Role of Seed Certification in Quality Assurance

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Abstract

High-quality seed is a "*sine qua non*" condition to achieve maximum crop productivity and good returns. The national seed sector, composed of the public and private players, plays a key role in making available high-quality seed in sufficient quantity by following its regulatory framework and adhering to the quality standards stipulated in it. The seed laws of different countries operate on the basic philosophy of encouraging breeding and variety development to meet the demand for quality seeds of many superior varieties of different crops suitable for various agro-ecologies and discourage unscrupulous practices in the seed supply system. However, the mechanism of applying the laws, operating procedures, classification, and quality standards is formulated keeping in view the seed scenario, availability of infrastructure, and trained human resources to handle the seed system. At the same time, given the fast-expanding global seed trade, it is desired for all participating countries to harmonize their national regulations with the international conventions and treaties that provide a regulatory framework to guide and oversee the interests of breeders, seed producers, and consumers globally. It is equally important that the said national regulatory frameworks facilitate farmers' access to seeds of the best quality of superior/

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improved varieties while promoting competitive seed markets with only the essential checks and lesser barriers to seed trade.

Keywords

Seed certification · Seed quality · Quality assurance system · International seed movement · AOSA · ISTA · OECD and Indian seed certification

1 Seed Quality Assurance

Seed quality assurance is one of the basic requirements for the development of an effective seed industry, based on the confidence that farmers place in the seed they acquire. The establishment of a quality assurance programme from field-level production to marketing/distribution provides an adequate environment for securing high-quality seeds in the marketplace.

Seed certification is the seed quality control system conducted by government-designated agencies, where seed standards are established in the national seed regulations, and checks and controls are put into place to ensure that the quality of seeds in the field and market comply with the standards. It is a process designed to secure, maintain, and make available seeds (and vegetatively propagating materials) of superior varieties so handled as to ensure desirable levels of seed quality.

Seed certification system helps in accomplishing the following objectives:

- Release, Registration, and Notification of superior varieties.
- A rapid increase in the production and availability of quality seed of newly released/registered varieties repeatedly, for a long time, on a large scale- in their original constitution.
- Maintenance of identity and purity of varieties.

The principal components of seed quality, which are central to the certification process, are:

- Variety identity/purity.
- Genetic purity.
- Physical/mechanical purity.
- Physiological status (viability, germination, vigour, and longevity/storability).
- Phytosanitary status (seed health).

A variety is defined in Article 1 of the International Convention for the Protection of New Varieties of Plants, 1961 as

> a plant grouping which can be defined by the expression of the characteristics resulting from a given genotype or a combination of genotypes; can be distinguished from any other plant grouping by the expression of at least one of the said characteristics; and which can be considered as a unit concerning its suitability for being propagated unchanged (UPOV website. https://www.upov.int/overview/en/variety.html).

While the variety identity refers to the official description of its characteristics, resulting from a given genotype or combination of genotypes, genetic purity refers to the proportion of plants or seeds within a population that conforms to the declared (official) description of the variety. Plants or seeds are considered to be varietal impurities (off-types) when they are different from the official description of the variety. Therefore, the genetic purity of a seed lot of a variety is evaluated by the trueness to the variety during various stages of seed production and handling/conditioning.

The physical quality, also known as physical or mechanical purity, is evaluated for the presence/absence of (a) any non-seed inert material such as soil, stones, and dust, (b) non-seed plant parts such as dried stems, leaves, or chaff, (c) seeds of other species (including weed seeds), and (d) ill-filled, undersized, poorly developed, mechanically damaged/injured seed.

The physiological quality refers to the viability, germination, vigour status, and longevity/storability of the seed after harvest and processing (conditioning) at the time of labelling, tagging, and sealing, because the physiological quality may be affected on account of because of poor harvesting, processing/conditioning, and storage conditions.

The phytosanitary quality refers to the absence of insect pests and pathogens in a seed lot that may affect crop performance including yields.

Most countries have developed seed certification regulations that suit their specific needs while in harmony with international norms, and have independent authorities for their implementation. While the system followed in the EU, UK, and other industrialized countries, following the basic OECD certification schemes, are somewhat similar, in many developing economies such as India, other SAARC nations, and the African continent, variety registration, and seed certification are not compulsory, but quality assurance of the seed producer by labelling is mandatory. The seed laws of the USA permit both voluntary variety registration and certification and a quality assurance by truth-in-labelling.

1.1 Seed Certification

Seed certification is the main instrument in the process of quality assurance. Seeds intended for domestic and international markets are controlled and inspected by official sources to guarantee consistent high quality for consumers. The purpose of seed certification is to make available quality seeds of superior/registered varieties, bred, and released for cultivation after a systematic process of evaluation. It ensures the varietal identity and genetic purity of the variety, physical purity, physiological

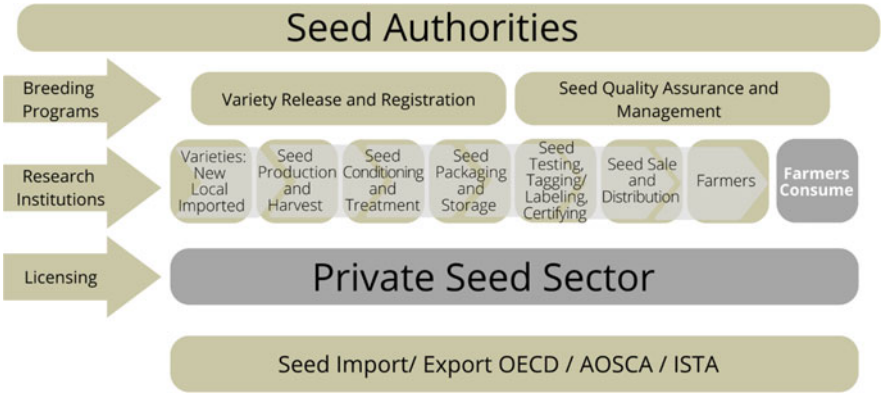


Fig. 1 Seed value chain

quality, and other quality parameters as per the standards set by the concerned authority under the Seed Laws. The seed certification schemes include minimum quality standards for different classes of seeds of specific crops; inspection processes in both the field (seed crop) and post-harvest stages; representative seed sampling procedures; seed testing, tagging, labelling, and sealing. The inspections carried out should ensure that there is no varietal contamination and that the variety is true to type. This is accomplished by maintaining safe isolation from possible contaminants, by both space [i.e. distance] and time, inspections of the seed crop at critical growth stages, and growing samples in pre- or post-control plots, as required, to verify and confirm that the progeny conforms to the characteristics of the said variety.

Figure 1 shows a broad outline of the activities that are essential in the seed quality assurance system from variety release and registration up to the distribution to farmers.

The actual system implemented by different countries may vary within this general framework. However, the following broad aspects are common:

- The Seed Act should include the general provisions for seed quality assurance, while the specific requirements and standards shall be included in the regulations so that changes may be easily updated. The Seed Act also defines the designation of the government authority responsible for the application of the legislation to the quality and market control.
- The scheme is valid only for registered/notified/released varieties, for which a well-defined system of testing the Distinctness, Uniformity, and Stability (DUS) and the Value for Cultivation and Use (VCU) must be in place.
- The scheme includes the Plant Variety Protection Law which should be based on the UPOV guidelines or an internationally accepted *sui generis* system of Plant Variety Protection (PVP). Its enforcement will encourage the breeding of new

varieties by public and private institutions, and safeguard the rights of the breeders as well as the farmers through the seed production/distribution systems.

- The activity of seed certification includes the filing of the formal application, verification of the seed source (generation class), field/seed crop inspection to verify conformity to the prescribed Field Standards, seed crop approval, harvest clearance, supervision during harvesting, seed lot identity allotment, seed processing/conditioning, seed sampling, seed testing to verify conformity to the prescribed Seed Standards, tagging, labelling, and sealing. When the entire activity of certification is concluded, based on the inspection reports and seed quality results, a seed certification certificate is issued for the entire seed lot with a validity period (concerning germination), and the individual seed containers constituting the seed lot are tagged, labelled, and sealed based on the regulations. The colours of the tag labels for certification are also specified in the regulations to distinguish the generations in the seed chain for the different classes of seed under different systems.

Under the seed law, the government seed authority is responsible for the process of seed certification, carrying out the official task for the purpose. For more efficient utilization of resources, the seed laws of most countries have provided for the "accreditation/authorization/licencing" of agencies or individuals to undertake certification activities, following the national framework for accreditation. In some of these countries, e.g. the USA, part or the entire seed certification scheme may be delegated to third parties, either public or private, to carry out any or all of the activities. Different countries worldwide are using various denominations for this activity, i.e. accreditation, authorization, designation, franchising, or licencing.

The process to conduct/perform seed certification requires skilled personnel with a level of understanding and knowledge of the steps involved. Therefore, there should be a continuous investment in human resource capacity building and exposure to emerging new knowledge.

1.1.1 Seed Certification System Operating in the USA, EU, and the UK

Seed certification is the process to ensure that the *genetic* identity and purity of a plant variety are maintained during multiplication from one generation to the next. The seed certification schemes rely on regulatory standards and procedures implemented at each step of the seed production process for different crops. Seeds put on the market with a label of "Certified seed", means that the seed complies with the quality standards prescribed for certification. Under the seed law, the government seed authority is responsible for the process of seed certification, meaning that they carry out the official task for seed certification.

There are different schemes for seed certification. In the USA, the initial recognition of certification and official certifying agencies was established under the US Federal Seed Act of 1939. In 1969, in the Federal Seed Act Regulations—Part 201 and under the Association of Official Seed Certification Agencies (AOSCA), the standards for land history (concerning the previous crop), field isolation from

designated contaminants, and varietal purity in the field and seed stages were incorporated.

The Federal Seed Act also established the seed certification standards and regulated the interstate shipment of agriculture and horticulture seeds. The seed companies are required to use truthful label provisions, with the quality information disclosed on the packages to place seeds in the market. The national certification standards under the AOSCA seed system are used by the seed industry as the base standard, meaning that the quality will fulfil the minimum stipulated standards. However, most seed companies, to establish a market reputation, try to reach for higher standards through their stringent and more elaborate internal quality management programmes.

All the states in the USA have seed laws that are based on truth-in-labelling to provide customers with the identity and quality of the seed put into the market. For interstate seed marketing, the Federal Seed Act must be followed, and the United States Department of Agriculture-Agricultural Marketing Services (USDA-AMS) is responsible for the enforcement of the seed standards. The voluntary certification scheme in the USA requires the application of the DUS criteria, and the seed is produced under a limited generation system that ensures the varietal identity, genetic purity, and the desired levels of quality. In the US seed system, voluntary registration and certification, together with truth-in-labelling, allow the seed companies to have unrestricted market access.

In Europe, variety registration is compulsory, and seeds may only be put on the market if it is certified (except in the case of vegetables). The variety must be listed in an official catalogue, together with completed DUS and VCU testing results. The certified seed put into the market needs to have a certain level of quality, such as germination and disease-free conditions. Europe follows the OECD seed schemes; for non-European countries that want to sell seed in the international market, they must have equivalence with the EU. This signifies that the exporting country must meet the same criteria for seed quality, characteristics, examination, identification, labelling, control, and packaging. Seed sampling, fastening, and labelling of containers can be carried out under the official supervision of the competent authorities (in third countries) based on the OECD rules. All seeds sold must be registered in the National Catalogue or the European Common Catalogue of Agricultural Plant Varieties, to confirm that the variety has passed identity and purity tests. Europe conducts post-control grow-out tests with small field plots to that allow certification inspectors to verify the varietal identity and genetic purity, varietal identity, and genetic purity status of the variety.

Depending on the national seed framework, there are different criteria for accepting varieties for certification. Some countries request that the eligible varieties, to be submitted for certification, should be released and registered in the national list; others accept varieties listed in non-official lists or varieties registered for protection in the List of Protected Varieties. The important condition is the availability of the description of the variety. In general, the certification schemes around the world require that the person who applies for seed certification needs to be registered under the national seed legislation. Usually, there is an application form to be completed

with basic information about the variety, such as denomination, botanical description, and characteristics. This is followed by the registration of the seed field which includes information on the location, field ownership, the size of the seed plot, and previous cropping history.

Varieties considered eligible for certification are those that have been approved by the AOSCA National Variety Board, the Plant Protection Office, the Official Seed Certifying Agency, and/or the OECD Seed Schemes. Varieties of foundation and breeder seed may be accepted for inspection if an adequate description is provided with the final certification, subject to later approval, when the breeder, owner, or agent of a variety provides the more information, such as a description of the morphological, physiological characteristics, and any other information that validate the identity of the variety.

Variety Release: Pre-condition for Certification

The variety release and registration is a process that is a mandatory requirement before seed certification. The national, regional, or international list of registered varieties provides the information on Distinctiveness, Uniformity, and Stability (DUS) of the variety, as well as its performance on Value for Cultivation and Use (VCU).

DUS testing is a system of determining whether a new variety is distinct from existing varieties within the same species (Distinctiveness), whether the characteristics are expressed uniformly in a population (Uniformity), and whether the characteristics do not change over the generations (Stability). This morphological description is mandatory for the grant of plant variety protection and is also used for the field inspection in the seed certification scheme to verify the genetic identity.

VCU testing, on the other hand, emphasizes the evaluation of the performance of a variety to be grown in pre-established agro-ecological conditions, dependent on the marketing zones decided by the breeder and/or seed enterprise, together with the use to be made of the harvested crops and the products produced from the variety. Some countries establish that the candidate variety must have superior cultivation value in comparison with the existing varieties published in the national list. The most important aspect of testing for VCU, usually, is the yield performance under a given set(s) of agro-ecological condition(s), but other characteristics must also be checked that may be different and superior from crop to crop, such as insect pest/disease resistance, nutritional value, commercial quality, adaptability, agronomic merits, etc.

The release and registration of a new variety with DUS and VCU tests provide the basis for quality assurance under the seed certification scheme, the registration in the Plant Variety Protection system, and the maintenance of the nucleus and breeder seed.

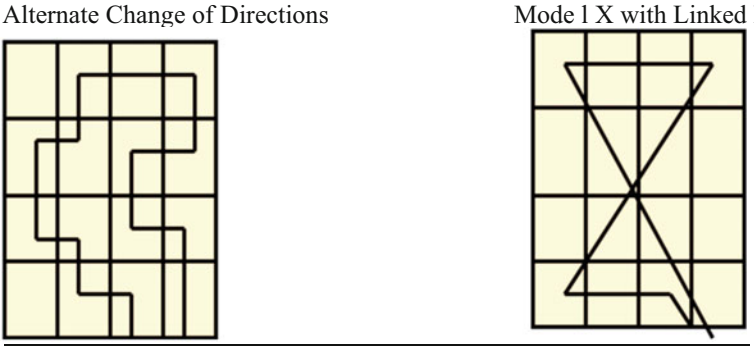
Seed Certification Phases

As mentioned above, the receipt and checking of the application is the first phase of seed certification, in which the general eligibility requirements are considered. The

second phase is the verification of the seed source for compliance with generation limits, by checking the tags, labels, containers, or purchase receipts/records.

The third phase is the conduct of field inspections during critical crop growth stages to ascertain that the expected/prescribed field standards are met and to make sure that factors which can cause irreversible damage to genetic purity or seed health are not present beyond the maximum permissible levels. The certification inspector takes into account various factors:

- Isolation by both space (distance) and time from all the possible source(s) to prevent undesirable/foreign pollen from contaminating the seed crop, by complying with the recommended isolation.
- Off-types: The observation that the field/seed crop has been cleared of contaminants including plants that do not conform to the description of the variety; weeds, and diseased plants). The seed grower must undertake roguing at specific stages of crop growth to remove all undesirable plants at the right stages. The certification personnel would identify and count the number of off-types to decide accepting or reject the seed crop for harvesting and conditioning.
- The number of inspections: Usually 3–4 inspections are recommended—preliminary inspection before sowing/ planting; pre-flowering at the emergence of the flowers/inflorescence; flowering, post-flowering, and pre-harvesting when the seed has reached physiological or harvest maturity.
- Pattern to follow: Certain patterns are used when inspecting seed fields for certification to get maximum coverage while walking a minimum distance, i.e. alternate change of directions and model X with linked ends as shown below.



Source AOSCA

To provide some flexibility to the inspector for moving within the seed crop, some other models as shown below are also available. Depending on the field size-dimensions, crop condition, spacing, population, etc., the inspector may opt for any of the models shown, ensuring that the same plant is not counted again.

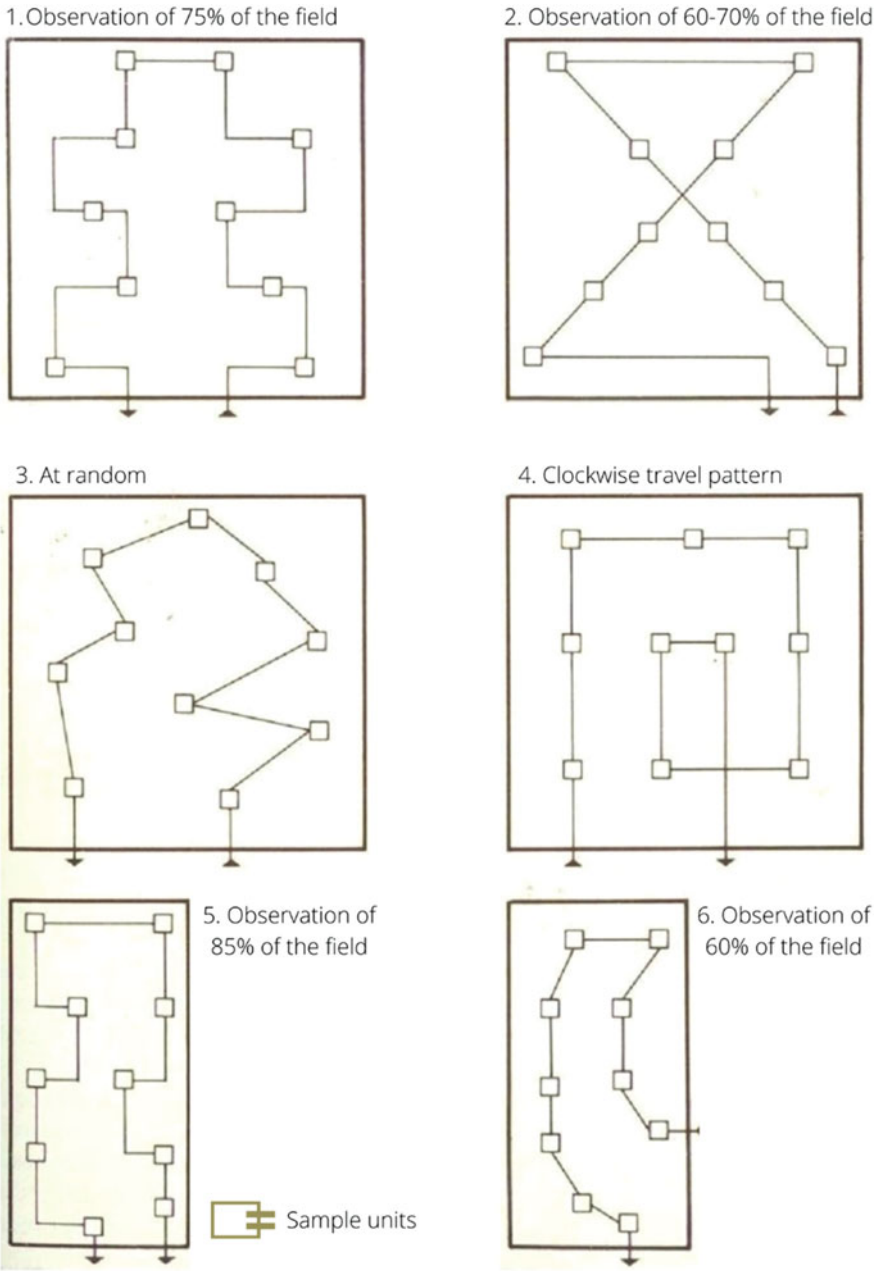


Table 1 Equivalence classes of seed

Generation	AOSCA (USA)	OECD (EUROPE)
1	Breeder	Breeder
2	–	Pre-basic
3	Foundation	Basic
4	Registered	Certified 1st
5	Certified	Certified 2nd

OECD seed scheme recommends field inspection following the quadrat method. In this sampling procedure, a detailed examination is made of small areas of the seed crop, called "quadrats". The number and size of these areas are decided on the minimum varietal purity standards of the specific crop. For crops like wheat, barley, and oats, at least 10 quadrats of 10 m^2 (1 m × 10 m) is recommended.

In the seed certification scheme, different classes of seed are designated, such as breeder seed, foundation or basic seed, registered seed, and certified seed.

Breeder seed is outside the ambit of the certification process and is produced under the direct and personal supervision of a qualified Breeder, and it is controlled by the originating breeding institution or person. It is expected to have 100% genetic purity.

Foundation seed is the seed produced from the breeder seed, the registered seed is the class of seed produced from the foundation, and the certified seed is the seed that is the progeny of the foundation, or registered seed.

In all classes, it is necessary to follow the procedures that ensure the maintenance of genetic purity and variety identity.

In addition, the number of generations that the variety may be multiplied will be limited by the breeder or owner of the variety and will not be more than two generations beyond the foundation seed class with some exceptions that, in case of emergency, may be established.

Depending on the seed certification schemes, there are different seed classes as shown in the table below. The class names may differ between the denomination in AOSCA classes of seed and the OECD classes, but the equivalence is the same (Table 1).

Field inspections are conducted by the seed certification agency or the accredited/designated institutions, either public and/or private. Usually, two to four inspections are conducted based on the established requirements for each crop.

Field standards include:

1. Isolation, i.e. minimum distance from other varieties of the same kind/species [other species in some crops] and the same crop not meeting the varietal purity requirements for certification.
2. Off-type, i.e. the plant that deviates in one or more characteristics/features from the one described originally for the variety under seed production/certification. Off-type plants and other varieties, exceeding the standards must be rogued out and removed from the field well before they contaminate the seed crop and prior to inspection.

Table 2 Purity standards for some field crops as per OECD certification schemes

	Genetic purity (% minimum) for different seed Classes		
Crops	Basic	Certified CS1	Certified CS2
Barley, wheat, paddy, oats	99.9	99.7	99.0
Groundnut	99.7	98.0	97.0
Sunflower varieties	99.7	99.0	98.0

Under the Common Rules of OECD, Post-control is obligatory for all samples of Certified Seed, when the lot is to be used for the production of further seed generation. In this case the post-control is also a pre-control of the following generation

3. Pollen shedders (in male-sterile female parents), shedding tassels (in the female parent of maize hybrids), selfed bolls (in the female parent of cotton hybrids), selfed flowers, ears, heads, fruits (in the female parent of rice, pearl millet, sorghum, castor, sunflower, and vegetables).
4. Weed plants and other crop plants, seeds of which are likely to get mixed up with the crop seed and are difficult to remove during the post-harvest conditioning process. Some of them are designated as "Objectionable/Noxious" for certification purposes. They should be rogued out and removed from the seed field before setting seed and the inspection of the seed crop.
5. Plants affected by designated diseases, if any, for the crop under inspection.

Post-control grow-out testing is a robust mechanism for verifying/confirming the varietal purity of the seed produced under certification process most conclusively. It is mandatory for the pre-basic seed of pure line varieties, and also for the basic seed of the parental lines of hybrids, though the post-control of breeder seed is the breeder's responsibility and not that of the certification agency. The permissible number of off-types varies with the seed classes (Table 2).

Sampling: After harvest, the seed should be kept in a single lot to obtain a sample that represents the lot with a unique number assigned to the crop variety and class of seed. The entire seed lot must be made homogenous and processed/conditioned before the sample is drawn, which is then sent to the laboratory to conduct the tests for seed quality. The sample must be drawn properly, following the prescribed procedures for sampling so that it truly represents the seed lot, whether the seed is in small containers, bags, or bulk. The Composite Sample obtained by pooling together all the Primary Samples is divided into two samples, one for sending to the lab as Submitted sample and the other as Guard/Reference sample to be retained by the Sampler.

Usually, before the seed certification agency takes a sample, the seed must be packaged in containers with the seed company's identification. Also, the seed company is authorized for taking the samples and sending them to the official or accredited seed testing laboratory to check the quality. There are also the maximum seed lot sizes and the minimum Submitted and Working sample sizes established by indicated in the ISTA Rules that should be followed. Usually, for species with seed size similar to that of wheat, paddy, and barley, one lot is not more than 30,000 kg; a

lot of smaller seed-sized crops such as mustard or Finger Millet (*Eleusine coracana*) will not exceed 10,000 kg, whereas, in maize and other crops having bigger seed size, a lot will be as large as up to 40,000 kg.

Seed testing includes physical purity, germination, moisture content, seed health, and any other quality test that is required by the authority or the producing agency (see chapter "Testing Seed for Quality"). If the results of the laboratory comply with the seed certification standards, the authorized body or the seed certification agency can issue one certificate for the entire seed lot, and certification tags for all the containers in the lot.

All the containers of seed to be sold as certified must be tagged and must be securely sealed in such a manner that they cannot be removed without tampering damage. The certification tag content includes the crop/variety name, class, lot number, name or number of the applicant, net weight, percent pure seed (purity), inert matter, other crop seeds, weed seeds, germination, MC, and test date. The colour of the tag/label is based on the class of seed: white for foundation seed, purple for registered, and blue for certified seed.

1.1.2 Accreditation for Seed Certification System

Under the seed law, the government seed authority is responsible for the process of seed certification. Due to the limitation of resources to comply with these activities, the seed laws of some countries have included the possibility of accreditation/authorization/licencing of the activities of certification by accredited persons or entities following the national regulations. Accreditation is defined as "the formal recognition of technical competence to carry out official specific tasks". An accredited person or entity is defined as "a public or private body empowered by the Minister to undertake quality control and certification activities". Accreditation allows seed quality control to be performed by individuals, third parties, seed laboratories, or seed entities that shall be allowed to inspect fields, take samples, test seeds, and issue labels.

There are different examples of accreditation in the seed sector, such as the Organization for Economic Cooperation and Development (OECD) Seed Schemes, and the International Seed Testing Association (ISTA) seed testing accreditation programme. The National Seed Health System (NSHS) and the Accredited Seed Laboratories (ASL), in the USA, are also successful examples. The Economic Community of West African States (ECOWAS) Seed Regulation, the South African Seedsmen Association (SANSOR), and the Zambia Seed Certification and Control Institute (ZSCCI) are examples of accreditation at regional and national levels.

1. The OECD seed accreditation is established under the Guidelines for the Authorization of some certification activities under the OECD Seed Schemes (OECD Paris 2012). The OECD accreditation scheme allows third parties to perform certain activities necessary for seed certification on behalf of the Designated Authority. OECD has authorized accreditation for field inspection, sampling (including labelling and sealing), and testing activities.
   - The inspectors, having the required qualifications and expertise, are authorized to inspect certified seeds to carry out the tasks to take care of all the steps involved in certification. The level of check/supervision by the official authority is established at the level of at least 5% of the production, and the designated authority needs to fix penalties for the infringement of the rules.
   - The authorized seed samplers shall have technical qualifications through training courses; use approved sampling methods and equipment; be independent persons; be persons employed by a neutral or legal entity that does not involve in seed activities; or be persons employed by seed companies. The sampler employed with a seed company can take samples only on seed lots produced on behalf of his employer. The Designated Authority will conduct auditing, monitoring, and checking of random sampling in at least a proportion of 5% of the cases.
   - The authorized laboratories shall maintain the conditions required, have staff with necessary qualifications and training; be an independent laboratory; or be a laboratory belonging to a seed company. Official supervision shall be conducted by the Designated Authority through auditing, monitoring, and check analysis in at least a proportion of 5% of the samples (Organization for Economic Cooperation and Development, OECD, website 2020).
2. The ISTA accreditation programme includes the member laboratories that have proven their technical competence in carrying out seed testing following the ISTA Rules and operating an effective quality management system. To be eligible for accreditation an ISTA member laboratory needs to participate in the proficiency tests and establish a quality management system developing a quality manual, after which an audit is conducted by ISTA experts who evaluate and make the decision for the accreditation. The ISTA accreditation is a formal recognition of the technical competence of a seed lab to carry out specific tasks, for which the accredited labs need to clear periodic evaluation of their proficiency. These laboratories are authorized to issue international Seed Analysis Certificates such as Orange Certificates (for details, please see International Seed Testing Association, ISTA website 2021).
3. In seed health management, there is a well-established system for accreditation in the USA. The National Seed Health System (NSHS) is a USDA-APHIS (USDA-Animal Plant Health Inspection Service) programme administered by Iowa State University's Seed Science Center to accredit both private and public entities to perform certain activities needed to issue the federal phyto-sanitary certificates for the international movement of seed.

The activities for which entities can obtain NSHS accreditation include:

- Laboratory seed health testing: A laboratory-based programme to test for plant pathogens in seeds. A comprehensive list of approved NSHS Seed Health Testing labs and methods is published.
- Phyto-sanitary field inspection: Inspection is conducted to detect the diseased plants grown to produce seed in the field, nursery, or greenhouse.
- Seed sampling: Sampling of seeds is done as per the recommended procedure to be submitted to the laboratory for seed health testing.
- Visual inspection: visual inspection of seed shipments at exporter's facility, before issuing phyto-sanitary certificates.

There are two Reference Manuals to support NSHS. Manual A deals with the administration, procedures, and policies of the NSHS; and Manual B with the Seed Health Testing and Phytosanitary Field Inspection Methods (Iowa State University, Seed Science Center Website 2021).

Another example of accreditation is the programme for seed labs testing for purity and germination in the USA. This covers species contained in the Association of Official Seed Analysts (AOSA) Rules for seed testing and/or the Federal Seed Act. The eligible laboratories are members of the AOSA and the Society of Commercial Seed Technologists (SCST). These laboratories are required to develop a management system, participate in proficiency testing, and issue seed analysis reports/certificates.

4. One of the Regional Examples is the Technical Agreement of the Economic Community of West African States (ECOWAS) under the Regulation 4/05/2008 for the Harmonization of Rules on Quality Control, Certification and Marketing of Plant Seeds and Seedlings in the ECOWAS Region, Article 13: "*Seed quality control in each Member State shall be carried out by the official quality control and certification authority or any other accredited private body, following the provisions of the regulations*"

Similarly, in South Africa since 1989, SANSOR (South African Seedsmen Association), has been the designated authority (DA) to manage and execute all functions regarding seed certification on behalf of the government. This includes not only the National Seed Certification Scheme but also the international seed schemes such as AOSCA, OECD, and SADC (Southern African Development Community Seed Certification System).

In the case of Zambia, the Plant Variety and Seeds Act has a provision "for licencing seed companies as certifying agencies, and for approval of any person as an official seed inspector, sampler or tester for a certifying agency". Seed Control and Certification Institute (SCCI), Zambia's seed authority may licence any seed company or institution as a certifying agency for inspecting, sampling, or testing seed. According to the African Seed Access Index (TASAI), which monitors indicators that are essential to seed sector development at the national level, Zambia has 118 licenced seed inspectors, including 83 private seed inspectors (Mabaya, Miti, Nwale and Mugoya, Zambia Brief 2017, The African Seed Access Index (TASAI) September 2017). Zambia's Plant Variety and Seeds Act, Chapter 236,

regulates seed production, control, sale, import/export, certification, and testing with quality standards.

An accreditation scheme should include different procedures to have an efficient and effective seed certification system in compliance with the national and international seed standards. The Seed Science Center of Iowa State University has developed Accreditation Procedures Manuals for different regions and national authorities (J. Cortes and A. Harries, Procedures Manuals for Seed Certification/ Accreditation, Seed Science Center-Iowa State University 2015).

The necessary accreditation system is for entities, individuals, and laboratories, where different criteria are established and in which a National Seed Authority (NSA) must be satisfied that the Third Party/Seed Entities have been sufficiently trained and are competent to carry out seed certification. The following conditions are suggested for the establishment of a national accreditation system:

- The Accredited Entity (AE) shall establish, document, implement, and maintain a quality management system that ensures that the service conforms to the requirements of National Standards. The AE must continually improve the effectiveness of the quality system.
- The AE should have a documented quality management system that describes its regulations, organization, working procedures, and standards. The AE shall establish and maintain a quality manual that includes an organization chart, the scope of the quality system, documented procedures, activities, references, and a description of the interaction and interlinkages between the procedures.
- The AE should develop and maintain documented procedures for the accredited activities, inspection, sampling, and/or testing activities to verify the specific requirements to be met by the product.
- Records shall be established and maintained to provide evidence of conformity to requirements and of the effective operation of the quality system. The required activities for field inspection, sampling, and testing, and the way to record shall be described in the quality manual.
- The Accredited Individuals (AI) should demonstrate commitment to quality service and meeting requirements of seed regulations and assure the ability to carry out the inspection services, sampling, and/or testing. The system should also include technical training, both theoretical and practical, conducted by the seed authority.
- The AI should keep records of complaints related to field inspection, and sampling, investigate the reasons and take corrective actions. He/she also shall establish and maintain documented procedures for performing, verifying, and reporting that the activities meet the specific requirements.

Similarly, in countries such as the USA, the national seed authority also undertakes accreditation of seed testing laboratories (STLs), based on the competence of the technical staff; necessary infrastructure; quality management system including a quality manual, records of maintenance, and calibration, reference materials, etc. The STL must clear the proficiency tests administrated by the national seed authority before the grant of accreditation, and periodically thereafter.

Having an accreditation scheme at the national level saves time and economic resources, as it is difficult for government inspectors to inspect/check all the sites for field control and timely completion of testing thousands of samples. For seed enterprises to have their seed inspectors and a list of accredited laboratories to conduct seed testing on time, is considered a better practice for enforcing the quality management concept in the production of certified seed.

1.2 Truth-in-Labelling/Truthfully Labelling System

This system may be considered an officially recognized methodology of self-control, through which the seed producers take care of the quality of seed during the entire process of production, processing/conditioning, storage, and marketing, following the official standards and the company's internal quality control standards. This system is used in one or the other form in different countries worldwide, such as India, the USA, Japan, Korea, and Thailand. The international seed trade of vegetable seeds, for example, is based on an effective truth-in-labelling system (ISSD Africa Synthesis Paper-Effective Seed Quality Assurance, Kit Working Papers 2017).

The truth-in-labelling system is based on two major premises:

(a) The seed company has the responsibility and control of the entire quality assurance process. This allows for a speed-up of the process and the reduction of associated costs. Another advantage is that the seed producer needs to maintain the reputation in the market, and therefore, the internal controls and corrective activities are in the best interest of the seed company. There are different opinions on this concept, but in practicality, the scheme is considered an ideal self-regulatory quality assurance system providing a seed production enterprise the opportunity to demonstrate its capacity and professional quality seed system. One disadvantage of this scheme in developing countries is the lack of speedy judicial systems for sanctions against the seed producer when they don't meet the internal quality standards.
(b) Consumers should have the freedom to choose which varieties are best for them so the responsibility for quality control is not under the seed authority. The basic condition regulated in the USA is the truth-in-labelling (Department of Agriculture Agricultural Marketing Service, 7 CFR Part 201 [Docket No. LS–02–12], Enforcement of the Varietal Labeling Provisions of the Federal Seed Act) through the Federal Seed Act that controls the labelling of seed marketed between and among states. The seed is controlled by the State Department of Agriculture with qualified inspectors who may draw samples, and submit the same to a designated STL to test and verify the variety and quality declared on the label. A similar system also prevails in countries that allow the sale and use of the Labelled seed (often referred as Truthfully Labelled seed), as in India (Prasad et al. 2017). Any violation of the labelling provisions, or the seed being sold as labelled and not meeting any of the prescribed quality standards,

involves monetary penalties to the seed companies (Federal Seed Act Policy: The Federal Seed Act (FSA) (7 U.S.C. 1551–1611).

1.3 Seed Quality Assurance System in India and Other SAARC Countries

Given a strong association between quality seeds, crop yields, and production, Singh and Jain (2014) noted that developing countries like India and Bangladesh will be in greater need to produce and use high-quality seeds because of their fast-growing population, changing demographic profiles, and also the need for poverty alleviation. Realizing the role of quality seeds in bringing the Green Revolution during the 1960s and 1970s that led to achieving food security, seed legislations were introduced in India, Pakistan, Bangladesh, and Nepal, which adequately provided for seed quality assurance. The Seeds Act, 1966 (India), the Seed Act, 1976 (Pakistan), the Seeds Ordinance, 1977 (Bangladesh) (which was amended in 1997, 2005, and 2007), and the Seeds Act, 1988 (Nepal) were vital instruments introducing a system of seed quality control in these countries, which have many similar features, and recognize the needs of a large proportion of farmers who use farm-saved seed (Koladya and Awal 2018). The Indian system of seed certification, discussed below, presents a general model being followed in these countries with some minor variations.

The organized seed sector, particularly in agricultural crops, in India took its roots with the establishment of the National Seed Corporation, a Government of India undertaking in 1963. With the enactment of the Indian Seeds Act in 1966, and the Seed Rules in 1968, seed certification gained a legal status. Agriculture being a State subject all the 28 States have been given the powers to establish the State level certification agencies either under the Department of Agriculture or as an autonomous body, and govern these under the Seeds Act, 1966. The first official Seed Certification Agency as part of the Department of Agriculture was established by the state of Maharashtra in 1970, whereas Karnataka was the first state to establish an autonomous Seed Certification Agency in 1974. Currently, there are 25 State Seed Certification Agencies in India; and the Central Seed Certification Board (CSCB) at the national level takes care of the standards and procedures for uniform adoption by all the State agencies. Elaborate seed certification standards specifying the crop-wise quality norms, i.e. Field Standards and Seed Standards are prescribed by the CSCB in the Indian Minimum Seed Certification Standards (IMSCS) prescribed by the Government of India. So also the procedures involved in the various phases constituting the certification process are periodically announced by the CSCB. There are 132 notified Seed Testing Laboratories (STL) for testing the seed quality for certification/labelling or other purposes. These are technically supported and guided by a Central Seed Testing Laboratory (CSTL), a Referral Lab, established under the Department of Agriculture and Farmers Welfare, Govt. of India. There are 20 ISTA member STLs in India, of which eight laboratories (6 in private sector and 2 in public sector) are accredited with ISTA which perform seed testing as per ISTA

Rues and are entitled to issue the orange certificate for international seed trade. India is a member of OECD seed schemes. However, like in the USA and many other countries, seed certification is voluntary, while labelling is mandatory for any seed in commerce.

The number of varieties notified and released since the enactment of the Seeds Act in India is ~5300, of which nearly 2000 varieties are in the seed chain. While public research institutions are the major contributors to notified varieties, with a share of 89%, private seed companies also contribute 11% of varieties, mainly hybrids (Yadava and Chowdhury 2021). Varieties can be released by the State Seed Committee or Central Seed Committee (SSC or CSC) based on the Release Proposals presented by the research system. For bringing the released varieties under the ambit of the Act, they are notified at the central level by the CSC. The receipt of indent and monitoring of the Breeder Seed allocation and supply (for the production of Foundation and Certified Seeds) is the responsibility of the Seeds Division, Govt. of India. The steps undertaken for the production of certified seed are similar to those in other countries as discussed above. The Labelled Seed is required to meet the minimum quality parameters prescribed for Physical Purity and Germination for certified seed.

The broad differences/similarities between the Indian and OECD systems of seed certification are presented below (based on Trivedi and Gunasekaran 2015):

Parameters	Indian Seed Certification System	OECD Seed Certification Scheme
Eligible varieties	Only the varieties notified under Section (5) of the Seeds Act, 1966 of the Govt. of India can enter seed certification chain	All varieties in the National List of varieties for OECD seed schemes are eligible
Variety nomenclature	Compulsory	Compulsory
Variety maintenance	Responsibility of the breeders/ breeding institutions	Responsibility of the breeders/breeding institutions
Generation system of seed multiplication	Breeder → Foundation → Certified (FS1 to FS2 or CS1 to CS2 are permissible, provided seed multiplication under Certification does not exceed four stages beyond breeder seed)	Pre- Basic → Basic → Certified1 → Certified2 (seed multiplication is permitted for two generations of Certified seed)
Nucleus seed	No specific tag; nucleus seed is maintained by the breeder/breeding institute; used for breeder seed multiplication	No specific label; controlled and maintained by the maintainer/breeder; used for pre-basic seed multiplication
Breeder seed/ pre-basic seed	• Golden yellow label • Monitored by a multi-disciplinary team of experts • Produced by the Breeder Seed Production (BSP) centres as per the indent allocated by the DAC, Govt. of India • Used for producing Foundation Seed (FS1)	• White label with diagonal violet stripes • Controlled by the Designated Authority (DA)/concerned Certification Agency and the Maintainer/breeder/institution • Produced officially by the recognized institutes/organization • Used for producing basic seed • Cannot be commercialized

(continued)

Parameters	Indian Seed Certification System	OECD Seed Certification Scheme
Foundation seed/basic seed	• White label • Monitored by the Seed Certification Agency • Used for producing Certified Seed (CS1) or FS2 seed with the necessary approval • Produced at Institutional Farms/by registered seed growers • Pre-/post-control plot tests are not mandatory • Validity of seed quality: Germination result]valid initially for 9 months from the date of testing, and subsequent validation is for 6 months	• White label • Controlled by the Designated Authority (DA)/concerned Certification Agency • Used for producing Certified Seed (CS1) • Produced officially by the designated institutions • Pre-/post-control plot tests are mandatory if used for further multiplication • No limit to the validity of seed quality
Certified Seed/ Certified 1(CS1) Seed	• Azure blue label • Produced by the registered seed growers • Monitored by the Seed Certification Agency • Can be used for CS2 seed production, provided FS1 seed was used • Validity of seed quality: Germination result is for 9 months from the date of testing for the initial certification. For the subsequent validations, the validity period is 6 months as long as the seed lot is meeting the quality standards	• Blue label for Cs1/red label for CS2 • Produced by registered seed producers • Controlled by the Designated Authority (DA)/concerned Certification Agency • No restriction for the validity of seed quality
Labelled seed/ standard seed	• Labelled seed/truthfully labelled seed: Opal green tag label • Seed is monitored by the producing organization itself • Must meet the minimum standards for physical purity and germination prescribed for the certified seed	• Standard seed: Carries dark yellow label • Seed is declared by the supplier as being true to the variety and of satisfactory varietal purity. It must conform to the appropriate conditions in the scheme
Field inspections, seed sampling, and testing	• Field inspections and seed sampling are performed by the officials of the Seed Certification Agency • Seed testing is conducted by notified STL only, including the STL of the Certification Agency	• For certified seed production, non-official, but licenced inspectors and seed samplers are also allowed • Seed testing may be conducted at non-official STLs as authorized by the DA
Grow-out test and pre- and post-control plots	• Grow-out test is compulsory only for the hybrids that are produced following a system of manual emasculation and pollination; or using chemical hybridizing agents (CHA) • A post-control plot may be compulsory for the Breeder seed of certain species, as identified	• Pre-control test is compulsory for pre-basic and basic seed • A part of every sample of basic seed and 5–10% of the certified seed shall be checked in a post-control test

The quality of certified seeds for use within the country will be regulated by the Seeds Act, 1966 and the Indian Minimum Seed Certification Standards (IMSCS) as amended from time to time, whereas that for OECD certification will be as agreed by the DA. Seed analysis of certified seed is performed by the notified laboratories, following the national Seed Testing Manual approved by the Ministry of Agriculture & Farmers' Welfare, GOI. However, ISTA Rules for Seed Testing serve as authentic reference source on the subject. OECD certification can be performed at the STLs approved by the DA, which may include notified STLs or ISTA-accredited labs.

The norms for field inspection, sampling, and seed testing could be more stringent in specific cases under the national seed regulations than under OECD, and vice versa.

1.4 Quality Declared Seed (QDS) System

The Food and Agriculture Organization of the UN (FAO) established a category of seed referred to as Quality Declared Seed (QDS), to have an alternative quality assurance system for developing countries. One major challenge in designing the QDS system was to promote flexibility in its implementation while retaining the basic principles of quality assurance (Quality Declared Seed, FAO, Rome, Paper 185/2006).

QDS is a quality management system with established standards to provide quality seed to farmers with a label and is considered an intermediate seed system. The implementation of a QDS system has the following requirements:

- A list of varieties eligible for the system should be available.
- Seed producers should be registered under the national seed authority.
- The national seed authority should check at least 10% of the fields registered to produce QDS and 10% of the seed offered on sale.
- The national seed authority should establish seed quality standards that can and must be achieved.
- The registered seed producer has the responsibility to apply for the production of QDS providing all necessary information and details of the seed to be produced and the location of the fields.
- One important premise in QDS is to produce quality seed while keeping the procedure simple, inexpensive, and not bureaucratic so that the smallholder farmers can adopt the same.

Thus, the QDS is seed produced by a registered seed producer that follows the QDS standards and requirements. The varieties for producing QDS include local varieties or landraces, varieties obtained by conventional breeding, and varieties obtained by other systems such as "participatory plant breeding". In all cases, the applicant needs to provide a statement of the origin of the variety, data of the variety,

a description of the morphological characteristics, the recommended agro-ecological zone, and a statement of the procedures used to maintain the variety.

For bred varieties, a description of the morphological aspects and other characteristics of the eligible variety is required, together with the agro-ecological zone recommended for cultivation. The procedures for maintaining the variety must also be provided for QDS certification. To maintain the genetic purity for this seed category, the limitation of generations and/or the additional isolation of seed crops may be established.

The production process of QDS includes:

1. Ensuring that the seed production fields have satisfactory previous cropping and the seed used is eligible to produce QDS.
2. Ensuring that the seed crop is well grown and measures are taken, such as roguing of off-types, weeds, and diseased plants to ensure healthy crops.
3. Inspecting fields based on the standards and rejecting those that do not reach the standards.
4. Ensuring that the identity of the seed at harvest is maintained and is delivered for conditioning in identified containers.
5. Ensuring that seed conditioning is performed preserving the identity and varietal purity of the seed.
6. Securing appropriate samples of the lot and submitting them for testing to a laboratory.
7. Keeping records of all activities, inspections, test results, and completing the QDS declaration.

The QDS system helps smallholder farmers who wish to buy improved seeds but have no access to improved certified seeds from any known source. The system also allows farmers with QDS to trade with other farmers. This seed has been used as a "relief seed" in many developing countries during emergencies, natural calamities etc. when shortfalls in seed availability can occur.

Summary of a case study from Tanzania is given below, in which the production of QDS helped farmers considerably.

Quality Declared Seeds Production in Tanzania (Pearl Millet, Sorghum, and Groundnut 2016)

(Source: Eco ACT project, Global Climate Change Alliance)

This was a model where farmers that could not afford to buy certified seeds, produced QDS seeds that was distributed to over 2500 farmers in target communities. Farmers improved their capacity to manage fields for seed production and obtained quality seeds and traded 1 kg of QDS seeds for 2–3 kg of crop produced.

This project also allowed farmers to expand their business.

Summary of another case study carried out in Uganda by ISSD is given below:

QDS Filling the Gap Between Formal and Informal Seed Systems: A Case of Common Beans in Uganda 2013
Farmers involved in producing QDS in a local project produced 4% of quality seed in the region at less cost as compared with certified seed. These farmers became local seed businessmen. Another success of this project was that good quality bean seed increased yield to 670 kg/hectare, resulting in extra income for farmers and good agricultural economic development.

There are also other uses of QDS, such as for relief purposes in climate and hunger emergencies. It also serves as a reference scheme for seed supplies since national seed organizations are often unable to provide comprehensive documentation for rapid international movement. There are other potential suppliers including cooperatives, farmer groups, large private farms, and NGOs for whom QDS could provide a cost-effective entry point to seed quality assurance.

In developing countries, the intermediate seed system may include the QDS scheme that requires seed producers to conduct internal quality assurance and declare the quality of their seed based on limited quality controls established by the regulatory authorities, e.g. an inspection of 10% of the total seed produced instead of undergoing the full inspection and quality testing procedures.

QDS is not proposed as a global scheme that countries would formally recognize or adopt as a basis for trade. However, it may facilitate seed movement at the national and regional levels if no other such scheme is available. Likewise, the standards set out here may provide a basis for regional seed schemes to develop their standards according to their specific trading needs.

2 International Certification Systems for Seed Movement

2.1 Association of Official Seed Certifying Agencies (AOSCA)

The AOSCA is committed to assisting its clients in the production, identification, distribution, and promotion of certified seeds. It was established as an International Crop Improvement Association including all Seed Certifying Agencies from the USA in 45 states. Other countries such as Canada, Argentina, Brazil, Chile, Australia, New Zealand, and South Africa are members of the AOSCA and are governed by AOSCA Rules.

The purpose of the association was to establish minimum standards for genetic purity and identity for the classes of certified seed for the national and international movement of seed. Also, AOSCA cooperates with the regulatory agencies in seed regulations and procedures related to the seed movement intra-state, inter-state, and

internationally (Association of Official Seed Certification Agencies, AOSCA, Web-site 2021).

The seed certification agencies from the states are members of AOSCA, applying the standards and procedures of AOSCA and the Federal Seed Act Regulations.

The programme ensures that the seed is produced, harvested, cleaned, and tested under very strict guidelines that include the following:

- The AOSCA classes of seed: Breeder seed, foundation seed, registered seed and certified seed.
- Application: The applicant must complete an application form with a tag or invoice accrediting the class of seed, variety, lot number, and grower number for the seed to be planted.
- Special field requirements: The field selected to produce certified seed must be free of noxious and restricted weeds. The field also should not have been planted in the previous season with another variety of the same crop or class of seed that could produce volunteers that may cross with the variety being planted. The field must be isolated from other varieties of the same kind and same variety not meeting the genetic purity requirements by the prescribed distances so as avoid chances of contamination by cross-pollination/mechanical admixture.
- Eligible crop varieties: Eligible crops are governed by each certifying agency. Typically, a crop is eligible if it has passed the review of one of the following review boards:
  - Plant Variety Protection Office.
  - National Certified Variety Review Board, a division of AOSCA.
  - Member agency of the AOSCA.
  - Organization for Economic Cooperation and Development (OECD) Seed Scheme.

Field inspections: Seed crops are inspected by the state to ensure that they comply with the standards. The agency may reject a field where its conditions do not allow an adequate inspection to verify the genetic identity and purity. The inspectors may also reject the fields if they are excessively weedy, have poor stand development, or the crop has disease, insect damage, or other factors that would affect the quality or genetic purity of the seed.

Harvesting: Certified seed must be harvested with equipment that is not contaminated with other crops or weed seeds.

Conditioning: Certified seed can be cleaned only in the facilities that have been approved during the inspection by the certifying agency. This is to ensure that the conditioning facility and machinery significantly improve the quality of harvested seeds.

Seed sampling and testing: A sample of the conditioned seed is typically drawn under the auspices of a state representative and tested in an officially recognized seed testing laboratory.

If the tested seed meets the minimum requirements for purity (genetic/physical) and germination that is specified by the state, it is eligible to be a certified seed. Each

lot of certified seed receives tags that are affixed on the bags. The colour of the tag depends upon the generation of seed produced. The classes and tag colours are as follows:

Breeder Seed (White tag): This is the first-generation seed of the variety produced from Nucleus/ Breeder Seed. This class of seed is directly controlled by the entity releasing the variety. This class is outside the ambit of certification and forms the source for the subsequent generation, i.e. foundation seed class.

Foundation seed (White tag): This is produced from breeder seed. This class of seed is typically a second-generation seed.

Registered seed (Purple tag): This class is produced from foundation seed. It is typically a third-generation seed.

Certified Seed (Blue tag): This is produced from registered or foundation seed. This is typically a fourth-generation seed. It is the class of seed usually sold for commercial crop production purposes and not meant for further certified seed production. Blue-tagged certified seed is not eligible for further seed multiplication.

Substandard certified seed (Blue tag): A seed that has gone through the certification process but has failed the minimum mechanical purity and germination requirements, may be tagged as a substandard certified seed. Doing so is completely up to the state certifying agency and is considered on a lot-by-lot basis.

Source-identified seed (Yellow tag): This is the seed that has been harvested from natural stands or grown in field production but has not been tested for its traits. It is produced under the auspices of the state and if it meets the prescribed quality requirements it is labelled as source-identified seed.

Selected seed (Green tag): This is the class of seed that exhibits characteristics of a variety but has not been definitively proven to have traits that can be inherited by subsequent generations. It is usually material that is undergoing testing and awaiting conclusions. It may be field-produced or harvested from natural stands.

2.2 Organization for Economic Cooperation and Development (OECD) Seed Schemes

This is an international seed certification programme designed for international seed movement/trade. The programme was initiated in 1961 with the aim of facilitating a transparent international seed trade through common quality standards for seed certification. The objective is to encourage the use of certified seeds of high quality, authorize the use of labels and certificates produced for international trade according to agreed standards, and enhance cooperation between importing and exporting countries.

The main instruments of this OECD Seed Scheme are the Rules and Regulations (2022), the OECD list of varieties, and the guidelines for control plot tests and field inspection for seed crops.

The scheme is open to OECD countries as well as non-OECD countries from the United Nations (UN) and the World Trade Organization (WTO). Currently, there are 61 participating countries.

The OECD Seed Scheme is applied for those varieties that are officially recognized as distinct, uniform, and stable and having an acceptable value for cultivation and use in at least one participating country. An OECD list of eligible varieties is published annually. There are over 62,000 crop varieties that are traded internationally (Quality Seeds for World Needs, OECD Seed Schemes, 2021). For a country to issue OECD labels, it is required to register the variety in this OECD List of Varieties.

In addition, satisfactory conditions of production and conditioning of basic and certified seeds must be ensured through field inspections and post-control tests.

The OECD Rules establish quality standards for seven groups of species: (1) grasses and legumes, (2) crucifers and other oil or fibre species, (3) cereals, (4) fodder and sugar beet, (5) subterranean clover, and similar species, (6) maize, sorghum, and (7) vegetables. It also establishes common rules and regulations for seed certification.

The categories or classes of seed in this scheme of certification are the following: Pre-basic seed, basic seed, and certified seed. For the pre-basic seed, the colour of the labels is white with a diagonal violet stripe. In the case of basic seeds, the label colour is white, while for certified seeds, first generation is blue and second generation is red. For not-finally certified seeds, the label colour is grey. While all classes of OECD-certified seed lots must be accompanied by an ISTA OIC, the seed which is categorized as "not finally certified" (grey label), OIC is not required. A category known as "standard seed" refers to the seed that is declared by the supplier as being true to the variety with satisfactory variety purity. It must.

conform to the appropriate conditions in the Schemes. It carries a dark yellow label. This category mainly exists in the vegetable seed scheme (Trivedi and Gunasekaran 2015).

Seed-not-finally certified is the seed that is exported from one country of production after field inspection with labelled containers. The designated authority of the importing country must verify the final certification process with all the information and documents provided by the designated authority from the country of production.

The designated authority should ensure the availability of the description of the variety or of the parental components before the time of the field inspection. The description should be based on the international guidelines developed by the International Union for the Protection of New Varieties (UPOV).

The designated authority is responsible for ensuring that the appropriate labels are affixed to the containers.

The process of OECD seed certification includes the control of the production and carrying out field inspections to verify the varietal identity and purity. The crops standards include minimum requirements of the previous cropping, field isolation, noxious weeds present, number of inspections, species purity, varietal purity, size of the seed lot, and special conditions. One or more field inspections shall be conducted, but at least one after the emergence of the inflorescence/during flowering. The inspectors shall check the compliance with the requirements prescribed for each crop.

2.2.1 OECD Labels

After harvesting and conditioning, the seed lot must be sampled to test the quality of the seed. All activities of sampling, fastening, and labelling must be conducted by the designated authority or by authorized persons. The sample size must be enough (see chapter "Testing Seed for Quality" for details) to carry out the tests by the laboratory. The tests shall include analytical purity and germination. The designated authority shall store a sample for 1 year under appropriate conditions that ensure the maintenance of the seed quality. Based on the results of field inspections and seed testing, the designated authority will issue the OECD certificates.

In the case of certified seeds, tests of post-control are conducted to verify the purity and identity of the variety. This is a comparison between plants grown from the seed lot produced and those grown from the standard sample. This post-control test will help the designated authority check the efficiency of the seed certification process for the verification of the maintenance of varietal purity and identity. The post-control test shall be conducted by the designated authority or under their supervision who will define the percentage of post-control of the certified seed. Generally, that level is between 5 and 10%. OECD has developed guidelines for control plots and field inspection of seed crops (Guidelines-control plot and field inspection, OECD Seed Scheme 2019). The guidelines include methods and techniques that help to determine varietal purity and identity at different stages of seed production.

2.3 International Seed Testing Association (ISTA)

ISTA was founded in 1924 to develop, adopt, and publish standard procedures for sampling and seed testing with the primary purpose of promoting uniform use and application of the methods for testing of seed that is moving in the international trade. ISTA is an independent non-profit organization supported by the cooperation of seed scientists and analysts.

The ISTA's vision is "uniformity in seed quality evaluation worldwide". ISTA plays an important role also in seed testing at national and regional levels by publishing the ISTA Rules that are globally available, annually updated, and harmonized with uniform seed testing methods. It promotes the application of uniform procedures for the evaluation of seeds intended for the market. Presently it has 226 member laboratories in 82 countries of which 136 are ISTA-accredited laboratories (International Seed Testing Association, Website 2021). This has been accomplished through the publication of the International Rules for Seed Testing, a laboratory accreditation system, the ISTA international certificates (orange and blue), and the knowledge of science and technology. Following ISTA rules for seed testing at the national and international level facilitates seed trade, ensures the quality of seed available to the farmers, and contributes to food security.

Twenty technical committees of ISTA work on seed testing issues and are integrated by more than 200 technologists and scientists around the globe. The technical committees are:

Advanced Technologies Committee; Bulking and Sampling Committee; Flower Seed Testing Committee; Forest Tree and Shrub Seed Committee; Germination Committee; GMO Committee; Moisture Committee; Nomenclature Committee; Proficiency Test Committee; Purity Committee; Rules Committee; Seed Health Committee; Statistics Committee; Seed Storage Committee; Tetrazolium Committee; Variety Committee; Vigor Committee; Editorial Board (SST); Seed Science Advisory Group; and Wild Species Working Group.

The ISTA Rules describe the principles and definitions of the standard methodologies, techniques, and procedures for seed sampling, testing, and reporting of results. The quality tests included are heterogeneity, physical purity, other seed determination, germination, moisture content, seed viability, vigour, seed health, varietal/cultivar purity, and detection of genetically modified organisms in the seed. The ISTA rules are developed and supported by experts that develop and validate methods for each component of seed testing. ISTA also publishes different handbooks on specific aspects of seed testing such as Germination; Seedling Evaluation; Seed Health Testing; Flower Seed Testing; Forest Tree and Shrub Seed Testing; Moisture; Nomenclature; Purity; Laboratory Equipment; Statistics; Tetrazolium; Variety Testing, Vigor, and Tolerances. These are widely used by researchers and seed analysts globally.

ISTA has an accreditation programme with a quality management system that includes the quality documentation developed by the laboratory based on the ISTA accreditation standards. When the applicant provides the quality manual to the technical department, ISTA auditors conduct the on-site assessment regarding staff, facilities, seed sampling, and seed testing. If the auditors identify any non-conformity, it must be addressed with a formal corrective action procedure. If the audit approves the quality system, then the accreditation approval procedure is initiated through the Executive Committee. Once it is approved, the lab will receive a certificate of accreditation and authorization to issue international certificates. The proficiency tests are compulsory and the Quality Management System is audited every 2 years to maintain its accreditation.

Laboratories that are accredited by ISTA are entitled to issue the "international certificates", called "Orange Certificate", provided by ISTA as a seed quality passport for international seed trade. ISTA accreditation is a formal recognition of the laboratory's technical capacity to carry out seed tests that are repeatable and reproducible in any laboratory around the world. Therefore, countries with laboratories accredited by ISTA ensure their capability to issue seed certificates for the international movement of seeds.

ISTA also supports advances in seed research by publishing original papers and articles on various aspects of seed science and technology, namely seed quality, physiology, production, harvest, processing/conditioning, sampling, testing, storage, packaging, treatment, genetic conservation, habitat regeneration, distribution, etc. in "Seed Science and Technology" (SST), an international journal; and articles on advancements of seed testing in Seed Testing International (STI), a news bulletin.

2.4 International Plant Protection Convention (IPPC)

Phytosanitary measures are handled nationally by the National Plant Protection Organization (NPPO) of each country. The International Plant Protection Convention (IPPC) is a multilateral treaty commissioned in 1951 that promotes effective actions to prevent and control the introduction and spread of pests of plants and plant products (International Plant Protection Convention, IPPC, Website FAO 2021).

IPPC allows countries to evaluate the risks to their national plant resources and to use science-based measures for the safety of their cultivated and wild plants. Under this principle, IPPC is protecting the farmers, biodiversity, ecosystems, industry, and consumers from pests and diseases. The active participation of member states as parties of the IPPC is very important as the states are part of developing international standards that help to protect the movement/import and export of commodities including seeds. The effective implementation of the Convention is based on exchanging technical and official phytosanitary information among the member states.

Specific information, such as the NPPO contact information and description; phytosanitary restrictions and legislation; entry/exit points; list of regulated/objectionable weeds, pests, diseases, organisms, and objects; emergency actions; non-compliance; pest status; the rationale for phytosanitary requirements; and pest-free areas are published by the member states.

As defined in the International Standards for Phytosanitary Measures, in the context of the international movement of seeds (ISPM38), a seed-borne pest is carried by seeds externally or internally that may or may not be transmitted to plants growing from the seeds, causing their infection/infestation. Whereas, a seed-transmitted pest is a seed-borne pest that is transmitted via seeds directly to plants grown from these seeds, causing their infection/ infestation. Seed can be a pathway for the introduction and dissemination of pests in a new geographic area through seed trade. Safeguarding seed health is critical in avoiding the spread of pests. It is of crucial importance to provide national plant protection organizations (NPPOs) with an updated, scientifically-evidenced list of seed-associated pests.

The International Standards for Phytosanitary Measures (ISPM) are standards adopted by the Commission on Phytosanitary Measures to protect sustainable agriculture, facilitate trade development, protect the environment, and enhance food security. The ISPM on Seed, ISPM #38, was adopted by the Commission in 2017 and provides guidance to assist NPPOs in identifying, assessing, and managing the pest risk associated with the international movement of seeds. ISPM #38 also provides guidance on the procedures to establish phytosanitary requirements to facilitate the seed movement internationally. Its guidelines also include inspections, sampling, and testing of seeds and the phytosanitary certification of seeds for export and re-export of commercial seed, as well as the seed used for research, breeding, and multiplication.

Pest Risk Analysis (PRA) is a tool promoted by IPPC to evaluate the risk of pest introduction and dissemination. For seed imports, the PRA will depend on the purpose or scope of the seed importation. In the case of seed imported to conduct

a laboratory test, it may not be necessary to conduct a PRA if the seed is to be destroyed during or after the laboratory test. In the case of imported seed for planting under restrictive conditions such as germplasm or seed to be used as breeding material, an NPPO may require relevant phytosanitary measures. If the seed is to be imported for planting in the field, the NPPO in the importing country may require a pest risk assessment depending on the country/zone of production. In the case of importing seeds of a mixture of different species or varieties, testing and inspections may be done on the components or the mixture or blend to be certified. One advantage of ISPM #38 is the establishment of a system approach as a preventive control or risk reduction in the entire seed production process, from breeding materials to commercial sales. Some of these seed chain components require risk analysis, and others are measures for mitigation of that risk.

Another element to keep in mind is the new technologies applied to breeding programmes where seed varieties with pest resistance are being developed. This may allow, for example, the NPPO of the importing country to consider the use of resistant varieties as an appropriate phytosanitary measure.

Seed treatments with pesticides or disinfectants and physical or biological treatments also can be applied to eliminate any infection/infestation. For imported seed, the importing country may require the "post-entry quarantine" in cases where the pest is difficult to detect when the expression of symptoms takes time, or there are no other phytosanitary measures.

In addition, specific requirements for inspection, sampling, and testing of seeds are established for phytosanitary seed certification. Inspections may be conducted on the seed consignment or in the field production or both. However, sometimes if the visual examination is not enough, it must be combined with laboratory seed health testing. In the case of using laboratory testing for pest detection, NPPO should ensure the use of internationally validated tests that follow diagnostic protocols for regulated pests.

The adoption of ISPM#38 provides a new systematic approach to establishing phytosanitary requirements for the import, inspection, sampling, and testing of seed that facilitates the international movement of seed. The advantage of a system approach is that preventive controls or risk reduction measures are put in place during the entire seed supply chain process.

At ISTA, the Seed Health Committee (SHC) is focusing on seed-borne pests (bacteria, fungi, oomycetes, viruses, nematodes) in more than 40 non-vegetable species from 21 botanical families of spermatophytes (seed plants), including cereals, legumes, oleaginous crops, forest trees, and fruit trees. It also includes a list of pests that were included in the last version of the Annotated list of seed-borne diseases, but that lack evidence of seed-borne status in the scientific literature. These pests will be regularly checked for information on their ability to not only be seed-borne but also to transmit to the progeny. The ISTA Reference Pest List will be updated regularly each time a list will be finalized.

The International Seed Federation (ISF) has prepared a training manual that provides information on the elements of the ISPM #38. It also describes the needs of the NPPO to address and implement this phytosanitary measure. At the same time,

ISF has developed a regulated pest risk database based on scientific evidence (International Seed Federation, ISF Regulated Pest List. PESTLIST. WORLDSEED.ORG 2021). For more information, see the ISF website (International Seed Federation, ISF, Movement of Seed, APSA Congress, Bangkok, June 2017). Finally, it is necessary that the countries design and use the system approaches for phytosanitary certification of seeds for the international movement.

Thus, an appropriate system of quality assurance, either through certification or labelling, is an essential instrument to ensure quality seed in the production chain both for the domestic and international markets.

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