.gov.uk/government/publications/seed-crop-inspection-reports)*

The certifying authority provides detailed instructions for crop assessment during inspection. Alternatively, refer to the OECD guidelines.

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Reject numbers

Instead of carrying out a calculation based on absolute values, inspectors can use reject numbers (values) to accept or reject a crop. Reject values allow for "errors" during inspection, including factors such as non-random distribution of off-types and different tillering rates between the plants in the crop and off-types. Reject values do not, however, compensate for poor inspection technique. Field inspectors are usually issued with a set of reject numbers against which the crop findings are compared (see below).

Completing the inspection report

At the end of the inspection, the inspector records the number of off-type plants observed and the number of plants per hectare. With reference to the reject number tables, the number counted is compared with the number permitted.

A recommendation can then be made to the certifying authority. It is the responsibility of the certifying authority to issue a result for each crop – usually not until all field inspections have been completed, but before harvest. The final result is based not only on the field inspection findings but also on the control plot results; it is important to recognize that the final result may not be that of the field inspection.

Figure 5.6 Frame (1-m^2) for ear counts and examination

notes

CONTROL PLOTS

Control plot tests monitor the identity and purity of a variety at various stages in the seed multiplication programme. The national designated authority can thus be sure that the quality of seed produced in seed certification schemes is of a satisfactory level. In most European countries, all samples of pre-basic and basic seed are sown in control plots for official post-control. However, the percentage of certified seed for official post-control varies from 5 to 10%, depending on the country.

What is varietal purity?

Varietal purity is traditionally based on visually distinguishable traits, although biochemical traits are also used for identification. Varietal purity can refer to:

- the relative phenotypic uniformity; or
- the proportion of plants or seeds within a population that conform to the official description of the variety.

For field crops, varietal purity standards range from 98% (certified status seed in some crops) to 99.9% (high generation seed), and are applied in field inspection, in control plots and in the laboratory.

The OECD, through its seed schemes, provides recognized methods to determine varietal purity in seed by means of control plots and field inspection.

Purpose of control plots

The control plot tests are designed to answer **two questions**:

1. Does the varietal identity conform to that stated on the label?
2. Does the sample conform to the published standards for varietal purity?

To answer **question 1**, it is necessary to make a visual comparison between the control plot (sown with a sample of seed representative of the seed lot and drawn by an official or authorised sampler) and a plot grown from an authenticated reference sample ("standard sample"). It is then possible to do a **"living description"**.

To answer **question 2**, it is necessary to identify off-type plants (i.e. plants that do not conform to the description and which therefore are not the variety) within the control plot so that their numbers can be related to the standards published in the OECD seed schemes.

For varietal identification and purity, control plots offer the **advantage** of a comparison between the official variety description and the living description at **various stages** during plant development. Control plots can be used to determine whether:

- the breeder's quality management system works and the seed is as pure as possible;

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- the grower has avoided contamination of the seed stock and consequent production;
- the seed field inspector has missed any visual off-types during inspection;
- the seed processor has contaminated the seed during handling; and
- seed certification procedures and practices, in general, are effective.

Control plot siting and management

When siting control plots, the certification agency must take into account **previous cropping** and ensure that the field is suitable. It is imperative that there be no risk of contamination from volunteer plants of the same or closely related species or of similar crop groups. Good **management practices** must be followed as described below.

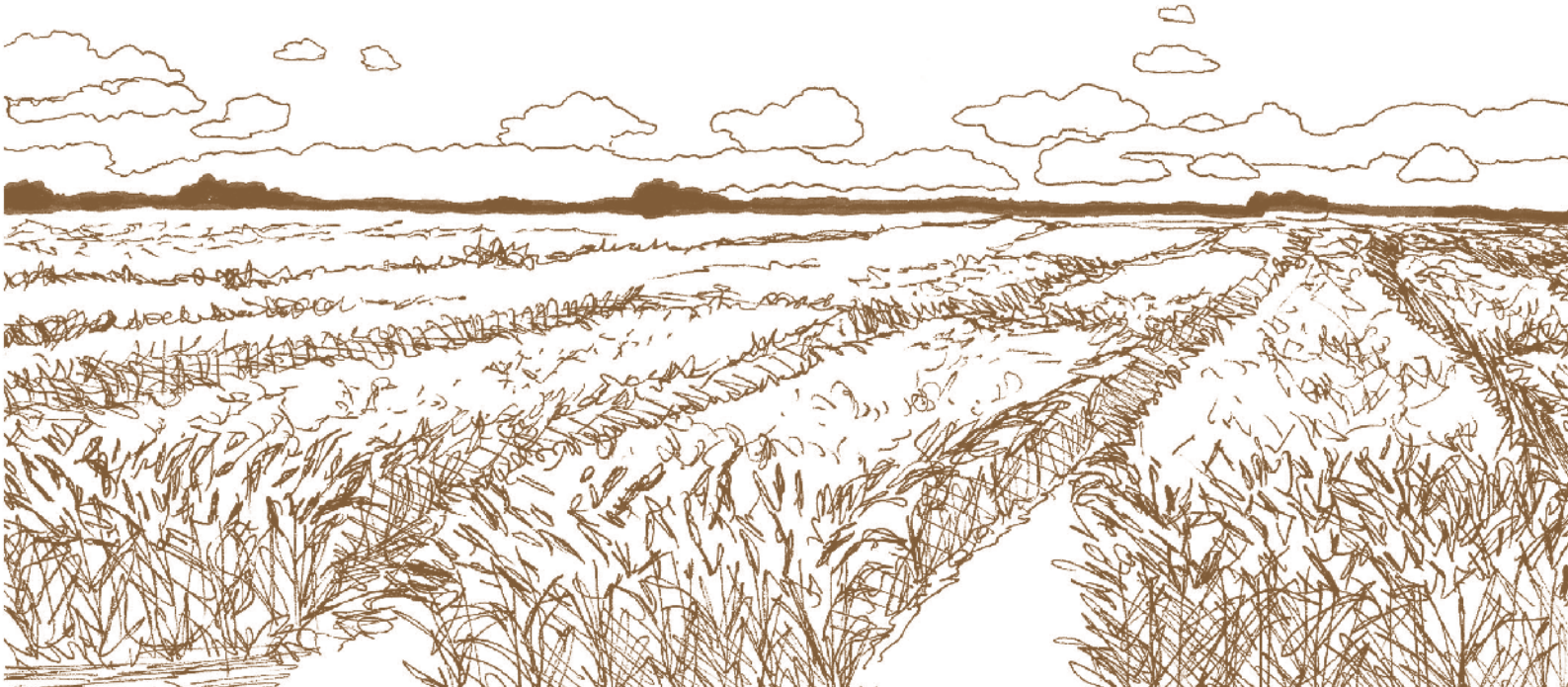
Husbandry:

- Maintain a good uniform seed bed to promote the rapid and uniform establishment of control plots.
- Meet requirements for control plots as for commercial crops – with the addition that it is important to maintain as far as possible variety differences and characteristics.
- Keep fertilizer levels at a minimum to avoid lodging, especially in cereal crops.
- Use herbicides and plant growth regulators with care – they could affect the morphology of the plant.

Layout:

- Arrange control plots to facilitate observation.
- Whenever possible, duplicate plots in another part of the field to obtain additional data.
- Design plots to enable appropriate statistical analysis of the results and decision-making based on conventional confidence limits.

Figure 5.7 Control plots for cereals



notes

Size:

- For cereals and similar species, adopt dimensions: length 10 m and width 1 m (i.e. 1/1 000 of a hectare). It is then easy to scale the results up to field size; moreover, it is the same size as a quadrat.
- Sow plots at commercial seed rates, and apply distances between rows as for seed production farms.
- Sow over a slightly larger area, and trim the plots back to 10 m after seedling emergence.

Recording:

- Begin recording once plants reach growth stages at which varietal characteristics have been recorded for DUS purposes - i.e. during vegetative growth stages, at flowering or at full maturity, depending on the species.
- Record control plots for species purity and for the presence of seed-borne diseases, as required.
- For the main characteristics to use in control plot tests, consult the OECD guidelines[3]. For many species, they are based on the UPOV Guidelines for the Conduct of Tests for Distinctness, Uniformity and Stability, divided into "primary" and "secondary" characteristics for OECD seed scheme purposes[4].

Use of control plots

Pre-control

Pre-control plots are used for variety verification of seed generations eligible for further multiplication: pre-basic and basic seed. Pre-control is an important component of a seed multiplication and certification programme.

When an early-generation seed lot is multiplied to produce a further generation of seed, control plot data are extremely valuable. They provide the national designated authority with information on identity and quality at the same time as - or even before - field inspection of the next seed crop. Varietal identity and varietal purity **issues are identified at an early stage**, before they become a major widespread problem.

3 Available at : http://www.oecd.org/tad/codeguidelinesforcontrolplottestandfieldinspectionofseedcrops.htm.

4 Available at http://www.upov.int/resource/en/dus_guidance.html

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Advantages for national designated authorities of pre-control plots

- Frequent observation of plants representing the seed lot.
- Extension of the observation period from seedling emergence to full maturity.
- Detailed examination of all plants in the control plot population if necessary.
- Comparison with the standard sample.
- Comparison with seed lots of the same variety in the same and previous generations.
- Standardized recording – one expert can make judgements on all control plots for all varieties and categories.
- Guarantee that all off-type plants observed in the control plot originated in the seed sample (provided the land is free from volunteers and clean machines are used for sowing).
- Use of an adverse pre-control plot test result to reject seed crops sown with the same seed lot.

Post-control

Post-control is normally applied to variety verification of certified seed that is not further multiplied. In the year that the plots are being grown, the certified seed has already been sold to farmers and planted for production. Consequently, test results will arrive too late for remedial action – unless the seed lot (or part of it) was not sold. It is called post-control, because the **result becomes available after the seed has been certified**.

Post-control tests are nevertheless **valuable**:

- They monitor how efficient the seed production process has been in maintaining varietal purity.
- They identify ways to improve the system.
- They allow the national designated authority to monitor quality and give assurance that minimum standards are upheld.

For certified seed that is to be further multiplied (e.g. C1 seed multiplied to produce C2 seed), one control plot can serve two functions:

- Post-control C1 seed lot from the last harvest.
- Pre-control C2 seed crop for the next harvest.

In the case of hybrid varieties, since the varietal identity and purity of the hybrid cannot be verified in the seed production field, it is necessary to assure production quality in post-control plots. The hybrid variety observed in post-control plots must be true to its varietal identity, and the plants must conform to the characteristics of the variety listed by the national designated authority at the time of registration.

notes

Reject numbers

Reject numbers are used to compare the number of off-type plants observed in a sample with a published standard, in order to evaluate the risks entailed in incorrect acceptance or rejection of the seed lot.

"Reject tables" are used, rather than straightforward application of the standard. Standards are converted into reject values using binomial probability distribution. A sample is considered to be non-conforming to the standard – hence rejected – if the number of off-type plants is equal to or greater than the reject number for a given population.

Example (see Table 5.1): For a varietal purity standard of 99.9% (i.e. an impurity threshold of 1 per 1 000), the rejection rule (i.e. 9 or more off-type plants out of a sample of 4 000 plants observed) limits the risk of incorrectly rejecting a seed lot to 5% (0 < 0.05).

Note that at this level of probability (95%), the system favours the seed producer, since the risk of an incorrect acceptance of a seed lot is higher than the risk of an incorrect rejection.

Table 5.1 is applicable only when plants are counted. If ears are counted then larger reject values are required and table 5.2 is used.

Table 5.1 Reject numbers for various sample sizes and varietal purity standards (α < 5%)

Sample size (plants)	Varietal purity standards		
	99.9%	99.7%	99.0%
	Reject number		
200	-	-	6
300	-	-	7
400	-	4	8
1 000	4	7	16
1 400	5	9	21
2 000	6	11	29
4 000	9	19	52

Note: "–" indicates that the sample size is too small for a valid test.

5

Table 5.2 Reject numbers for various sample sizes and varietal purity standards (α < 5%)

Sample size (ears)	Varietal purity standards		
	99.9%	99.7%	99.0%
	Reject number		
200	–	–	7
300	–	–	9
400	–	5	11
1 000	5	9	20
1 400	6	11	26
2 000	7	14	34
4 000	11	23	59
8 000	17	39	106

Note: "–" indicates that the sample size is too small for a valid test.

In order to use reject tables, it is necessary to determine the population of the control plots by counting the number of ears (plants) along a certain number of metre lengths in the rows, and multiplying the figure so that it represents the whole plot.

Example: Counting the ears in 5 separate metres in 5 different rows:
If there are 7 rows each 10 m long, the total is 70 m. Dividing the number of ears by 5 and multiplying by 70 will give a reasonable estimate of the number of ears in the whole plot. This figure can then be applied to the reject tables to establish the varietal purity level.

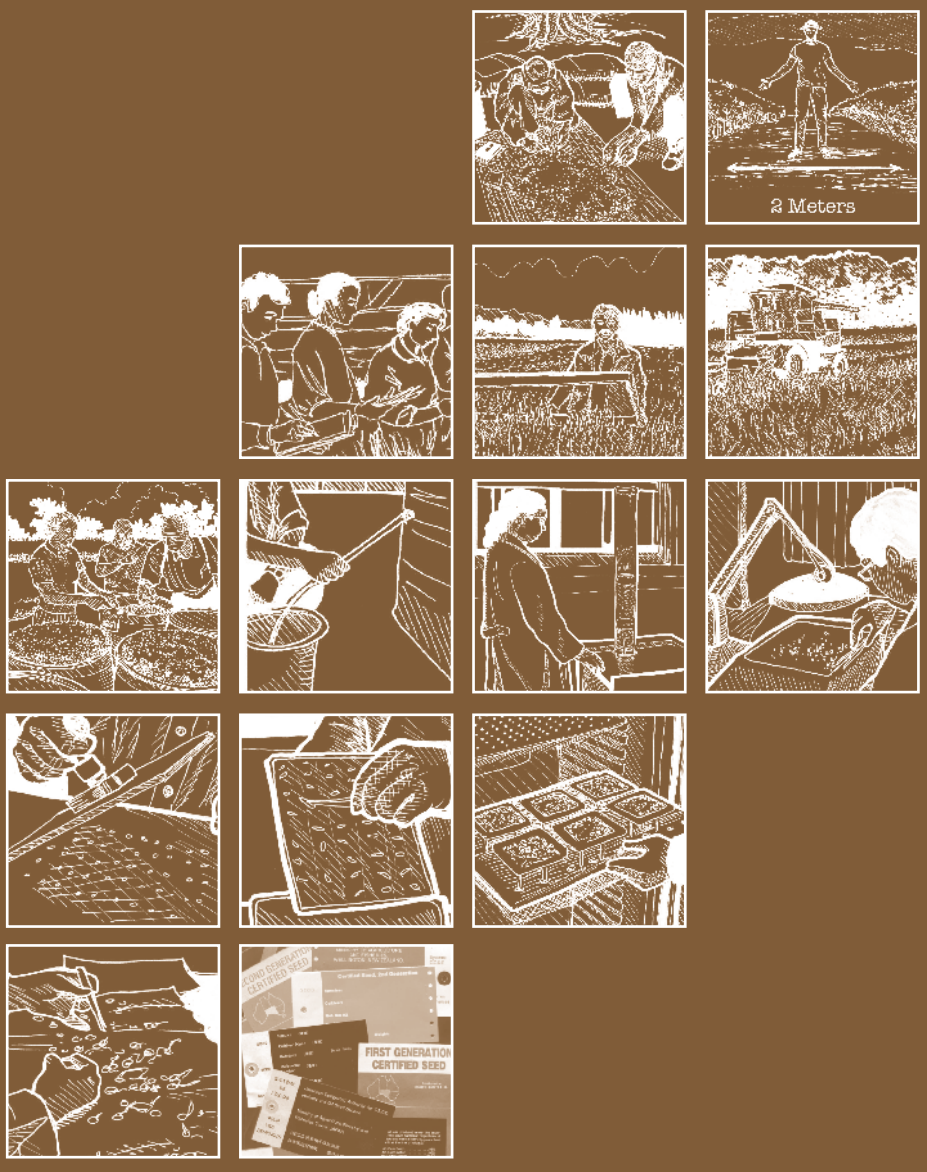
In summary, the national listing system, together with seed certification and labelling:

- ensures that seeds of one variety are sold under one name;
- assures that named varieties offered to growers are distinct and possess identifiable and lasting characters, including agronomic;
- guarantees that the seed purchased by a farmer meets minimum standards for varietal purity and seed quality.

EXERCISES AND DISCUSSION POINTS

1. What are the principal stages in the certification process?
2. What is the purpose of field inspection?
3. What is the main purpose of control plots?
4. What are the differences between pre- and post-control plots?

6 Management aspects and international considerations of seed certification



AND FISHERIES,
WELLINGTON, NEW ZEALAND.

Systeme
O.C.D.E

COND GENERATION
CERTIFIED SEED

Certified Seed, 2nd Generation

O.E.C.D.

Species:

Cultivar:

Ref. No: NZ

Weight:

O.E.C.D.

SEED

Species (種類)

Cultivar Name (品種)

Category (階級) Basic Seed

Reference Number (番号)

(種類)

SYSTÈME DE L'O.C.D.E. POUR LES SEMENCES

Japanese Designated Authority for O.E.C.D.
Herbage and Oil Seed Scheme
Ministry of Agriculture, Forestry and
Fisheries, Tokyo, JAPAN

O.E.C.D. 牧草種子登証制度
日本国指定機関 農林水産省

FIRST GENERATION
CERTIFIED SEED

Produced in
SOUTH AUSTRALIA

...d was produced under the super-
... the South Australian Department of
...ture and met the following guaranteed
...rds at the time of release:

Min. Pure Seed 99%
Min. Germination 90%
Max. Other Seeds 10/kg

O.E.C.D.
SEED
SCHEME

O.E.C.D.
Seed
Scheme

Pre-Basic Seed

Species:

Cultivar:

Ref. No: NZ

Region of Production:

Date:

Weight:

...ber of Generations by which the Seed Precedes Certified Seed First Generation:

Management aspects and international considerations of seed certification

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TYPES OF SEED QUALITY ASSURANCE AND CONTROL SYSTEMS

Depending on the level of state involvement, there are **three types of quality control system**:

- Certification (compulsory and voluntary)
- FAO's quality declared seed (QDS) system
- Truth in labelling

Certification system

Within a certification system, the certification body is either public (government) or independent. In **public certification**, seed quality control is the responsibility of public certification agencies and certification is usually **mandatory**. Alternatively, an **independent certification** service may be part of a compulsory certification system, but use of its services is usually **voluntary**. For example, most seed certification in the United States is carried out by state level independent agencies formed by farmer cooperatives or associations. Independent certification works well when farmers are aware of the meaning and value of certification.

Compulsory certification

In a compulsory system, certification is in the hands of **government agencies**. In addition, seed companies can obtain a licence to produce seed labelled as certified seed. In such cases, seed company technicians receive training from the seed authority and are then granted a licence to carry out seed certification activities. The state certification agency must carry out auditing inspections to ensure that the system is enforced, issuing penalties for seed producers who fail to meet the standards.

In the **EU (European Union)**, certification is compulsory for all species covered by EU Directives. Seed in all Member States must meet the same quality criteria to facilitate trade between states. Companies must arrange for government officials to visit seed production fields and check for varietal purity and quality attributes. The EU system also allows for certain activities (e.g. field inspection, seed sampling and seed testing) to be carried out under licensed/accredited arrangements, subject to official government supervision. Both public and private agencies are involved in seed certification for field crops. It is illegal to sell seed that has not been officially certified.

notes

Voluntary certification

In a voluntary certification system, seed producers can choose to contract the services of an **independent certification agency** in order to add value to their product.

Some commercial seed categories are certified on a voluntary basis by independent certifying agencies – for example, members of the Association of Official Seed Certifying Agencies (AOSCA) in the United States. AOSCA has certifying agencies in North and South America, Australia, New Zealand and South Africa. Many other countries (e.g. India and Bangladesh) also have voluntary systems.

Public certification system

Disadvantages:

- *Limited budget and human resources. Inability to mobilize resources can lead to delays and serious losses, because seed that has not been inspected cannot be marketed.*
- *Standards not adapted to farming conditions. Seed production and inspection bodies do not always have the technical capacity to ensure that standards are met.*
- *Limited quality control at the point of sale. Most resources are allocated to monitoring and supervising seed production and immediate post-harvest conditions.*
- *Centralization of certification activities. Seed production capacity in many countries is spread over a large area - decentralization of seed quality control would enable closer contact with seed producers and users and facilitate regulation enforcement.*

Advantages:

- *Seed of subsistence and important crops are inspected by the official certification agency.*
- *Official supervision is preferable for seed produced by grower cooperatives distributed over a wide area or by small-scale projects.*
- *Costs of certification are absorbed by the government.*

FAO quality declared seed and quality declared planting material systems

The concept of quality declared seed (QDS) was developed by FAO to provide guidelines for establishing a seed regulatory system that could be operated with limited resources (FAO, 2006). Government certification agencies and seed producers share responsibility: seed-producing farmers and seed companies are responsible for seed quality, while the government has a monitoring role (e.g. using extension staff for field inspection).

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Vegetatively propagated crops (e.g. yam, cassava and sweet potato) are not included in QDS, despite their important role in agricultural production and food security in many developing countries. Only potato and Musa species are well integrated in formal seed quality regulatory systems. In 2010, FAO developed and prepared a set of protocols and standards for the production of quality planting material of the most important vegetatively reproduced crops. Although quality declared planting material (QDPM) is not a certification system, it provides a practical tool for use by seed producers and technicians at community level, national seed services and the agricultural research community.

Truth in labelling

Minimum standards (purity, germination etc.) for truthfully labelled seed may be determined by the state regulatory agency or left to the discretion of the seed producer. Consumers monitor adherence to standards and report failure to meet standards, while regulatory agencies oversee the situation and carry out spot checks.

Enforcement is the responsibility of the courts or a regulatory agency. The regulatory agency is not responsible for the direct supervision of seed production – the **seed producer must ensure that the seed meets the minimum standards** described on the label.

Truthful labelling is a means for promoting the commerce of improved seed in areas where certification systems do not work well. It helps promote the modernization of small and micro seed enterprises operating at village level in developing countries by allowing them to set their own standards. However, the system is more appropriate for **advanced markets** with highly developed seed companies and educated and informed farmers.

Examples:

- **United States of America.** Truth in labelling allows companies to set their own quality standards and carry out their own tests. Companies are required to label seeds with accurate information on variety, germination, purity, inert matter etc.
- **India.** Privately produced seed may be sold as truthfully labelled. A rigorous mechanism for seed quality control is in place, with voluntary seed certification and compulsory labelling monitored by provincial level seed law enforcement agencies.

notes

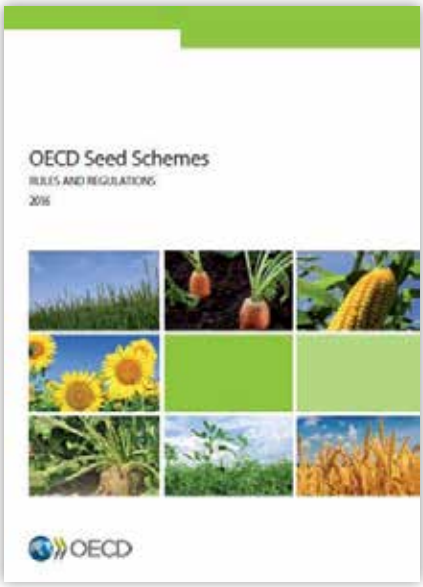
INTERNATIONAL SEED CERTIFICATION SCHEMES

OECD seed schemes

OECD seed schemes provide an international framework for the certification of seed to facilitate the growth in international trade of seed by reducing technical barriers. The schemes were established in 1958 to encourage the use of "quality-guaranteed" seed in participating countries. There are now 59 participating countries and as of January 2016 the scheme covers **seven groups of species**:

- Grasses and legumes
- Crucifers and other oil and fibre species
- Cereals
- Beets
- Subterranean clover and similar species
- Maize and sorghum
- Vegetables.

The OECD provides rules and guidelines for the whole certification process. The schemes are designed to verify varietal identity and establish varietal purity, and do not deal with other seed quality issues (e.g. physical and physiological seed quality). However, they are normally used in tandem with ISTA seed lot certificates, which carry the results of seed quality tests.



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OECD seed schemes are based on the following principles:

- Only varieties officially recognized as distinct and of acceptable value are included in the variety list. The names and breeder of varieties eligible for multiplication are listed.
- Three categories of seed are recognized: pre-basic, basic and certified.
- Certified seed must be directly related to authentic basic seed of the variety.
- Control plot tests are conducted in association with the field inspection to help confirm varietal identity and purity and to ascertain whether the schemes are operating satisfactorily.
- Variety descriptions are required and a reference sample of the variety must be used for a living description.
- There is a maximum seed lot size. The size of a seed lot depends on the size of the seed of the species involved.

The procedure for joining an OECD seed scheme entails the following steps:

- Sending of official letter to the OECD secretariat.
- Provision of basic documentation explaining seed certification procedures in the country.
- Fulfilment all OECD technical requirements (e.g. establishment of variety list, implementation of pre- and post-control tests for ≥ 3 years prior to application).
- Payment of all fees related to the evaluation mission.
- Admittance or rejection on basis of evaluation report.
- Final approval (if admitted) by consensus at the OECD Seed Schemes Annual Meeting, the OECD Committee for Agriculture and the OECD Council.

OECD seed labels

Each generation is identified by the label colour:

White with a violet diagonal stripe – pre-basic

White – basic

Blue – certified C1

Red – certified C2

(OECD, 2013)

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AOSCA seed schemes

AOSCA was originally established in 1919 as the International Crop Improvement Association. Its membership includes seed certifying agencies across the United States, as well as agencies in Canada, Argentina, Brazil, Chile, Australia, New Zealand and South Africa.

AOSCA:

- sets out the minimum standards for seed purity and seed identity;
- cooperates with the OECD and international organizations involved in the development of standards, regulations, procedures, and policies to expedite movement of seed and encourage international commerce in improved varieties;
- has no concept of a seed lot size;
- recommends minimum standards for seed quality for the different classes of certified seed[5]; and
- recognizes four categories of seed: breeder, foundation, registered and certified seed.

AOSCA seed labels

- *White – foundation and breeder*
- *Purple – registered*
- *Light blue – certified*

(http://www.nrcs.usda.gov/Internet/FSE_PLANTMATERIALS/publications/idpmstn04265.pdf)

QDS and QDPM systems

The quality declared seed (QDS) system was introduced by FAO in 1993, and later revised and updated in 2006. The quality declared planting material (QDPM) system was developed in 2010. The systems are not as rigorous as the OECD schemes. They set standards for seeds and planting material in **countries in the early stages of seed industry development**. These systems are particularly useful when there are insufficient resources or lack of infrastructure to establish highly developed seed and planting material monitoring systems, such as seed certification. QDS and QDPM reconcile the continuing

5 *For more information, see www.aosca.org.*

notes

need to improve seed and planting material supply to farmers with the desire to reflect and accommodate the diversity of farming systems, particularly in challenging areas where highly organized seed systems do not function well. They are relatively open schemes, **flexible to the needs of farmers** while not compromising the basic standards of seed quality.

QDS and QDPM systems are of particular relevance for seed and planting material purchased for **emergency relief supplies**. They provide effective reference systems, especially in international seed movement.

They are useful for potential seed suppliers (e.g. farmers' groups and cooperatives, private farms and NGOs) requiring seed and planting material quality assurance. The systems are designed to optimize a country's existing seed quality control resources.

QDS and QDPM systems enable farmers and growers to have access to seed and planting material of a satisfactory standard. The systems recognize **three types of varieties**:

- Varieties developed through conventional breeding technologies.
- Local varieties evolved over time under particular agro-ecological conditions and adapted to local conditions ("land race" or "ecotype").
- Varieties developed through alternative plant breeding approaches (e.g. participatory plant breeding).

The QDS system is based on **four principles**:

- A list of eligible varieties for production as quality declared seed is established.
- Seed producers register with an appropriate national authority.
- National authority checks ≥ 10% of seed crops.
- National authority checks ≥ 10% of seed on sale as QDS.

ISTA Seed Analysis Certificates

ISTA's main activity is to provide methods and services for the testing of seed moving in international trade. ISTA developed and published the International Rules for Seed Testing used by seed analysts throughout the world.

The ISTA Rules are adopted worldwide to test seed sold in domestic markets. ISTA Seed Analysis Certificates - widely used in international seed trading - are issued on the basis of ISTA Rules. There are **two types of certificate**: orange International Seed Lot Certificate and blue International Seed Sample Certificate:

- **Orange** - results of a known sample taken from a known seed lot, providing the end user with a measure of the average quality of the seed lot.
- **Blue** - results of the sample only, establishing no link between the sample and the seed lot.

Blue International Seed Sample Certificate:
- Sampling is not the responsibility of an accredited laboratory.
- Testing only is the responsibility of the laboratory.
- Sample–lot relationship is not the responsibility of the laboratory.

ISTA Accreditation verifies whether a seed-testing laboratory is technically competent to carry out seed-testing procedures in accordance with the ISTA Rules. The ISTA Seed Testing Laboratory Accreditation Standard specifies the criteria that seed-testing laboratories must fulfil in order to obtain and maintain their status as an ISTA-accredited laboratory and their authorization to issue ISTA Certificates. The standard covers all steps from sampling through to issue of ISTA Certificates.

The **accreditation procedure** entails five steps:
1. ISTA membership.
2. Participation in the ISTA proficiency testing programme.
3. Establishment of a quality management system, appropriate to the laboratory's size and work range.
4. Implementation of an ISTA audit to document the competence of the laboratory, followed by accreditation by the ISTA Executive Committee.
5. Payment of fees. Accredited laboratories pay an annual fee for their status. The audit fee is payable every 3 years prior to the audit.

Institutional arrangements and support for seed certification

Institutional arrangements and funding are key issues in seed certification. Should certification be a free or subsidized service to improve seed quality? Should there be a scale of fees for each of the main services provided?

For the development and long-term sustainability of seed certification in developing countries, the government through its **ministry of agriculture** could take over full ownership of and responsibility for the certification process. Alternatively, the **private sector** could develop the seed certification system with the promotion of a constructive public–private partnership.

In **government-backed seed certification**, there are three basic approaches:
- **Government-controlled** - government inspectorate responsible for the inspection of all crops. Inspectors issue labels and tags and ensure that only certified seed is sold. Skilled temporary employees may carry out inspections, but the inspectorate must oversee their work to ensure correct practice.
- **Self-certification with regulation** - inspection carried out by farmers on behalf of the government. Farmers may take samples of their own crops for laboratory testing by private laboratories. Government inspectors license farmers to carry out these inspections. In addition, they check a proportion of the crops (about 10%) themselves to ensure quality standards are met.

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- **Independent certification** - inspection carried out by a third party. An independent body is licensed by the government to carry out inspections on its behalf. The licensed body must have the trust of both farmers and government, as there is no routine inspection by government inspectors to ensure quality standards.

In many developing countries, government control may seem the only viable option, because institutions may lack the tools to avoid conflicts of interest and moral hazards. Nevertheless, it is important to explore potential options in the private sector and build the capacity of selected entities taking into account relevant experiences and lessons learned from other countries in similar situations. Indeed, for reasons of sustainability, many countries combine self-regulation and independent certification. In any case, when deciding which approach(es) to adopt, it is necessary to consider carefully the following **challenges**:

- **Cost of certification.** Government-controlled systems, in particular, require a large number of staff to carry out field and laboratory work nationwide, incurring high costs. Self-certification schemes, therefore, markedly reduce costs for the government.
- **Willingness to pay for certification services**. Seed certification is a new idea in many developing countries and farmers may initially be reluctant to pay for certification services.
- **Establishment of trust.** For self-certification, it is first necessary to establish trust in the entities responsible for inspecting themselves. Moreover, there is the risk of corruption and self-interest, and it is not always easy to enforce the code of conduct and impose penalties for malpractice.
- **Conditions of private sector.** In many countries, private sector seed production may be absent or in the early developmental stage. There may be limited facilities available and a shortage of trained staff. It is necessary to consider carefully whether the private sector is ready to take on additional certification functions.

EXERCISES AND DISCUSSION POINTS

1. The seed certification agency exists only when certification is compulsory. True or false? Explain.
2. Explain the difference between compulsory and voluntary certification and truth in labelling.
3. What is truth in labelling? Give an example.
4. What is the main purpose of OECD seed schemes?
5. What are the objectives of the FAO quality declared seed system (QDS)? Under what circumstances is QDS more suitable to use?
6. What is the role of ISTA, and who can issue its certificates?

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Glossary

Abnormal seedlings - Seedlings that in a germination test show damages on critical structures of the embryo, with the likelihood that the capacity for continued development into a normal plant may not materialize. The critical structure(s) may be damaged, deformed, decayed, or reveal other defects.

Analytical purity - The percentage by weight of the seed that is of the required crop species. The impurities can include inert matter, weed seed, damaged seed and other crop seed.

Basic seed - The progeny of basic seed, produced by or under the responsibility of the breeder and intended for the production of certified seed.

Breeder - The person or organization developing new or improved groups of plants by selection, hybridization, and similar methods.

Certified seed - The progeny of basic seed, produced under contract with selected seed growers under the supervision of a seed enterprise (public or private).

Character - A trait, property, quality or attribute (morphological, physiological, anatomical, cytological or biochemical) that may be observed or quantified and that may serve to distinguish one taxon from another.

Characteristic - The possession of a distinctive character.

Commercial seed - Seed that is intended for crop production, but that has not been produced under a recognized certification scheme.

Composite sample - A sample obtained by combining and mixing all the primary samples taken from the seed lot for testing purposes.

Cultivar - An assemblage of plant that has been selected for a particular character or combination of characters and that is clearly distinct, uniform, and stable in these characters and that when propagated by appropriate means retains those characters (International Code of Nomenclature for Cultivated Crops, 2004, art 2.2

Dormancy - The condition in which a seed with a viable embryo fails to germinate in conditions conducive to plant growth.

Embryo - The generative part of the seed that will develop into a plant.

Endosperm - The nutritive tissue within a seed but external to the embryo on which the developing seedling can draw nutrients until it is able to photosynthesize on exposure to light.

Foundation seed - The progeny of breeder seed, used as planting stock for registered and certified seed in the AOSCA seed scheme. Genetic purity - The true-to-type nature of the seeds and whether they come from a distinct variety.

Germination - The emergence and development of the seedling to a stage at which the appearance of its essential structures indicates whether it can develop further into a satisfactory plant under favourable conditions in the field.

Germination capacity - An indication of the proportion of live seeds capable of producing normal seedlings.

Germination rate - The percentage of the pure seed with the ability to germinate and that can develop into normal seedlings under appropriate conditions of optimum moisture, temperature and light.

Growing media - A substrate that provides sufficient pore space for air and water, growth of the root system and contact with solutions (water) necessary for plant growth.

Inert matter - Seed units and all other matter and structures not defined by ISTA as pure seed or other seed, such as broken pieces of pure seed and crop seed species that are half or less their original size; soil particles, sand, stones, chaff, stems, leaves, flowers; and smut balls, ergots and nematode galls.

Isolation - The separation of the field of seed crop from the field of other crops in order to prevent mechanical or genetic contamination of the seed to be harvested. Isolation could be in the form of distance, time and physical barriers.

Maintenance - The product of the regeneration of a variety, either seed propagated or vegetatively propagated, which is representative of that variety and is sufficiently uniform.

Normal seedlings - Seedlings with potential to develop into satisfactory plants when grown in good quality soil and under favourable conditions of moisture, temperature and light.

Noxious weeds - A weed species defined by law as being noxious; usually highly objectionable when found in crop seed lots. Technically, it is a weed seed that is difficult to control by any known cultural means.

Off-type - A plant in a seed crop that deviates from the typical description of the cultivar.

Open-pollinated variety - A heterogeneous variety of a cross-pollinated crop that is allowed to inter-pollinate freely during seed production; in contrast to hybrid seed production representing controlled crosspollination.

Other seed - Seed units of any plant species other than that of pure seed.

Pre-basic seed - Seed material of any generation between the parental material (nucleus seed) and basic seed. It is produced by the breeder.

Primary sample - A portion taken from the seed lot in the warehouse in a single sampling action.

Pure seed - The species stated by the applicant, or that found to predominate in the test, and including all botanical varieties and cultivars of that species. The pure seed fraction comprises mature undamaged seeds of the species; and pieces of broken seeds that are more than half the original size.

Registered seed - A class of seed in a certified seed scheme that is produced from foundation seed and planted to produce certified seed in the AOSCA seed scheme.

Relative humidity - The ratio, expressed as a percentage, of the quantity of water vapour actually present in the air, to the greatest amount of vapour that could be present at that temperature.

Roguing - The process of removing rogues from the crop.

Sampling - The method by which a representative sample is taken from a seed lot to be sent to a laboratory for analysis.

Seed - The ripened ovule, consisting of an embryonic plant together with a store of food or other structure including the ovule, used by farmers as planting material.

Seed certification - A regulatory process designed to maintain and make available to farmers high quality seeds and propagating materials of superior crop varieties, grown and distributed to ensure genetic identity and genetic purity.

Seed certification agency - The competent authority – independent from the industry – responsible for implementing the certification scheme.

Seed equilibrium moisture content - The percentage of moisture in a seed at a particular temperature and relative humidity.

Seed health - The presence or absence of disease-causing organisms (e.g. fungi, bacteria and viruses) and animal pests (e.g. nematodes and insects).

Seed lot - An identifiable quantity of seed of one variety, of known origin and history, and recorded under a single reference number in a seed quality assurance scheme.

Seed pathology - The study of seed-borne diseases, including the infection mechanism; seed transmission; role of seed-borne inoculum in disease development; techniques for detection of seed-borne pathogens; seed certification standards; deterioration due to storage fungi, mycotoxins and mycotoxicoses; and control of seed-borne inoculum.

Seed producer - A natural or legal person whose activity is the production of seeds either by himself or under contract with seed growers.

Seed quality - A concept that expresses the extent to which a given seed lot meets the standards set for certain attributes determining the quality status of seeds.

Seed testing - An analysis of physical parameters and physiological qualities of a seed lot, based on a small representative sample.

Seed vigour - 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.

Seedling - A young plant as it emerges from the seed until it is established physically and physiologically as a completely independent plant.

Submitted sample - A sample sent to the testing laboratory. It may comprise the entire composite sample or a subsample obtained using one or more ISTA reduction methods.

Sub-sample - The portion of a sample obtained by reducing the sample using one of the sampling methods prescribed in ISTA regulations.

Varietal purity - The percentage by weight of pure seed that will produce plants that exhibit the characteristics of that specific crop variety.

Varietal purity test - Determination and verification of identity and purity of species and cultivar (e.g. morphological characteristics of the seed or seedling, chemical properties and cytological aspects).

Variety - Synonymous with the term "cultivar" as defined in the International Code of Nomenclature for Cultivated Plants, 1980, Art. 10: "The international term cultivar denotes an assemblage of cultivated plants which is clearly distinguishable by a group of characters (morphological, physiological, cytological, chemical or others) and which, when reproduced (sexually or asexually), retains its distinguishing characteristics."

Seed viability - The capability of the seed to germinate and produce a normal seedling. It indicates that a seed contains the structures and substances required to germinate under favourable conditions in the absence of dormancy.

Weed - An unwanted plant appearing in a cultivated crop.

Working sample - A sample obtained in the laboratory from the submitted sample using an appropriate reduction method and it is used in a test.

The Seeds Toolkit

Seeds are the vehicle for delivering the improvements in a crop to the farmer's field. They are therefore a critical input in agricultural production. Seeds are unique in that they must remain alive and healthy when they are used and they are also the input that farmers can produce by themselves.

These factors were borne in mind in preparing the Seed Toolkit that comprises the following six interrelated modules:

1. Development of Small-Scale Seed Enterprises. This provides a stepwise guide for the establishment of commercially viable seed enterprises in farmers' communities. It covers the critical steps from the business plan to the production of seeds for sale.

2. Seed Processing. This presents the underlying principles of seed processing, the equipment used and the overall best practices from reception through conditioning to final delivery to customers. This module focuses on the use of affordable small-scale equipment for seed processing and sowing that may also be fabricated locally.

3. Seed Quality Control. This assists seed practitioners and other stakeholders in meeting the set quality standards for seeds and in implementing procedures for certification. The topics covered include field inspections and seed conditioning, packaging and tagging, storage, sampling/testing, and distribution.

4. Seed Sector Regulatory Framework. This provides information on the elements of the regulations that govern the seed value chain – from variety registration through quality seed production to distribution and marketing. The materials covered include information about national seed policy, seed law and regulations, their definitions, purpose and interactions.

5. Seed Marketing. This presents the underlying principles for valuing and exchanging seeds. This module describes all the activities that are undertaken in getting seeds from the producers to the end-users or farmers. The reader is provided with guidance on how to conduct relevant research of the market for seeds, develop effective marketing strategies, articulate a marketing plan and manage the associated risks.

6. Seed Storage. It is estimated that 25–33 percent of the world grain crop, including seeds, is lost each year during storage. To avert this obvious drawback to food security and nutrition, this module provides the underlying principles for effective seed storage and the associated practices. The module provides guidance on the preservation of seeds under controlled environmental conditions to maximize seed viability for the long periods that may be required from harvesting through processing to planting.

This module assists seed practitioners and other stakeholders in meeting the set quality standards for seeds and in implementing procedures for certification. The topics covered include field inspections and seed conditioning, packaging and tagging, storage, sampling/testing, and distribution.

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