# SEED ECONOMICS


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# CHAPTER 1

# EXPLORING THE IMPACT OF SEED TECHNOLOGY FOR NEW CROPS

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**ABSTRACT**:
Seed technology plays a pivotal role in the successful establishment of new crops, contributing to agricultural diversification and sustainable food production. This paper explores the significance of seed technology in the context of introducing new crops to agricultural systems. It examines the various stages of seed technology, from breeding and selection to processing and distribution, highlighting the challenges and opportunities associated with each stage.

The role of biotechnology and genetic engineering in enhancing the traits of new crops is also discussed. Additionally, the importance of seed quality, regulatory frameworks, and farmer engagement in the adoption of new crops is emphasized. Through a comprehensive review of seed technology's impact on new crops, this paper underscores its crucial role in shaping the future of agriculture and food security. Moreover, while the benefits of new crops are abundant, challenges such as regulatory hurdles, market acceptance, and socio-economic considerations must be acknowledged and addressed. To fully harness the potential of seed technology for new crops, collaborative research, interdisciplinary partnerships, and farmer involvement are essential.

**KEYWORDS**:

Agronomy, Biotechnology, Crop Improvement, Genetic Engineering, Germination, Hybridization.

## 1. INTRODUCTION

Since the dawn of civilization, the history of agricultural development has been shaped by the introduction of new crop kinds and crop seeds for cultivation. It was first accomplished by the cultivation of native yet valuable species as well as those introduced. Later, the scientists created a large number of new and improved varieties by the well-known procedures of selection, hybridization, mutation, polyploidization, and plant biotechnology.

However, unless a farmer can get seeds that are genetically pure, have a high germination rate and vigor, are high in purity, are in good health, etc., all of this scientific study will be of little use to him. When farmers do not get seeds with these characteristics, their harvests could not be as anticipated. Therefore, the rate of production advancement will primarily rely on how quickly we can produce and commercialize high-quality seeds of yield-boosting kinds[1], [2].

### Understanding Seed Technology

Cowan defined seed technology as "that field of study concerned with the production, upkeep, quality, and preservation of seeds.Feistritzer described seed technology as the processes used to enhance the genetic and physical properties of seeds. It covers tasks including seed production, processing, storage, and certification, as well as variety creation, assessment, and release.Therefore, seed technology is fundamentally a multidisciplinary discipline that covers a wide variety of topics. In its broadest sense, "seed technology" includes research on seed physiology, production, and handling based on contemporary botanical and agricultural sciences, as well as the development of superior crop plant varieties, their evaluation and release, seed production, processing, storage, testing, certification, and quality control[3], [4].

According to a strict definition, "seed technology" includes methods for seed production, processing, storage, testing, certification, marketing, and distribution, as well as any relevant study on these topics.

**Seed Technology Concept**

It is crucial to understand the difference between seed and grain since it is fundamental to agriculture. A seed is technically a "embryo," a live creature implanted in the tissue that supports or stores food.

The seed is material intended to be preserved for planting, with reproduction being its primary aim. Scientifically produced seeds have much higher seed quality, including enhanced varieties, varietal purity, lack of weed and other crop seed admixtures, high germination and vigor, seed treatment, safe moisture content, and more. Contrarily, cereals and pulses intended for human consumption are considered grains.

**Differences between grain and seed produced scientifically**

It is the outcome of a well thought out seed program.

- It is the portion of commercial output that has been set aside for planting or sowing.
- It is the outcome of careful scientific research, disciplined work, and financial investment in processing, storage, and marketing facilities. There is no need for such expertise or effort.
- The seed's heritage is guaranteed. It can be associated with the original breeders' seed.Unknown is the varietal purity of it.
- To maintain adequate seed purity and health throughout production, efforts are undertaken to remove off-types, sick plants, unwelcome weeds, and other crop plants at the proper phases of crop development. Such an attempt is not made. Consequently, the purity and health condition might be worse.
- The seed is carefully handled, packaged, and tagged with the correct lot identification.It is possible to physically clean the grain used as seed. In rare circumstances, it could also be treated before seeding. This item isn't marked.
- The seed is examined for germination, purity, mixing of weed and crop seeds, health, and moisture content before being used for planting. Regular seed testing is not carried out
- Typically, a non-production-related entity oversees the seed quality. There isn't any quality assurance.
- In essence, the seed must fulfill the "quality standards". As a result, the quality is highly recognized. On seed containers, labels and certification tags function as quality markings. Such criteria don't hold true in this situation. The quality is unknown and nondescript.

**Seed technology's function**

The following functions of enhanced seed were described by Feistritzer.

- Better seed serves as a conduit for emerging technologies When new types of high-quality seeds are introduced and carefully paired with other inputs, yield levels considerably rise. Over a 40-year period, the development of high yielding cultivars has contributed to an increase in food output in India from 52 million tonnes to approximately 180 million tonnes[5], [6].

- Better seed is a fundamental instrument for securing the food supply.
- Despite the country's rapidly growing population, the high yielding variety program's effective implementation in India has resulted in a notable rise in output and a reduction in food imports from other countries.
- Improved seed is the main tool for guaranteeing agricultural yields in less favorable production settings. One key factor in ensuring increased agricultural yields is the availability of high-quality seeds of improved kinds to these locations.
- Improved seed is a tool for quick recovery of agriculture after a natural catastrophe. The government will offer enhanced seeds from national seed stocks in regions hit by floods and droughts so that the agricultural output of food grains in the nation may be rebuilt.

## 2. DISCUSSION

The main objective of seed technology is to boost agricultural productivity by disseminating high yielding, high-quality seeds. Its objectives are as follows:

### 2.1 Rapid multiplication

Increasing agricultural output by distributing new plant breeders' kinds as quickly as feasible. The amount of time it takes to provide farmers with the appropriate number of seeds of improved kinds should be taken into account as a gauge of the effectiveness and sufficiency of the nation's seed technology development.

### 2.2 Timely supply

The better seeds of new types must be made accessible well in advance, to avoid disrupting farmers' planting plans and to allow them to utilize high-quality seed for planting.

### 2.3 Seeds of guaranteed good quality

This is essential if you want to get the benefits of using seeds from better types[7], [8]. The typical farmer should be able to afford the price of high-quality seed.Variety is a class of plants with distinctly recognizable traits that are retained after sexual or asexual reproduction.

### Developmental Variation

When a seed crop is grown under challenging environmental conditions for several generations in a row, such as diverse soil and fertility conditions, saline or alkaline conditions, diverse photoperiods, diverse elevations, or diverse stress conditions, developmental variations may manifest as differential growth responses. The variety should always be cultivated in the adap region or in the area for which it has been released in order to prevent or minimize such developmental differences. The fundamental seed, such as the nucleus and breeder seed, should be replicated in adap regions if for some reason it must be cultivated in nonadapareas for one or two seasons[9], [10].

### Mechanical Mixtures

During seed manufacturing, this is the main cause of variety contamination. From planting through harvesting and processing, mechanical mixes may occur in a variety of methods.

It would be important to check the seed fields at various phases of crop development and to take the greatest precautions throughout seed production, harvest, threshing, processing, etc. to prevent this kind of mechanical contamination.

**Mutations**

This factor is not particularly significant since spontaneous mutations only happen around 10-7 times every million years. If any obvious mutations are found, they should be rouged out. When crops are grown vegetatively, a periodic rise in true-to-type stock would eradicate mutations.

**Natural Crossing**

Due to the introduction of genes from unrelated stocks/genotypes, it is a significant source of contamination in sexually propagated crops. The degree of natural cross-fertilization, which results from natural crossing with unwanted kinds, offtypes, and sick plants, determines the level of contamination. Contrarily, the primary cause of contamination in cross-fertilized or often cross-fertilized crops is spontaneous crossover. The breeding method of the species, isolation distance, varietal mass, and pollination agent all influence how much genetic contamination is caused by natural crossover in seed fields. In order to solve the issue of natural crossover, separation must be maintained. The degree of contamination is reduced as separation distance increases. The direction of the wind, the number of insects present, and their activity all affect the level of contamination.

**Genetic drift**

Only little amounts of seed are harvested and saved for the next year's planting when seed is reproduced across huge regions. Such undersampling causes the genetic makeup of the population to shift since all genotypes are not reflected in the next generation. Genetic drift is what is meant by this.

**Tiny Genetic Variation**

It is not very significant, however owing to environmental differences, some tiny genetic alterations may happen throughout production cycles. The yields might vary as a result of these modifications. In self-pollinated crops, breeder's seed and nucleus seed testing of the variety must be done on a regular basis to prevent such tiny genetic changes. In often cross-pollinated species, little genetic diversity is a typical trait; as a result, care should be made while maintaining nuclei and breeder seed.

**Selective Impact of Disease:**

If important pests and diseases are not properly controlled, both the plant and the seeds may get afflicted.

a. The size of the seed is impacted by foliar diseases because diseased photosynthetic tissue produces insufficient amounts of carbohydrates, which reduces seed size.

b. Once a crop has been affected with a seed- or soil-borne disease such as downy mildew, ergot of Jowar, smut of bajra, or bunt of wheat, it is risky to utilize seeds for commercial purposes.

c. When new crop kinds emerge off of seed production programs, they often develop a susceptibility to new races of diseases. For instance, Phalguna and Surekha developed a sensitivity to gall midge biotype.

8. Breeder's Techniques: If it is not accurately analyzed at the time of release, instability may result in a variety owing to genetic irregularities. Premature introduction of a variety bred for a specific disease result in the creation of resistant and vulnerable plants, which may be a significant contributing factor to decline. The genetic diversity in both the sonalika and

kalyansona wheat types was still in the flowing stage when they were allowed for commercial production in India, and the breeders produced a number of secondary selections.

9. Male sterility breakdown: In hybrid seed production, male sterility breakdown often results in a combination of F1 hybrids and selfers.

10. Inadequate Seed Certification: This is not a factor that affects the quality of crop varieties, but if any of the other criteria listed above have a flaw that has not been addressed, the quality of the crop varieties may suffer.

**Preserving genetic purity when producing seeds**

For the purpose of maintaining genetic integrity, Horne had recommended the following techniques:

- Use of authorized seed in seed multiplication
- Examining seed fields before sowing
- Field inspection and crop approval at crucial phases for confirming genetic purity, finding mixes, weeds, and illnesses transmitted by seed.
- Sample collection and lot sealing
- Samples are grown using real stock or Test of growth

Following are many actions that Hartman and Kestar recommend doing to preserve genetic purity:

- Establishing isolation to avoid mechanical mixing or cross-fertilization
- Periodic testing of cultivars for genetic purity
- Routing of seed fields prior to planting
- Grow exclusively in suited locations to prevent genetic changes in the variety.
- Ensure seed harvests are certified to guarantee genetic purity and quality.
- Using a generational scheme

**Protective measures to maintain genetic purity**

- Control of the seed source is one of the key safeguards for ensuring genetic integrity throughout seed manufacturing.
- Earlier crop need
- Isolation
- Rouging of seed farms
- Seed attestation
- Test for growth

**Control of Seed supplier**

When cultivating a seed crop, the seed used should be of the proper class from an authorized supplier. Breeder seed is divided into four categories, which are listed and described by the Association of Official Seed Certification organization.

**Nucleus Seed**

This is a little number of seed that a careful breeder keeps for future multiplication. The nucleus seed is of the utmost genetic purity and has every trait that the breeder has inserted into it. The number of nuclear seed is specified in kg.

Breeder Seed, which is used to make foundation seed, is produced by the concerned breeder or sponsoring institution. Genetic purity is 100 percent pure. Golden yellow is the color of the label or tag supplied for B/s. The government-created monitoring team ensures the breeder seed's quality.Breeder seed is used to create foundation seed, which is kept pure and genetically distinct. Government farms or commercial seed companies produce it. A certification organization certifies the foundation seed's quality. Its genetic purity is more than 98%. White makes up the certification tag or label that was given out for F/s.

**The prerequisite crop**

This has been addressed to prevent contamination by stray plants and illnesses that are spread via contaminated soil.

**Isolation**

Isolation is necessary to prevent disease contamination from surrounding fields, natural crossing with other unwanted types, off types in the field, mechanical mixing during sowing, threshing, and processing, and natural crossover with other undesirable types. ProtectionFor the purpose of preserving genetic integrity and high seed quality, protection from various sources of contamination is required.

**Rouging of Seed Fields**

The presence of plants that are genetically unsound is another cause of genetic contamination. Off type plants are those that have traits that are different from those of the seed crop. The process of roughing involves the removal of off kinds. The primary causes of off kinds are: a. Plants that have been separated for particular traits or mutations; b. Volunteer plants from earlier crops; c. seeds of another variety that were accidentally planted; and d. diseased plants. In order to prevent off-type plants from pollinating and shedding pollen, they should be removed from the seed plots. Regular monitoring of qualified persons is necessary to achieve this.

**Seed Certification**

A system of seed certification maintains the genetic integrity of seed crops. The primary goal of seed certification is to provide farmers with high-quality seeds. To do this, field inspections are conducted by competent and trained SCA staff at the proper phases of crop development.

By taking samples from seed batches after processing, they also carry out seed inspection. Both filing and seed criteria are verified by the SCA, and the seed lot must pass to be approved as certified seed.

**Grow-out Test (GOT)**

To ensure that seed-producing types are being kept true to form, GOTs should be conducted frequently to check for genetic purity. In order to verify the purity of the parental lines utilized in the creation of hybrid seed, the GOT test is required for hybrids created by manual emasculation and pollination.

**Seed Quality and Seed Classes**

The goal is to multiply high-quality seed under the watchful eye of a seed certification agency's breeder and distribute it for sowing purposes.By involving ICAR Institutes/State Agricultural Universities, State/National Seed Corporations, and Seed Certification Agencies, seed of notifiable varieties is replicated in a four-tier system.

**A. Nucleus seed**

Produced under the direct supervision of the relevant plant breeder, this seed is 100% genetically and physically pure.

### B. Breeder's seed

This is the offspring of the nucleus seed replicated across a broad region while being watched over by a committee and a plant breeder. It offers 100% physically and genetically pure seed for the development of foundation class. The producting agency issues certificates in the color golden yellow for this category.

### C. Foundation seed

Under the guidance of the Seed Certification Agency, recognized seed-producing organizations in the public and private sectors manage the offspring of breeder's seed in a manner that ensures its quality is preserved in accordance with the established standard. For foundation class seed, the Seed Certification Agency gives a white color certification. Seed Corporation buys foundation seed from seed farmers. In the case of a scarcity, Seed Corporation may once again produce foundation seed using the same seed certification criteria.

Certified seed is the offspring of foundation seed that has been grown by licensed seed farmers under the direction of the Seed Certification Agency while maintaining the basic requirements for seed certification. A bleucolor certificate is issued by the Seed Certification Agency.Nucleus seed is the little quantity of original seed that the original breeder collected from a few carefully chosen plants of a specific variety for upkeep and purification. To supply breeder seed, it is further multiplied and maintained under the guidance of an experienced plant breeder. This serves as the foundation for all subsequent seed production. It possesses the greatest levels of physical and genetic purity.

## 3. CONCLUSION

In conclusion, the effective introduction of new crops into agricultural landscapes depends heavily on seed technology. A new crop goes through a number of related processes before being commercially available, all of which primarily rely on good seed technology. The traits and performance of new crops might be revolutionized by breeding techniques, both traditional and cutting-edge biotechnological ones, to meet the demands of shifting climatic conditions and dietary requirements. This investigation has shown that the success of novel crops depends on more than just advances in the lab; it also depends on efficient distribution systems, reliable processing, and quality control. It takes a coordinated effort from the public and commercial sectors, as well as supporting regulatory frameworks, to ensure that farmers, especially those in disadvantaged areas, have access to high-quality seeds.

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# CHAPTER 2

# INVESTIGATING THE INTERNATIONAL SEED TESTING ASSOCIATION

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**ABSTRACT**:

The International Seed Testing Association (ISTA) occupies a central role in shaping global agricultural practices by establishing and disseminating seed testing standards. This paper delves into the significance of ISTA in ensuring seed quality, facilitating international seed trade, and promoting agricultural productivity. It explores ISTA's mission to harmonize testing methodologies, quality assessment protocols, and certification procedures, underscoring the importance of these efforts in maintaining uniformity and reliability across diverse seed markets. By examining ISTA's impact on seed industries worldwide, this paper highlights its pivotal contribution to safeguarding seed quality and advancing sustainable agricultural development.The International Seed Testing Association's pivotal role in the world of agriculture is undeniable. As elucidated in this exploration, ISTA's commitment to developing and disseminating globally recognized seed testing standards has far-reaching implications for both farmers and consumers. The harmonization of testing methodologies not only ensures the reliability of seed quality assessments but also facilitates international seed trade by promoting consistency and transparency in the market.

**KEYWORDS**:

Accreditation, Crop Improvement, Germination Testing, International Standards, Seed Certification.

## 1. INTRODUCTION

To evaluate the characteristics of the seed batches that must be made available for sale, seed testing is necessary. The moisture content of the seeds, their germination and vigor, their physical and genetic purity, their lack of disease- and insect-transmitted illnesses, are examples of these quality characteristics. Moisture, germination, and physical purity of seeds are often assessed in India during seed testing. The International Seed Testing Association has created standardized seed-testing protocols for the assessment of seeds, and seed experts from throughout the globe have played a vital part in these advances. If the seed is going into the international commerce, seed analyzers are required to abide by the standards set out by the International Seed Testing Association (9ISTA, 1985) for seed testing[1], [2]. The standards established in the nation may be followed for testing seeds for quality control reasons, but, if the sale of seeds is subject to government regulation in the nation. The following goals for reducing the dangers of planting poor quality seeds have led to the development of the science of seed testing, or the science of determining the planting value of seed:

**Goals of the Seed Testing**

- To assess their appropriateness for planting, or their quality
- To pinpoint issues with seed quality and their likely causes
- To assess if drying and processing are required, as well as the precise steps that are to be taken.

- To check if seed satisfies prescribed criteria for quality or labeling.
- To determine quality and serve as a foundation for pricing and customer discrimination among market lots.

As seed testing advanced, it became clear that collaboration across seed testing facilities was essential for the development of standard testing procedures that would guarantee consistency in test assessment and findings. The International Seed Testing Association was established in 1924 as a result of this requirement. The main goal of ISTA is to create, implement, and publish standardized methods for sampling and testing seeds as well as to encourage their universal use for the assessment of seeds that are being traded internationally. It also encourages cultivar certification, promotes research in all areas of seed science and technology, such as sampling, testing, storing, processing, and distribution, takes part in training sessions and conferences aimed at advancing these goals, and establishes and maintains contact with other organizations with similar or related interests in seeds. There are fifteen separate committees that handle the organizations' technical and scientific activity. The association's publication, Seed Science and Technology, publishes contributions that are both scientific and technological. The International Rules for Seed Testing were adopted, and this is one of ISTA's greatest accomplishments. These regulations provide testing methods that are supported by scientific evidence, precise within specified statistical bounds, and workable in day-to-day operations. The following goals have acted as a reference while creating the regulations for seed testing[3], [4].

- To provide techniques for precisely determining the quality of seed samples.
- To provide procedures that will allow seed analyzers operating in various labs across several nations to get consistent findings.
- To the greatest extent feasible, connect the laboratory findings to planting value.
- To finish the exams in the quickest time feasible, taking into account the aforementioned goals.
- To carry out the tests as cheaply as possible.

It’s ISTA Each of its member nations conducts seed testing in accordance with the rules.Another significant accomplishment is the creation of the International Seed Analysis Certificate, which is extensively used in the global seed trade.

**Creating a Seed Testing Laboratory**

The center of seed quality control is the seed testing laboratory. Services for seed testing are sometimes needed to learn more about the planting value of seed batches. To effectively carry out these duties, seed testing laboratories must be established, staffed, and equipped in a way that allows any samples received to be analyzed in the shortest amount of time, thereby effectively meeting the needs of the seed industry[5], [6].The following factors are necessary for assuring successful seed testing, according to Kahre et al.

- A highly responsible crew that must keep working diligently even while the manager is absent.
- Standardization of tools, processes, and interpretations. In other words, reliable quality infrastructure and knowledgeable analysts.
- Good service, which includes quick analysis and a collaborative attitude among staff.
- Leaders with scientific backgrounds to provide guidance to all sorts of clients and, where appropriate, to those who submit samples, explanatory notes in reports.
- Encouragement of research that improves testing methods and the whole seed program by submitting real-world issues for scientific study.

## 2. DISCUSSION

A. It is important to prepare the physical infrastructure and facilities based on the average anticipated demand at the busiest time of year in order to handle seed samples effectively and without creating unnecessary delays. The workspace has to be big enough. This is significant since the amount of time spent reporting outcomes is quite significant [7], [8]. If necessary, there should be enough room left over for any additional sections, exams, etc.

B. In order to include provisions in the plan, it is necessary to determine in advance the types of tests that will be performed or are likely to be performed, such as routine testing, seed health tests, varietal purity tests, etc.

C. The choice and quantity of the equipment should be made in a way that allows for the effective management of the task. The apparatus must adhere to the necessary requirements.

D. To lessen the pressure of otherwise taxing job, adequate furnishings, light arrangements, and other essentials should be given. Building A seed testing lab may be situated in a separate structure or as a section of a larger structure that houses a Department. The full project may be set up in a hallway or in several rooms. The number of samples to be handled and the kind of tests to be conducted determine the size of the facility or area needed. The following measurements may be used as a general reference for evaluating 10,000 samples annually. There should be plenty of natural, glare-free light in the purity room in particular. It should be recommended to place windows in this area on the building's north side. Additionally, it would be ideal for the bottom window panes to open horizontally so that air entering the room is directed upward rather than straight into the seed analyst's workspace. The exterior of windows should also be screened to keep out insects and birds [9], [10].

The number of employees in the seed testing laboratory should be based on the quantity of samples, the types of crops that will be handled, and the types of tests that will be run. The ensuing standard might be used as a reference for a lab that receives 10,000 samples annually. During the busiest times, there is always a need for more workers. Graduate students should be hired on a daily salary basis to fulfill this demand.The kind of equipment and its specifications are included in the rules for testing seeds. Therefore, the tools for a laboratory for evaluating seeds need to be chosen appropriately. The only thing to buy should be the greatest. The equipment list that follows might be used as a general reference.Seed testing methods for evaluating quality for effective processing of seed samples, the following may be utilized as a management guidance for the work at a laboratory for seed testing.

**Receiving and registering seed samples**

Samples should be placed into a pre-printed register or forms and given a test number that will be utilized throughout the analysis. The information, such as the sender's name, the sample type, the tests that must be performed, the crop, the seed variety and class, etc., should be accurately documented. After assigning the test number, the samples that were specifically received for the moisture test in the moisture-proof containers should be sent to the moisture test section as such. It would be ideal to concurrently produce individual seed analysis cards and working sample envelops for quick operation. Each card and the envelope would always be printed with the test number. These are given to the person in charge of making the working samples. The whole project should be planned out so that it can be finished in one day.

**Moisture test**

Samples prepared for moisture testing need to be handled carefully since they might otherwise lose or absorb moisture from the environment. These samples should be sent for moisture testing analysis as soon as the test number has been assigned.

**Working sample**

After inputting the samples, the working sample or other tests are prepared. To reduce the amount of time needed to complete the seed tests, the first goal should be to create a workable sample for the germination or viability test. This will ensure that the seed testing process only takes as long as is necessary to complete the seed germination or viability test, as applicable. The seed washing on laboratory model equipment or the test weight determination may then be done if required at this point. For forwarding to the relevant department, working sample envelopes for the different tests should be serially arranged in sample trays together with the associated analysis card.

**Standard Tests**

In a seed testing facility, standard tests include germination tests, purity tests, tests for other seeds, and moisture tests. These tests should also be included in the normal testing for all such crops when the analysis for damaged seeds or other variety seeds is also wanted on a regular basis. To avoid unjustified delays in transmitting the findings, every effort should be taken to quickly analyze the samples. Rules outlined in the "Seed Testing Manual" must be followed while conducting these tests.

**Additional tests**

Every effort should be made to finish them as soon as feasible. These should be completed in accordance with the protocols provided. However, while presenting the findings, the name of the selected process must be provided.

**Reporting of findings**

Following the conclusion of the testing, the results are duly recorded on a printed form known as the "seed analysis certificate." The "length of time," or the number of days it takes to submit the result, is one of the frequent criticisms leveled against seed testing labs. Therefore, it's crucial to prevent unwarranted delays. Under the terms of the Seeds Act, the results of seed samples obtained from seed inspectors must be transmitted within 21 days of the date of receipt, but in no circumstances later than 30 days.

**Guard sample storage**

The submitted samples that the seed testing laboratory receives and on which reports are provided shall be held after analysis for a period of one year from the date of report issuance, under circumstances designed to prevent any quality changes from occurring significantly.

**Upkeep of records**

Records for every sample tested during the current year, season, or at any other defined period must be instantly accessible to meet the demands of seed certification, farmers, and other applicants. The records should be kept such that any information required may be found right away.

**Identification of Varieties Using Grow-Out Test and Electrophoresis**

Determine the genetic purity of the variety of the provided sample is the primary goal of the grow-out test. Growing the plants in the field allows researchers to investigate plant traits that are highly heritable and less impacted by the environment. Growing the variety where it has been introduced will allow the variety's traits to completely manifest themselves and allow for genetic purity testing. The specified cultural treatments should be followed when planting each sample to ensure that the variations between the kinds are adequately reflected.

**Sampling**

The standard protocol must be followed and the sample for the grow out test must be taken at the same time as the sample for the other quality tests.

The supplied sample must have the following size:

- 1000 g for species of the genera maize, cotton, groundnut, soybean, and others with seeds of a comparable size
- 500 g for species of other genera with seeds of a comparable size, such as sorghum, wheat, and paddy.
- 250 g of other genus species with seeds of a comparable size.
- 100 g each of forbajra, jute, and all other genera' species.
- 250 tubers, roots, cuttings, etc. Sweet potatoes, seed potatoes, and other crops that are vegetatively propagated.

Procedure The seed should be checked on a diaphanoscope to detect any seeds of a different kind before being sown in the field. It is necessary to separate the seeds from other varieties and record the proportion. The suspicious seed might also be separated and sowed separately for inspection. In parallel plots with standard samples at regular intervals, the different samples of the same cultivar are planted. Self-pollinated crops have permanent features that make it simple to recognize plants of different cultivars. For comparison between the samples to be tested and the standard sample, it is crucial to seed the real samples at regular intervals in cross-pollinated crops where character variability is higher. The sample plots need to be continuously monitored during the crop's whole growing season since some of the traits emerge at the seedling stage, while others do so at the blooming or maturity stages. Depending on the crop, there will be variations in plot size, row length, etc.

Depending on the germination rate of certain samples, the seed rate may be changed, and the sowing method may be done by dabbling. Following thinning is not advised. Both the test crop and the control may be grown in the locations suggested for the variety or in nurseries during the off-season. The testing station/Agency must follow standard operating protocols to preserve the genuine control sample from the source plant breeder/breeding institution. A minimum of 200 control sample plants will be cultivated alongside the test crop.

**Observations**

All plants should be examined while bearing in mind the distinctive traits listed for the cultivar in both the test crop and the control. In the event that the control is determined to be diverse, necessary changes may be included.Departures from the standard sample of the same variety are noted throughout the complete growing season or for a time period defined by the original breeding institute. The plots are carefully inspected at the sui development stage, and any plants that are clearly of a different cultivar are tallied and documented.

## 3. CONCLUSION

ISTA's consistent commitment to improving seed quality is in line with the demand for productive and sustainable agricultural systems worldwide. ISTA improves agricultural yields, food security, and economic development by developing strict quality assessment methods and promoting their use. Additionally, the association's attempts to keep up with technical developments show that it is flexible and attentive to the changing requirements of the seed sector. In conclusion, the International Seed Testing Association promotes cross-border cooperation and innovation by acting as a beacon of quality assurance. Its contributions are felt in fields, marketplaces, and kitchen tables all over the globe in addition to labs and testing facilities. ISTA's dedication to excellence endures in the face of the difficulties posed by a changing environment and increasing demand, and it plays a critical role in determining the course of future advancement in global agriculture.

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# CHAPTER 3

# A BRIEF DISCUSSION ON ECONOMICS OF GENEBANK COSTING

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**ABSTRACT**:

The Economics of Genebank Costing examines the economic dimensions associated with the management and maintenance of genebanks, crucial repositories of plant genetic resources. This paper delves into the complexities of costing genebank operations, considering factors such as infrastructure, personnel, technology, and conservation efforts. It highlights the significance of accurately assessing the economic implications of genebanks to make informed decisions about resource allocation and prioritize biodiversity conservation. By analyzing the economic considerations involved in genebank operations, this paper contributes to understanding the broader value of conserving plant genetic resources for sustainable agriculture and future food security.The Economics of Genebank Costing presents a critical lens through which the value of genebanks and their contribution to agricultural sustainability can be understood. As discussed in this exploration, genebanks are not just storehouses of seeds; they are reservoirs of genetic diversity that underpin crop resilience, adaptation, and innovation in the face of environmental changes and emerging challenges.

**KEYWORDS**:

Life-Cycle Assessment, Plant Breeding, Resource Allocation, Seed Production, Sustainability, Technological Innovation.

## 1. INTRODUCTION

To preserve germplasm, the "material that controls heredity," genebanks are a relatively new institutional invention. For the majority of agriculture's 10,000-year existence, farmers were the ones who stored seeds for sowing in a subsequent season. It wasn't until the early 20th century that the concept of storing seeds from all over the globe in specialized facilities for future use by breeders and others in both the near and far future truly started to catch on. The renowned Russian scientist Nikolai Vavilov deserves the majority of the credit for this concept and its execution. He gathered the greatest collection of species and strains of domesticated plants in the world over three decades of travel across five continents, and he also formulated theories on how to utilize this material to breed better variations. Ex situ genebanks that concentrate on certain classes of crops have been formed and extended from the seed collections kept by breeders and researchers[1], [2].

Crop development was Vavilov's top priority rather than conservation. Even more recently, there has been an increase in investment in long-term conservation. The first such facility, according to Pistorius, was the US National Seed Storage Laboratory in Fort Collins, Colorado, built in 1958. Since then, significant funds have been spent on gathering and preserving landraces, wild crop species, and weedy species in genebanks all across the globe. Concerns that the genetic basis of agriculture, whether for commercial or subsistence production, was narrowing globally for many agricultural crops due to the introduction of more genetically uniform but superior-performing varieties developed at an accelerating rate beginning in the 1960s, served as the driving force behind these investments. Ex situ global collections now in use are estimated to number over 6 million accessions across more than 1300 genebanks globally. 10% of these accessions are kept in the Consultative Group on

International Agricultural Research's centers, the majority of them as accessions held "in trust" for the world's people by the Food and Agriculture Organization of the United Nations. Since the 1970s, the CGIAR's 11 genebanks, which presently house over 660,000 accessions of crops primarily cultivated by low-income farmers, staple foods eaten globally, and tree species utilized in agroforestry systems, have played a crucial role in the global conservation effort.Over the last several decades, there have been an increasing number of contemporary ex situ conservation facilities, and germplasm storage technology has advanced significantly. However, since performance improvement and capacity growth have taken center stage, important management issues have gone unaddressed. These include what should be saved and how much of it, where it should be kept and created when needed, how conserved germplasm is utilized, and how it should be used[3], [4].

All of these inquiries have an economic component, but it is difficult to provide a precise response.3 First, estimating the marginal benefits of conserving each type of genebank accession is a crucial, but particularly challenging, component, in part because it is difficult, if not impossible, to infer which portion of a plant's agronomic improvement can be attributed to the use of conserved germplasm. Second, since many contemporary genebank facilities are so recent, not enough time has passed for breeders to create a useful time series of realized benefits attributable to their construction. Beyond the immediate agronomic benefits that may theoretically be estimated, germplasm also has value in terms of future demand that has not yet been discovered as well as the simple value of its presence as opposed to extinction.4 Although there are approaches for evaluating the total economic gains from seed conservation, empirical data are always going to be inaccurate.

On the other hand, the cost side mostly consists of things that may, in theory, be estimated using previous data that is pertinent to the current genebank activities. It may not be necessary to face the challenge of precisely estimating the latter to establish the economic justification of the genebank operation if the total and marginal costs of the genebank operations are judged to be less than any reasonable lower-bound estimate of the corresponding benefits. The International Food Policy Research Institute, in close cooperation with colleagues at five CGIAR genebanks, has been leading a series of thorough costing analyses over the last several years[5], [6].

Different genebanks will have various cost structures as a result of the consequences of the aforementioned variances. We chose five CG centers for in-depth investigations in order to analyze the range of cost structure within a fair amount of time, standardizing the data treatment as much as possible to enable valid comparisons. The five centers, which represent approximately 16 different crop species and more than 87% of the total collection held by the CGIAR, are Centro Internacional de Agricultura Tropical, Centro Internacional de Mejoramiento de Maz y Trigo, International Center for Agricultural Research in the Dry Areas, International Crops Research Institute for the Semi-Arid Tropics, and International Rice Research Institute. These studies provide the groundwork for addressing significant genebank management problems by evaluating the expenses of various genebank operations for each crop. These include choosing storage options that are affordable, establishing prices for distribution services, and figuring out economies of scale.

Germplasm preservation is a long-term undertaking that is better characterized as a commitment "in perpetuity." worries about the diminishing financial resources for ex situ genebanks have sparked interest in an independent and permanent financing structure; the significance of these worries is confirmed by the rising gap between short-term financial assistance and the long-term goal of the conservation endeavor. To determine the magnitude of a conservation endowment money required to sustain the present level of CG Genebank activities permanently is also an additional goal of this research. Investing in land set aside to maintain biodiversity in situ is analogous to endowing a fund to help the ex-situ conservation of genetic resources. To assure the long-term preservation of biological variety, both need an initial infusion of financial resources.

## 2. DISCUSSION

### Economics of Genebank Costing

Saving seeds in a genebank is more like keeping animals in a zoo or maintaining a botanical garden than it is like preserving books in a library or running a museum of history or antiquities. To maintain the health and long-term survival of seeds and other genetic material preserved as plantlets in unique growing media, specialized scientific knowledge and ongoing care are required. It takes a substantial amount of technical knowledge and access to equally extensive financial data to cost ex situ conservation operations in a way that is useful for policy and practice. In order to identify distinct cost components and evaluate the effects of various scientific management and conservation choices, it is also necessary to have a fundamental understanding of economic theory. Such cost information may be used wisely to identify possible efficiency advantages from changing course as well as serve as the foundation for assessing the costs associated with long-term germplasm conservation.The majority of seed samples kept at genebank facilities are packed into packets or tiny containers and kept there as an active collection for medium-term storage. As a basic collection, a large portion of this content is also stored in long-term storage facilities. The majority of seed samples, though not necessarily all of them—hence the need for caution—are believed to last for 20–30 years in medium-term storage and up to 100 years in long-term storage, depending on the species, the quality of the original seed, and the details of the storage environment. Every 5 to 10 years, seed samples are examined for viability and, if viability falls below a certain level, are regenerated[7], [8].

In field genebanks, vegetatively propagated species are preserved as whole plants. They are also preserved as living specimens, often kept in test tubes placed in warm, well-lit areas as part of so-called in vitro genebanks on a particular growing medium. Plants in field genebanks can be easily assessed and described, but they are subject to environmental changes. Due to increasingly severe phytosanitary regulations, they are also challenging to distribute worldwide. Plants are kept in controlled surroundings with less chance of natural catastrophe in in vitro genebanks, which also make it easier to ship disease-free resources throughout the world. Utilizing cryoconservation methods, which preserve plant material at very low temperatures, is another alternative for long-term conservation that could become commercially appealing. particular material is now kept in this manner, but the best cryoconservation practices for many speciesand even particular genotypes within a specieshave not yet been established, despite ongoing research.

The World Agroforestry Centre follows different preservation and distribution procedures for tree germplasm than the rest of the CGIAR generally does for crop species. While some material is preserved in field genebanks, the majority of distributions are created from seed obtained from "nuclear or catalyst stocks" housed at different sites across the globe. Some tree species are retained as seed in cold storage, but other material is preserved in this manner.

### Shipping Plant Materials and Seeds

The distribution of free seed and other plant samples upon request is another significant service provided by genebanks, particularly CG genebanks, as a complement to the conservation services. Samples for immediate dissemination are kept in active collections for medium-term storage, requiring more regular viability testing and regeneration. the total number of seed samples distributed during a recent 7-year period from several CG genebanks. Nearly 600,000 samples were distributed by the CG genebanks between 1994 and 1999, more than half of which were given to breeders and other researchers at each center[9], [10].

Landraces and wild species make up the majority of the samples stored in the CG genebanks. Although this material is a significant source of genetic diversity, crop breeding programs currently have less access to it due to the limited knowledge about specific traits that may exist in particular varieties and the expense of expressing any such traits in advanced breeding lines or commercial varieties that are ready for release to farmers. As a result, breeders have less need for this kind of material than they do for breeding lines with more established breeding characteristics. Despite the fact that a sizable number of samples have been provided, the figure may not accurately reflect real use. More thorough data on the material's influence on international crop-breeding efforts as sources of novel, desired characteristics, among other applications, is required in order to accurately estimate the use value of the CG genebanks' material.

We divided the genebank activities into three major service areas for the costing analysis: distribution, information, and conservation. In order to sustain the stored plants and seeds for use in the far future, conservation services involve keeping agricultural genetic variety in the form of a "base collection" kept under controlled environmental settings. storing healthy, viable germplasm in long-term storage, regularly testing viability and regenerating stored material as necessary, and storing copies of the collection at other places for safety are all necessary for properly carrying out this job. Maintaining records of each holding's size, condition, and 'passport' information, which includes information on the sample's origin and physical characteristics, are additional basic conservation duties. For the goal of disease detection or plant regeneration, a large portion of this agronomic data is gathered while the seeds are being cultivated in greenhouses or on the ground.

The distribution efforts include supplying particular samples in response to requests. In order to provide samples of seed or in vitro plantlets of crops like cassava to researchers, crop breeders, farmers, and other genebanks, this usually entails keeping a "active collection" of germplasm in a medium-term storage facility. The environment in active storage facilities is less conducive to long-term conservation, and seed sample sizes gradually decrease and eventually need replenishment even if the seed is still viable, so material stored in active collections typically requires more frequent regeneration.

For the goal of facilitating the use of material for crop improvement or other research reasons, information services provide a variety of valuable and consistently available data about each accession. Some of this data is gathered by specifically searching the genebank collection for cultivars that are resistant to certain pests and illnesses. A growing number of contemporary biotechnology technologies are being employed to gather molecular data, determining the genetic foundation for certain characteristics and other genetic data considered desirable in breeding programs.

It's not always easy to distinguish between genebank and breeding tasks. various information services in various contexts come from crop-breeding initiatives. In certain instances, prebreeding procedures that are generally carried out as part of breeding programs come within the purview of genetic resource or genebank programs. We limited the scope of our costing exercise to those tasks that are necessary to meet the demands for conservation and dissemination imposed on a genebank in order to effectively compare different centers using a uniform set of core conservation operations.

## Genebanking's Simple Economic Theory

In order to organize the costing exercise, we thought about how genebank operations fit into a production economics framework, where inputs like labor, facilities, machinery, and purchased seeds are processed to create outputs like seeds that are stored and distributed as well as the data that goes with them. Seeds that have been properly preserved may be distributed on demand for use right away or kept in storage as usage alternatives that can be used again if required in future years.

As previously mentioned, we also divided total costs into their variable, capital, and quasi-fixed components before summing up each group in terms of average and marginal costs

- Dependent on the operation's size, variable inputs include labor inputs like technicians and temporary employees who are often paid on a daily basis, as well as operational inputs like electricity and a variety of material inputs.
- Capital inputs, such as structures and durable machinery, are unaffected by the operation's size.
- Uasi-fixed inputs are indivisible units that cannot be readily divided and are sensitive to minute changes in the amount of genebank activities, but they are more variable than capital items. They are neither fixed nor variable, but rather "lumpy," meaning they are more variable than capital items. The expenses of "human capital," or skilled labor and scientific knowledge, such as genebank administrators and lab scientists, are considered quasi-fixed inputs in this approach.

With the use of this categorization, it is feasible to assess the scope of potential economies of scale, which, broadly speaking, relate to decreases in the cost of producing one unit of output as an activity grows in size. The phenomena reflects elements like the proper division of labor and the declining surface area to volume ratio of the refrigeration plant. In bigger businesses, comparably well-paid geneticists or agronomists may be entirely occupied with managing the genebank as opposed to devoting time to less beneficial duties like sorting and categorizing seed, which are best delegated to less costly technicians or temporary employees. When the genebank facility is big enough to use additional lumpy fixed components, like physical infrastructure and scientific competence, as well as variable inputs, like hired labor and chemicals, effectively, economies of scale are further utilized.

When inputs are employed effectively, the mix of those inputs in the preservation and distribution of seed should shift when the relative prices of inputs, such as labor and chemicals, fluctuate. The degree of complementarity or substitutability between the various inputs determines how sensitive the input mix is to changes in relative pricing. When labor costs rise over time, for example, alternative inputs might be substituted for labor, such as enhanced refrigeration equipment that extends seed storage life and, in turn, shortens the regeneration cycle, lowering the need for labor overall.

Long-term changes in genebank technology also have an impact on the ideal mix, quantity, and cost of inputs. Improvements in express mail might speed up and reduce the cost of worldwide seed delivery, eliminating the need for additional global conservation facilities. Furthermore, according to the so-called "induced-innovation model of technological change," the pace and form of change in the technologies accessible may both be influenced by changes in relative pricing. The amount and direction of the short-term alterations in input mix caused by price changes will often be reinforced over the longer term by technological developments.

**Costing factors for genebank operations**

We took great care to guarantee uniformity in the range and handling of the cost data gathered and put together for this research. To do so required resolving a number of theoretical and practical problems.

**Adaptive protocols**

Most genebanks were rebuilding and reorganizing their operations throughout the study period, which changed some of their preservation processes. These adjustments were often prompted by the System-wide Genetic Resources Program's 1995 evaluation of the center genebanks, and they sometimes reflected plans carried out by specific centers.

For instance, one genebank was rearranging its storage space among different crops to better use the available space, while another was erecting brand-new buildings to suit increasing activities. Cost structures while activities are being handled in a stable state might vary significantly from cost profiles during a transitional phase. In order to mimic expenditures paid in future years, we projected these typical costs forward for this research, abstracting from anomalous characteristics and assuming away technology advancements. We then collected and analyzed the data for a "representative" snapshot year.

**Jointness-divisibility**

A CG center has several different programs, including the genebank. Most of the time, some services needed to run a genebank are centrally offered and shared with other programs. For instance, engineering units, field operation units, and seed health testing units often provide services to multiple programs within a center, reaping scale economies and other efficiencies in the process. Each of these services would need to be acquired separately by a genebank functioning as a standalone facility, increasing the expenses from those shown above. Because the expenses of the shared operations are divided among the programs in this research, a portion of them are allocated to the genebank depending on its percentage of service use. Other centrally delivered services with expenses that cannot be distributed in this manner are prorated into overhead costs.

The functioning of the genebank also raises the problem of jointness. Although the basic goal of regeneration is to restore seed supplies in just one area of the storage facility, when accessions are renewed due to poor viability or low stock, the common practice is to regenerate enough seeds for both medium- and long-term storage.

This analysis makes the assumption that both conservation and distribution functions are equally represented in the regeneration costs and that the regeneration is carried out for both reasons. Similar to this, all of the packaging for various reasons is completed at the same time as seeds are being packaged after washing and drying.

Once again, this analysis makes the assumption that the packing is separate, and it divides the expenses of packing across several processes in accordance with the quantity of labor and material needed for each goal.

## 3. CONCLUSION

Policymakers, researchers, and stakeholders may allocate resources wisely by thoroughly examining the expenses connected with genebank operations. Accurate pricing makes it possible to maintain the diversity and adaptability of plant genetic resources, which are necessary for creating new crop varieties that can meet changing agricultural demands. Genebanks represent an investment in resilience at a time of climate instability and rising needs for food supply. Their operating expenses go beyond simple financial ones; they also represent investments in the future of agriculture and food security. The Economics of Genebank Costing ultimately highlights the necessity for ongoing assistance and strategic planning to protect these priceless biodiversity repositories for the prosperity of the current and future generations.

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# CHAPTER 4

# DYNAMIC COSTS AND LIFE-CYCLE CONSIDERATIONS GERMPLASM

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**ABSTRACT**:

Dynamic costs and life-cycle considerations are critical factors in germplasm management, impacting the sustainable utilization of genetic resources. Germplasm, the genetic material of plants, is integral to crop improvement and breeding programs. This study explores the multifaceted dimensions of dynamic costs and life-cycle considerations in germplasm management. We examine how various elements, including collection, conservation, characterization, distribution, and utilization of germplasm, contribute to the overall costs and sustainability of genetic resource programs. Through a comprehensive review of literature and case studies, we elucidate the economic, environmental, and social implications of different stages within the germplasm life cycle. Furthermore, we highlight strategies for optimizing germplasm management by considering these dynamic costs and life-cycle factors. Ultimately, understanding and addressing these aspects are vital for effective germplasm management and the long-term success of agricultural and biodiversity conservation efforts.

**KEYWORDS**:

Agricultural Economics, Breeding Programs, Cost Analysis, Genetic Resources, Germplasm Management, Life-Cycle Assessment.

## 1. INTRODUCTION

Two sets of conservation guidelines are outlined in the genebank standards of the FAO and the International Plant Genetic Resources Institute. One is a "accep standard," which is thought to be minimum yet sufficient, at least temporarily. The second is known as the "preferred standard," which outlines the fundamental conservation requirements that result in a "higher and thus safer standard." Due to the budgetary realities, the majority of CG genebanks lack the means to fulfill the prerequisites for the desired standard. Genebank managers are therefore constantly compelled to balance priorities, adopting acceptable standards for certain components of the collection while meeting some aspects of the chosen standard for other sections, and in other circumstances, making due with less-than-acceptable standards[1], [2].

It is obvious that meeting the desired standard is more expensive than keeping the asset in an accep state, hence it might be challenging to take cost statistics at face value. If an operation in one genebank is somewhat expensive, it does not always mean that it is less effective than an equivalent operation in a genebank with lower costs. It can only mean a greater level of performance. Comparing expenses on the assumption that everything else is equal may be quite deceptive since quality standards change over time both across centers and within centers[3], [4].

### Capital expenses

We gathered data on the purchase costs of each capital item and merged the findings with ideas about the service profiles of each item and the actual rate of interest to estimate the yearly "user cost" of capital. Because previous capital purchases were made at various times, they were inflated forward and expressed as a set of base-year prices using the most appropriate price index series. We also made the assumption that depreciation would occur on a "one-hoss-shay" basis, meaning that the capital good would last until the end of its useful life before completely disappearing.1 The annualized cost may be simply determined using the interest rate and service life of each item in Appendix A as yearly depreciation costs are constant under this profile.A sample's viability is checked around every five years, and the expenses of certain activities, like storage, are spent yearly. In contrast, the costs of other processes, like regeneration, are incurred intermittently, about every 20 to 30 years. Therefore, the costs of conservation for a sample in any given year vary on the length of storage and the condition of the sample.The price of saving germplasm depends on a variety of elements, including the kind of crop, the conservation techniques used, the environment in which the germplasm is housed, and institutional arrangements. Few studies, however, make an effort to fully and sufficiently examine the financial implications of various conservation strategies for various crops in various locations. Some research uses a deceptive strategy by gathering data via surveys. The primary drawbacks of these survey-based systems are highlighted as subjective, inconsistent replies, and excessive aggregation. Other research, at a major time and labor expense, directly gathered data via site visits and interviews to overcome these constraints[5], [6].

Virchow evaluated per-accession yearly conservation expenditures for each country using national conservation spending data from 39 countries acquired as part of an international study carried out in 1995–1996. These figures are used to assess the effectiveness of various nations in protecting plant genetic resources. The estimated cost varies from $1 per accession in Austria to $1293 per accession in Egypt. The study's weaknesses include the ill-defined scope of the conservation actions, the highly aggregated data, and the replies' varying degrees of accuracy per nation. While the per-accession cost estimates were created using the number of accession- sions housed exclusively in ex situ collections, the stated total expenditures encompass both in situ and ex situ conservation initiatives.

Burstin et al. looked at the costs of preserving sexually and vegetatively propagated species in different French national genebank networks in a more in-depth survey-based analysis. The authors computed the yearly and long-term expenses of each operation using survey data on the costs of storing, regenerating, and characterizing each crop as well as the expected cycles of each operation. The relevant cost information for various crops could not be comparable since different genebank administrators may have used different criteria or incorporated different operating guidelines. This study's failure to discount the cost flows to net present value when calculating the costs of frequently conducted activities is another drawback[7], [8].

SGRP reported the necessary costs to bring the CG Genebank operations up to par with worldwide standards, while not being a costing study per se. The analysis estimated that an extra $20.8 million was needed to modernize all 11 CG genebanks in addition to their present yearly operational expenditures.Genebanks that are far from the acceptable standard must, of course, spend more money than those that are near to it. As a result, the amount of funding requested in this report reflected the current state of genebank operations in relation to the desired level; it did not include information on the current cost of conserving accessions or the structural or managerial changes that would improve the cost effectiveness of the genebank system as a whole or its individual components. It is clear that survey-based methods have issues. Genebanks are so heterogeneous and complicated that even if the survey is thoroughly planned and presented, the results are often inconsistent and open to the respondent's subjective interpretation. An alternate strategy is to explicitly gather information on each cost component via on-site inspections and interviews, rebuild the costs of running a genebank, and then compare and contrast the results. This method was used by Epperson et al. to analyze the expenses of maintaining the cassava collection at CIAT in Colombia. They calculated the variable and fixed costs of maintaining the cassava genebanks both in vitro and in the field. Although their analysis significantly outperforms other survey-based studies, it only took into account cost estimates for one year without taking into consideration the various conditions of stored accessions and the dynamic features of conservation costs.

## 2. DISCUSSION

The CIMMYT's maize holdings are based on a collection that was originally put together as part of a collaborative program between the Rockefeller Foundation and the Government of Mexico that was started in 1943 and aimed to increase the productivity of Mexico's staple food crops.

To carry out this program of study, the Mexican Ministry of Agriculture created an Office of Special Studies, and a Mexican seed bank was established in 1944. Its maize collection contained more than 2000 samples by 1947. Additional maize samples were gathered from journeys throughout Latin America, the USA, and Canada with the formation of a US National Academy of Sciences-National Research Council program in the early 1950s. In the NAS-NRC endeavor, almost 11,000 samples were gathered. The Mexican genebank at Chapingo, which OSS maintained and ran until 1959, had seeds from Mexico, Central America, and the Caribbean.

The Inter-American Maize Program was introduced simultaneously with the closing of the OSS and the subsequent transfer of its maize holdings to the newly established national research organization. The Government of Mexico and the Rockefeller Foundation collaborated on this endeavor to copy and rejuvenate the complete collection at the Instituto Nacional de Investigations Agrarians. A portion of the Latin American NAS-NRC collection, which served as the foundation for the CIMMYT maize collection and was sent to Mexico from the NSSL laboratory in Fort Collins, was also revived by the initiative. In the late 1960s, CIMMYT took part in a number of excursions to collect maize throughout Mexico and the Andes[9], [10].

Following then, the CIMMYT holdings developed more quickly, reaching their prior level of more than 17,000 accessions. The Special Cooperative Agreement to renew Latin American maize germplasm, which included 13 nations from 1992 to 1996, was a major cause of this faster increase. In all, 6736 accessions had been rebuilt by 1996, and backup samples had been sent to NSSL and CIMMYT for long-term preservation.

The regenerated samples' characterisation information was likewise captured by CIMMYT. The US Department of Agriculture oversaw the Pioneer Hi-Bred International-funded Latin American Maize Project, which analyzed over 12,000 Latin American accessions between 1987 and 1996. The CIMMYT maize breeding program, from which samples of elite experimental varieties, source populations, and inbred lines are obtained, is another important source of new genebank accessions.

The CIMMYT collection also contains two more species that are crucial to maize breeders in addition to Zea mays. CIMMYT collected 2500 samples as cuttings from 158 populations of the perennial plant Tripsacum spread over Mexico between 1989 and 1992. A live base collection of around 150 of these samples has been formed at the CIMMYT field station in Tlaltizapan, Morelos. This information is being utilized in a cooperative project between the Institut de Recherche pour le Development and CIMMYT to explore the transmission of apomixis from Tripsacum to Z. mays using novel molecular methods. The closest wild cousin of maize, teosinte, is likewise kept in stock by CIMMYT. Teosinte outcrosses with maize and other teosinte accessions, hence it is necessary to grow and conserve these plants separately on experimental plots, preferably via open pollination among more than 100 plants.

**Facility for Genebank**

Early CIMMYT activities focused almost entirely on raising wheat and maize yields, primarily via the creation of better varieties. This emphasis on crop breeding was reflected in the institute's germplasm collection. The National School of Agriculture, Chapingo's CIMMYT maize collection was held in refrigerated storage facilities in the basement of the soil science building from 1966 to 1971. The collection was moved to CIMMYT at El Batan, Texcoco, when a new seed-storage facility there was finished in 1971. The facility originally had two 145 m3 0°C-temperature refrigeration chambers, but in 1984 it underwent renovations to add one chamber for long-term storage of a base maize collection. It was decided to keep the second chamber for a working maize collection. The storage area was almost at full by the late 1980s.The wheat stocks maintained by CIMMYT were first kept in tiny, paper packets kept in ice chests. The gathering of wheat was transferred to a newly built 1500 m2 facility with four chilled chambers in 1981. Two smaller chambers, with a combined capacity of 180,000 accessions, were preserved at roughly 2°C for medium-term storage of a base collection of CIMMYT's research output, while two bigger chambers, with a combined capacity of 90,000 accessions, were maintained at 4-5°C for an active collection of germplasm. However, when CIMMYT's goals increasingly expanded to include germplasm preservation in the 1980s, it became imperative to build a suitable facility with low humidity and temperatures to hold this new base collection for the long term.

A new genebank facility was being built, with funding provided by the Japanese government, and the primary construction phase was finished by May 1996.1 A single facility was built to house the maize and wheat collections, and it is equipped with cutting-edge technologies for medium- and long-term storage. The primary building of the new genebank facility is a reinforced, two-story concrete bunker designed to resist the majority of conceivable natural or man-made calamities. The building has alarms, security features, and a backup power source, and the environment is managed to meet exact temperature and humidity requirements. The active collection is kept on the top level of the storage rooms at a temperature of slightly below freezing and a relative humidity of 25 to 30 percent. The 'functioning' portion of the bank is made up of this, and it is from this that CIMMYT and other scientists' seed requests are satisfied. The basic collection is kept at 18°C at the bottom level, largely for long-term archival purposes. To make the most use of the limited space, the seeds are kept on moveable shelves.

**CIMMYT Genebank prices**

**Costs of capital inputs**

There is a breakdown of the equipment expenses for CIMMYT's genebank operation as well as the capital costs associated with the genebank facility. A seed laboratory used for germination testing that is shared by the maize and wheat programs, drying rooms, different work rooms, offices, and rooms for cleaning, sorting, and packaging seeds intended for storage at CIMMYT or transportation elsewhere round out the storage facility. A backup power production unit also provides service to the genebank. The genebank receives a significant portion, but not all, of the backup power unit's cost. This decision was made after discussion with the plant management at CIMMYT. Each crop received an equal share of the costs associated with storing the maize and wheat collections.

**Preserving Seeds**

It is expensive to keep the storage facilities of the genebank at exact, low temperatures and low relative humidity. The cost of energy to operate the compressors, dehumidifiers, and fans, the cost of maintaining this equipment, and the associated expenses of running an emergency backup power plant are among the variable costs of maintaining the climate in the CIMMYT complex. It might be challenging to allocate these expenditures to the germplasm facility since they only make up a small portion of the total expenses associated with running the institute's physical plant. We directly costed the energy necessary to keep the genebank at its designated environment in order to arrive at the estimates. We also assessed the expenses of a regular maintenance plan for the climate-control equipment and backup power-generation unit.

The expenses associated with building, maintaining, and administering the numerous databases utilized in the functioning of the genebank are included in the information management costs. In order to prevent duplicate counting, we subtracted this price from the overall CIMMYT overhead rate. This includes the cost of software development by CIMMYT's computer-support employees. The cost of the technical employees, managers, and other general expenditures associated with running a genebank are all included in the "general management" category. One of the key justifications for keeping a genebank apart from the operational collections kept by breeders is the protection of genetic resources. From this vantage point, these charges are seen as a pretty lumpy group of expenses that were divided among the numerous conservation and disseminating tasks listed in the paragraphs that follow.

**Testing for Germination**

The viability of stored seeds steadily declines with time; thus it is necessary to monitor their germination rates on a regular basis. When processing seed for the first time upon admission into the genebank or after the most recent regeneration, CIMMYT starts the monitoring and regeneration operations for wheat with a germination test. A sample of each accession's seed is put in a germi- nation chamber for five days, and its viability is assessed; if the accession's germination rate falls below 85%, a cycle of regeneration is initiated. The sample is retested later if it meets the viability requirement. The active collection is sampled for germination testing using a computer program, which chooses a number of 5-year-old accessions, more 10-year-old seeds, more 20-year-old seeds, and so on. Currently, the maize genebank also uses samples from the active collection for germination testing, restoring both the active and base collections in the event that the sample doesn't successfully germinate. This process eventually settles at a 5-year period. The expenses of the labor necessary to conduct the tests, as well as extra costs associated with conservation and distribution at the CIMMYT genebank, make up a significant portion of the expenditures associated with viability assessments.

Regeneration Minimizing the chances of genetic drift and keeping a collection whose genetic make-up closely resembles that of the original holdings are the key management challenges in managing the regeneration of an ex-situ collection. The loss of alleles from one regeneration cycle to the next is referred to as genetic drift. To maintain sample size, regeneration cycles may be run more often, but the regeneration process must be carefully controlled to reduce genetic drift. For instance, in an open-pollinating crop like maize, hand-pollination may be required to avoid drift towards the higher-pollen feature if certain seeds in an accession have the tendency to produce more pollen than others. Additionally, if samples are grown in circumstances that significantly deviate from the native ecosystem in terms of soil, chemical inputs, or sun, genetic drift may be accelerated. When regenerating wild relatives and certain landraces that have been specially suited to their growing habitats, this is often more of a worry than when regenerating more sophisticated breeding lines and better cultivars. In a screenhouse in El Batan or in Mexicali, wheat accessions are now typically regenerated. With up to three cycles per year at staggered periods to disperse the usage of labor, regeneration may occur year-round under regulated and protected settings at the screenhouse plant. An unusually high number of accessions were created in 1996, the study's sample year, in order to address possible Karnal bunt issues while moving items from the old to the new storage facility that year. Before being transported to Mexicali, in the state of Baja California Norte, where they were sowed out in 1 m rows to scale up the sample size to 500 g, seed samples were first prepared in specific plots at the El Batan field stations. The time of harvest and the completion of field books, which record numerous morphological and physiological parameters for each accession, are when labor needs for the regeneration process are at their highest.

At Tlaltizapan, Morelos, CIMMYT regenerates the majority of their tropical low- and intermediate-elevation maize accessions, whereas El Batan is utilized for germplasm from the tropical highlands. For two cycles each year, maize occupies 1.5 hectares in El Batan and 2.5 ha in Tlaltizapan. A maize accession must regenerate at least 16 5-m rows, but we based our estimates on a 20-row standard to allow for unsuccessful regeneration. Since there are around 2000 rows per ha, 650 maize accessions must be distributed throughout a total of 6.5 acres.

Before the completion of this research, the maize program often did not renew incoming accessions before adding them to the genebank. Processing a new introduction to the genebank entails similar steps to processing an existing accession if regeneration is done, with a few more steps. The imported seed is extensively checked upon arrival for any known or suspected seed-health issues; if any are discovered, the seed is burnt. Before sowing, wheat and maize seeds are deep freeze to eliminate any insects. Under strict pest management protocols, the initial regeneration is carried out on introduction plots that have been specifically isolated. The plants that are used in this procedure are examined by the seed-health unit, as well as the seed that results. Maize seeds are collected from the introduction plots, formed into bulk samples, and then added right away to the genebank. In order to increase the quality of the wheat seed before storage, it goes through one more cycle of regeneration in the screenhouse before being sown at El Batan. Before an accession is officially added to the collection, other characterisation and data-entry tasks are completed in addition to the seed-health considerations.

Maize seeds must to be physically cleaned, sorted, and examined more thoroughly than wheat seeds since each ear of maize have to be checked for damaged or sick seeds. Wheat seeds, although being fundamentally simpler to handle, need relatively greater care with regard to elements of seed health, as mentioned above and in more detail.

The labor required to enter pertinent information into field books is comparable for maize and wheat accessions, although wheat's greater planting density allows for some time savings over maize. In two sets of containers, one for the active collection and the other for long-term storage in the base collection, each wheat and maize accession is kept at the CIMMYT headquarters. Every wheat accession, whether it be for short-term or long-term storage, is kept in an aluminum bag that costs 11 cents; every maize accession kept in the active collection is sealed in a plastic bucket that costs $2.80; and every accession kept in the base collection is put in two aluminium bags that cost 15 cents each. Also created for backup storage in the NSSL in Fort Collins, Colorado, is a sample of each accession.

## 3. CONCLUSION

Crop development and conservation programs are substantially impacted by the intricate interplay of dynamic costs and life-cycle factors that go into germplasm management. This research emphasizes the need of considering germplasm management as a whole process, whose costs go beyond simple financial outlays and include environmental and social aspects. The foundation is laid during the collecting phase, and effective and planned sampling has an influence on actions that take place afterwards. Short-term expenses and long-term sustainability of conservation strategies are influenced by the decision between in situ and ex situ approaches. Characterization and assessment let decision-makers make well-informed choices that result in efficient use of germplasm. The distribution of germplasm is crucial because fair sharing procedures have an impact on global partnerships and resource accessibility. Integration of cutting-edge technology and data management programs may boost productivity and save expenses across the board. Enhancing social capital and promoting capacity development within communities guarantees sustainable germplasm management.

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# CHAPTER 5

# EXPLORING THE SIGNIFICANCE OF SEED HEALTH IN MODERN AGRICULTURE

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**ABSTRACT**:
Seed health is a fundamental aspect of agricultural productivity and food security. Ensuring the quality and viability of seeds is essential for successful crop production and disease prevention. This review explores the significance of seed health in modern agriculture, encompassing the factors influencing seed-borne diseases, detection methods, and management strategies. We delve into the interplay between seed health, plant pathogens, and environmental conditions, highlighting the importance of early detection and preventive measures. By analyzing current research and case studies, we outline the pivotal role of seed health in sustainable agriculture and emphasize the need for collaborative efforts among researchers, farmers, and policymakers to safeguard global food systems.Seed health stands as a cornerstone of agricultural sustainability and food security. As highlighted in this review, healthy seeds are the first line of defense against crop losses due to pathogens. Understanding the complex interactions between plant pathogens, seeds, and the environment is crucial for effective disease management. The adoption of advanced detection techniques, including molecular methods and high-throughput screening, has revolutionized our ability to identify and characterize seed-borne pathogens.

**KEYWORDS**:

Disease Resistance, Fungal Pathogens, Genetic Diversity, Pathogen Detection, Plant Health, Seed-borne Diseases.

## 1. INTRODUCTION

Before being added to the genebank, every newly imported material is submitted to seed-health examinations. Our pricing plans take this criterion into consideration since all seeds that are sent out must also be certified as healthy. However, we were careful to avoid duplicate counting health expenses; for successive shipments of the collection's maize seed, all but rare circumstances, the inspections performed at the time of introducing or regenerating maize seed are sufficient.

When wheat seeds are introduced for the first time and again when samples are packed for transportation, checks are made. The majority of the relevant seed-health activities and related expenses are handled by CIMMYT's seed-health unit.

Although only a portion of the seed-health operation is related to accessions entering and leaving the genebank, only a portion of the overall seed-health costs are included. The labor and other operational costs for the genebank operation are included within the acquisition and dissemination costs[1], [2].

The genebank is responsible for certain direct seed-health expenses. A well-run genebank will routinely check for ambient spores, keep an eye on the cleanliness of the equipment used to process the seed, and take preventative measures to get rid of any potential contamination. At CIMMYT, this includes daily bleaching of all walls and floors in areas where seeds are processed. The genebank paid a price for the efforts made to combat Karnal bunt. Despite not being especially severe or economically significant, Karnal Bunt limits the acceptance of seed that has been contaminated or infected by the fungus by several national quarantine organizations[3], [4].

The Karnal bunt infestation in the CIMMYT fields at Ciudad Obregon, Sonora, which were regularly utilized by the genebank prior to 1987, is what caused CIMMYT's problems with this disease. The Karnal bunt issue prevents the Sonora fields from being exploited, despite the fact that they are in many ways perfect for renewing seeds. Instead, wheat seeds are now grown in sterile plots in El Batan, tested for spores in bulk samples after being chlorinated, revived at Mexicali, and then transported back to El Batan in sealed containers. As previously reported, a Jacuzzi-like technique for washing wheat seeds was created to assist large-scale disinfestation for Karnal bunt. Additional regeneration costs, unique shipping processes and associated phytosanitary certification expenses, extra chemical treatments, and increased seed-health monitoring costs are all associated with dealing with the infection. These expenses are included in the estimations given.

**Distributing and Multiplying Seeds**

Different methods of distribution from the genebank are used. The staff of the genebank uses certain material for characterization or review. In answer to specific requests from breeders, plant pathologists, and others at CIMMYT or abroad, more information is supplied. Additionally, seed is transported to other genebank sites, often as part of CIMMYT's collaborative collection and conservation efforts with national agricultural research systems in poor nations. The expenses of selecting the seeds that will best satisfy each request, assembling, treating, and packing the samples to be delivered, and then shipping them are all involved in responding to such a varied range of seed requests[5], [6].

The quantity of shipments produced, together with the size and destination of each cargo, affect another set of expenses. In addition, every cargo leaving Mexico is subject to phytosanitary inspections; this certification procedure is a time-consuming and expensive process. at addition to the expense of the certifications themselves, preparing the required paperwork and making the necessary arrangements for the shipping requires the time of employees at CIMMYT's seed-health unit and the genebank. Additionally, a Material Transfer Agreement must be created, monitored, and reported in order to accompany shipments of seed from CIMMYT and transfer use rights to the seed.

The backup wheat collections are packaged, labeled, and wrapped in aluminum-foil bags before being combined into cardboard boxes with up to 400 accessions each. These 'black boxes' are then delivered and stored. The boxes are air freighted to the storage location for the backup facility. We included the costs of setting up the samples and packaging each box into our pricing estimates. The last shipment of black boxes from El Batan to Fort Collins in 1996 cost $342 in freight for 35,000 duplicates. To save transportation expenses, duplicate wheat is gathered and delivered occasionally.

Instead of using the black-box strategy, CIMMYT's maize holdings are copied and preserved as a crucial component of the NSSL collection. Each year, NSSL receives new introductions and regenerated accessions, and by 1996, NSSL had backed up nearly 80% of the CIMMYT maize collection. The regenerated seed is dried and then between 1500 and 2000 accessions are transported annually in cheesecloth bags. The NSSL repacks and keeps the accessions in bags made of aluminum. Along with data on the quantity of seed in storage and its germination condition, CIMMYT identification numbers are put into the data-management system at NSSL.

**Management of Data and Information**

The maintenance of the data that describes each entry is essential to the genebank. Operationally, it is challenging to distinguish between the data created by and necessary for the breeding program at CIMMYT and elsewhere in the globe and the data utilized in the efficient management of genebanks. The data have many uses in certain cases.

The adoption of standardized accession ID numbers, similar processes for collecting and reporting performance assessment data, and suitable software for recording, storing, retrieving, and analyzing such data results in significant advantages for both seed conservation and breeding[7], [8].

The genebank's regular operations include entering passport information, which describes the seed's origin and source, when an accession first joins the collection, processing field data gathered during trials on new accessions and subsequent regenerations, and maintaining the database that tracks each accession's storage location, time in storage, seed viability history, and stock levels. To speed up this procedure, each maize accession in the genebank is being labeled with a barcode.

Systems for managing genebanks are a component of a larger initiative at CIMMYT to enhance the data base for the center's considerable maize and wheat holdings. Several changes have taken place recently:

- With joint project money from Australia and core funding from CIMMYT, a new system known as the Genetic Resources Information Package has been created. The System-wide Information Network for Genetic Resources has also been updated with the data submitted into this system.
- The International Wheat Information System, a computer database system that incorporates data from nursery trials through to pedigree information and is able to track lineages of advanced breeding lines, has included the Wheat Genebank Management System.
- By joining the SINGER project, the Maize Germplasm Bank Management System was also modified.
- All of CIMMYT's maize-bank accessions, including the initial collection and regenerations from continuing LAMP partnership, have passport information available on a CD-ROM thanks to LAMP.

## 2. DISCUSSION

In order to get a more accurate estimate of the yearly cost totals, we resorted to a more usual set of accession numbers in certain of the genebank activities that represented anomalous activity levels throughout the survey year. divides the $543,089 adjusted annual operating cost into its numerous cost segments. Labor inputs account for around 65% of the yearly cost of running the genebank, with the remaining expenditures being split between operational expenses and the annualized cost of capital.

The capital expenses of operating the CIMMYT genebank are not particularly indicative of a capital-intensive enterprise when presented in yearly terms. In fact, much like the crop improvement research it supports, maintaining a genebank is a labor-intensive task that incurs large, ongoing "overheads" costs due to the labor needed to operate the bank, replenish the collection, and do other things to keep it viable. The ideal way to handle the roughly two-thirds of these labor expenses that are lumpy is as a quasi-fixed input[9], [10].

Between wheat and maize, there are major differences in the cost structure. While there are significant disparities in the structure of their variable costs, the yearly cost of physical capital inputs is not significantly different across CIMMYT's wheat and maize operations. Each year, the maize program invests far more in rejuvenating its assets than the wheat program. In fact, only 28% of the variable costs for wheat and 58% of the expenses for maize are attributable to regenerating seed. Given the diverse, outcrossing character of maize, these discrepancies are mostly attributable to the much greater amount of labor needed to renew maize while preventing genetic drift.

**Average annual expenses**

The average costs per accession described in offer upper-bound estimates of the corresponding marginal costs given that the genebank is running at full capacity. These marginal costs are crucial for determining the economics of short-term or marginal adjustments to genebank operations. What would it cost to keep a current accession in storage for an additional year, or, in the alternative, what would it save in terms of costs by removing a duplicate accession from the genebank? The response relies on the crop in question as well as the sample's condition, including how long it has been in storage, when a regeneration or germination test was conducted, and other factors. Holding over an accession of any crop for an additional year is inexpensive if the sample is known to be viable; it costs only 19 cents for a wheat accession and 93 cents for a maize accession. The price of storing the seed for a further year, however, substantially increases to $3.45 and $109.64 for each accession of wheat and maize, respectively, if the viability of the seed has to be verified and the sample regenerated since it failed the test. It is obvious that removing duplicate accessions might result in significant cost reductions. In fact, it would be cost-effective to pay up to $109 to find out if a maize accession was replicated before regeneration in the CIMMYT holdings.

The cost of introducing a new accession into the genebank, assuming that the choice to preserve it is reevaluated a year, is a second policy dilemma related to the first. The procedure for new crop introductions, the quantity and condition of the sample, and other factors all have a role in the response. Almost all arriving accessions have their health condition checked as per CIMMYT's standard operating procedure. It should be possible to store the sample in the genebank and have a backup sample off-site with an appropriate sample size. The cost to CIMMYT for adding a new accession to their genebank and preserving it for a year, if it is viable and large enough to avoid the need to bulk up the sample, is $3.61 for wheat and $13.88 for maize. However, this cost rises to $8.08 per accession for wheat and leaps to $126.84 for maize if the sample has to be regenerated at the time of introduction. If regeneration is not necessary, the associated costs for distribution are $4.17 for wheat and $15.28 for maize, and $7.43 for wheat and $123.99 for maize when regeneration is necessary due to insufficient seed supply. Another dilemma concerns the relative expenditures of preserving an addition for an additional year vs eliminating it if the identical addition may be reintroduced from another location later on if necessary. Our calculations show that maintaining the current wheat accession for an additional year is obviously less expensive, provided that the current accession doesn't need regeneration to restock or improve viability. The tale gets murky if the current accession has to be generated, for instance, because the sample size is too small. Even though the newly introduced accession needs regeneration, it is beneficial for wheat to roll over the previous accession for another year. While it is inexpensive to roll over an existing accession in maize that does not need regeneration, the expense of introducing an accession from another source vs maintaining an existing accession that does is equivalent and significant.

If we simulate a more realistic time-cost situation, this sort of cost calculation and the corresponding management actions are considerably more complicated. The statistics on dissemination imply that many genebank accessions remain unused for long periods of time. In fact, the argument often offered for creating and maintaining a genebank is the option value of these accessions rather than their more direct use value. However, the option value can only be achieved if the sample is used in the future for breeding or other types of study. A more nuanced, yet equally important, question is: if an accession will be used for the first time in n years, how long must that delay, n, be before it becomes more cost-effective to rely on introductions from elsewhere rather than to maintain an existing holding? Regeneration costs are high, especially for maize. It may be more cost-effective to remove the entry from the genebank unless it is used within 2-3 years if a current maize accession needs regeneration and the identical accession is known to be kept elsewhere. In the same circumstance, the wheat cutoff duration is 7–10 years. It is more economical to preserve existing accessions judged beneficial in the near future since adding a wheat accession to the collection is more expensive than storing it. The cut-off times for wheat and maize, respectively, are 7–10 years and 5–6 years, respectively, in the absence of regeneration. Assuming transportation costs and other quarantine hurdles are not prohibitive, it is often preferable to preserve accessions at a single facility and transfer them to nearby genebanks upon request if they are unlikely to be utilized within a decade or so.

**Typical expenses over the long term**

The majority of the s above discuss the expenses of keeping an accession for an additional year with the idea that choices made today may be reviewed the next year. Genebanks may, however, want or be compelled to ensure the preservation of samples indefinitely, as is the case with accessions kept in trust by CGIAR centers as a result of their agreements with the FAO. Naturally, the price of such a guarantee is influenced by input prices, storage capacity, regeneration rates, and the level of future technology.

When no initial regeneration takes place, the average cost of conserving an existing accession of wheat in perpetuity ranges from $6.33 to $22.66; whereas, when an initial round of regeneration takes place, the average cost ranges from $9.58 to $25.91.3 The present values of conservation are more sensitive to changes in interest rates than they are to changes in initial regeneration protocols; however, the interest cost of securing thi In the case of maize, equivalent expenses per accession vary from $32.28 to $151.46 in the absence of an initial regeneration and from $140.98 to $260.16 in the presence of an initial regeneration. Since it has previously been demonstrated that maize regenerates at a substantially higher pace than wheat, adjustments to the initial regeneration process in maize will have a proportionately greater financial impact, particularly when interest rates are higher. An accession of wheat costs $6.33 and $9.58, respectively, representing only about a 65% increase, while conserving a sample of maize seed in perpetuity costs $32.28 without an initial round of regeneration and $140.98 with an initial regeneration, for example, at an interest rate of 6%.Separating the capital costs from the other expenditures is useful for management, different policy, and investment objectives. Our calculations show that, if the seeds are preserved in perpetuity and the genebank facility and other capital items are replaced on a recurring basis as needed, a total of $2,083,221 is required to underwrite the capital costs of conserving CIMMYT's current maize and wheat holdings for the life of the genebank. Taking into account the cost of capital, conserving the whole wheat and maize holdings for 40 years will cost $5,468,374 in labor and operational expenditures, and $6,907,034 if the seeds are stored indefinitely. These expenses go much beyond the labor and overhead needed to just store the seeds in the genebank. It accounts for the expenses of validating the samples, recreating them, and managing the data needed to manage the collection.

The price of dispersing the seeds is a separate expense from these. The cost of this function alone, over a 40-year time horizon and in perpetuity, would be around $4,178,702 in present-value terms and $5,278,064 respectively, if the genebank kept dispersing seed at the pace typical of the previous few years. By adding together all of these expenses, we predict that the genebank's capital, labor, and operating expenditures will come to $11,296,385 throughout its lifetime and $14,268,319 overall. This considerable, but not particularly big, quantity of money is the amount that would need to be saved over the long term at a real interest rate of 4% to support genebank operations at their current levels.

**The ICARDA Genebank's past**

In 1977, ICARDA was founded in Aleppo, Syria. In order to improve the management of rangelands and water resources, as well as the nutrition and productivity of small ruminants within the CG system, the institute conducts research on barley, lentil, and faba bean crops, with a focus on dryland areas in developing countries. Additionally, it is in charge of breeding, upgrading agricultural techniques, and safeguarding and increasing the region's water, land, and biodiversity's natural resource base. One-third of the world's agricultural land, including subtropical and temperate dryland regions inside developing nations, is thought to be covered by ICARDA. ICARDA has given special attention to preserving landraces and other basic materials of crops that originated in the area since it is rich in genetic resources.

The different genetic resources operations of ICARDA were consolidated into a new Genetic Resources Unit in 1983, which was created to manage the organization's efforts related to germplasm collection, conservation, documentation, characterization, and dissemination. Additionally, the unit's seed-health laboratory offers a service for seed-health to the whole center.

The GRU finished building its new facilities, which include cool rooms for medium- and long-term storage of seed samples, in 1989 with financial assistance from the Italian government. IBPGR recognized ICARDA as the owner of the bread wheat and chickpea basis collections as well as the worldwide base collections of wild wheat cousins, durum wheat, lentil, and faba bean.

GRU initially primarily supported ICARDA's crop improvement programs, but over time, relationships with regional national agricultural research agencies (NARAs) also gained significance.

This approach culminated in 1992 when ICARDA, IBPGR, and the FAO Commission on Plant Genetic Resources formed a network for cooperation in plant genetic resources in the CWANA area. In order to cooperate together on the protection of genetic resources, ICARDA, IPGRI, and five Central Asian nations of the former Soviet Union established another sub-regional network in 1996. The Central Asia and Transcaucasian Network for Plant Genetic Resources was created in 1999 when three Transcaucasian nations joined.

Collecting and preserving indigenous germplasm from other CWANA member nations as well as the Near Eastern centers of variety is a top focus for ICARDA. Local germplasm may include helpful genes for breeding stress-tolerant cultivars suitable to a variety of target locations and agricultural methods since it is well adapted to the harsh, stressful, and highly changeable conditions. at addition, it became crucial to amass a collection of wild relatives and landraces at an ex-situ facility due to the high speed of genetic erosion occurring across the area as a result of the loss of natural habitats for wild species. Using agronomic, biochemical, and molecular characterization approaches as well as amplified fragment length polymorphism markers, GRU has recently done studies to examine the genetic diversity within its collections of barley, durum wheat, lentil, chickpea, and medicago. A core collection with fewer accessions will be chosen to reflect the worldwide variety in each individual crop as a result of the study that has been done to better understand the regional distribution of crop diversity.

**Costs of capital inputs**

It gives a breakdown of the GRU's capital input expenses. The last column includes replacement prices and estimated service lives along with yearly user charges for these capital items in constant dollars using a 4% real interest rate. The medium-term storage area has several shelves and trays, as well as a refrigeration system. A comparable system sans dehumidifier is installed in the long-term storage space. Vacuum-sealed canisters that hold seeds for long-term preservation cost 70 cents apiece. For medium-term storage, plastic containers, which cost 8–26 cents apiece, are utilized. To assure a disease-free collection, the seed-health laboratory examines all arriving and departing accessions for seed-borne diseases and pests. The laboratory is housed in a separate structure and is furnished with necessary tools for laboratory testing as well as two greenhouses for field testing and quarantine purposes. The expenditures associated with such operations are not included here since they provide a support function for the breeding program at the center. Additionally, GRU has 20 screenhouses and two greenhouses for the regeneration of seeds that need particular care. Inputs that are often shared across crops or are difficult to assign to a single crop are included in the general capital items.

## 3. CONCLUSION

Additionally, sustaining the health of seeds requires integrated management techniques that include cultural practices, resistant cultivars, seed treatments, and biosecurity precautions. The prevention of seed-borne disease epidemics requires early diagnosis and a swift reaction. For the creation and promotion of best practices, cooperation is required between researchers, seed manufacturers, farmers, and regulatory organizations. Protecting seed health becomes even more important in a society dealing with shifting climatic circumstances and rising food demand. Keeping hazardous pathogens out of planting materials increases agricultural output and decreases the need for chemical pesticides, encouraging ecologically friendly and sustainable farming methods.

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# CHAPTER 6

# EXAMINING THE IMPORTANCE OF SEED-HEALTH TESTING

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**ABSTRACT**:
Seed-health testing is a critical component of modern agriculture, ensuring the quality, safety, and productivity of seed-based crops. This review examines the importance of seed-health testing, delving into the methods, techniques, and technologies used for detecting seed-borne pathogens and assessing seed quality. We explore the significance of accurate and timely testing in preventing the introduction and spread of diseases, as well as its role in supporting international seed trade. Through an analysis of current research and case studies, we highlight the advancements in seed-health testing and emphasize its pivotal role in maintaining global food security and agricultural sustainability.Seed-health testing plays a pivotal role in safeguarding agricultural productivity and food security. As evidenced in this review, accurate detection and identification of seed-borne pathogens are crucial for preventing disease outbreaks that can devastate crops and economies. Rapid advancements in diagnostic techniques, including molecular methods such as PCR and high-throughput sequencing, have revolutionized our ability to identify even low-level infections.

**KEYWORDS**:

Disease Detection, Diagnostic Techniques, Fungal Pathogens, Microbial Contamination, Pathogen Identification, Seed-borne Diseases.

## 1. INTRODUCTION

The introduction of novel or unfavorable diseases into the collection poses the danger of new germplasm being added. In a similar vein, spreading germplasm may unintentionally introduce infections to regions where they had not previously been an issue. The seed-health laboratory screens all genetic material entering ICARDA or disseminated outside for seed-borne diseases and pests to prevent the interchange of diseased accessions. All arriving seeds are visually examined and analyzed in a lab after fumigation or cold treatment. For one generation, post-quarantine regions are planted with only seeds that have been determined to be pathogen-free[1], [2].

Random seed samples for the accessions that will be distributed are examined. Samples from fields where possible seed-borne illnesses may have been discovered during field inspection are given further consideration. Tests are carried out appropriately to verify that seeds are free of disease if a receiving nation has designated certain diseases or pests as quarantined organisms. Following all of these tests, the seed-health laboratory requests a phytosanitary certificate and creates an origin certificate that is sent with the sent seeds.A plant pathologist oversees the daily operations of the seed-health lab with the help of a research associate, a technician, and five daily-hired temporary workers. Genebank operations account for around 20% of the activity at the seed-health laboratory. Due to the almost equal costs for assessing the health of entering and departing accessions, these expenses were divided between the acquisition and dissemination categories according to the proportions of acquired and disseminated accessions in the genebank[3], [4].

**Viability evaluation**

The viability of the seeds that have been preserved has to be routinely assessed, as with other genebanks. About 70% of the crops that ICARDA has and for which it has both a global and regional CG mandate have undergone at least one round of viability testing. The percentage of accessions that have been assessed for viability for lower priority crops is extremely low. A total of 67,405 accessions, or 6700 each year, have undergone viability testing throughout the last ten years40 seeds from each accession are deposited in four separate Petri plates, incubated for a week, and then visually inspected to determine viability. The labor needed to oversee and conduct the tests makes up a significant portion of the testing expenses. An accession is rejuvenated in the next season if the viability rate falls below 85%. Although a testing procedure is being developed, the time gap between subsequent rounds of viability testing has not yet been established[5], [6].

**Regeneration**

The regeneration of stored accessions to maintain sufficient viable stocks is one of the most labor-intensive components of germplasm conservation. Regeneration is done when seed viability falls to 85%, and multiplication to scale up accessions is done when the holding falls below a minimal sample size. Some accessions are also grown outside for characterization and assessment reasons.4 In 1998, the base year for our data, other accessions like wild wheat were doubled for prebreeding objectives. Before storing them, newly purchased accessions are also planted in the field or greenhouse to enhance the number of seeds per sample.

Each set of crops' regeneration efforts are overseen by two germplasm experts, who jointly process 4000-6000 accessions annually. After the first cycle of regeneration, the majority of cultivated cereals and food legumes reach the recommended storage amount; however, certain crops, such wild cereal, faba beans, and forage legumes, often need more than one cycle. For these crops, we estimated two regeneration cycles were necessary to provide an adequate sample size, and we modified the number of accessions appropriately. Two crop experts' labor costs total 80% of the cost of field management, with the remaining 20% going toward categorization tasks. Land preparation, seed treatment with fungicides, and scarifying the hard cover from the seeds of different legumes to promote germination are the actions done before to planting. The farmlands owned by ICARDA are maintained by the station operating unit, which also performs land preparation for planting on a $400/ha charge-back basis. Some species with large-sized seeds may be scarified mechanically, whereas small-sized seeds of wild food legumes and pastures need a labor-intensive hand-scarification procedure.

The majority of accessions are planted in field plots that are 3–4 m2 in size, with two rows of seeds that have been sown and two–three vacant rows to minimize seed mingling between neighboring plots.7 Some crops are grown in meshed screenhouses or plastic-covered greenhouses because they need more specialized care. To prevent cross-pollination, medicago and other pasture plants are planted in greenhouses with a limited number of seed samples, while faba beans are grown in screenhouses. Most of the time, planting by hand is recommended to prevent accidentally mixing seeds, and certain small-sized seeds shouldn't be planted by machine.The frequency of disease infestations, which in turn relies on temperature and other environmental conditions, determines how much pesticide is administered each year. Additionally, manual weeding is used when required since pesticides only work against a limited range of weed species. Throughout the growth season, plants are examined to characterize their morphological characteristics. For each set of crops, this task takes a total of 2 months from a specialist and 2 months from a daily laborer.The station operating unit, which acts as a driver for harvester equipment, aids in harvesting. Due to issues with seed cracking, several wild forage legumes, including lentil and faba beans, must be collected by hand in contrast to machine-harvested cereals and chickpeas. Harvested materials are transferred to the seed washing section in paper bags or cotton sacks. The seeds are subsequently mechanically or manually threshed and cleaned.Seed samples are weighed, segregated, and then put in a dehumidifying chamber for 4-5 weeks after being received from the seed cleaning area. In order to lower the seed moisture content to a range of 6-7%, the room is maintained at a constant 21°C and 10-13% relative humidity. The seeds are placed in plastic containers for medium-term storage after cleaning and drying, then in aluminum bags for long-term storage.

## 2. DISCUSSION

Requests for germplasm have grown as a result of increasing communication between CWANA national programs, ICARDA researchers, collaborators in cutting-edge universities, and other genebanks. Over the previous five years, 30,000 accessions have been provided to collaborators annually, with 40–50% of these accessions often going to researchers outside of ICARDA.

The first lines given to national testing programs were chosen from trials conducted at the main assessment locations of ICARDA in Syria and Lebanon. A total of 132 shipments totaling 27,700 accessions were made in 1998, including 54 international shipments that needed the aforementioned phytosanitary certificate. The locations of receivers and the weight of the shipment will affect the cost of shipping. The cost of sending to the genebank typically runs between $3000 and $4000 annually.ICARDA has many institutions that support its collection. Barley and wheat duplicate samples are forwarded to CIMMYT.

The faba bean collection is replicated at ICRISAT, the lentil collection is at the National Bureau of Plant Genetic Resources in New Delhi, India, and the chickpea collection is duplicated there as well. At the Federal Institute of Agrobiology in Austria, Medicago and Vicia are preserved, while Lathyrus is replicated at the Station Fédérale de Recherches Agronomiques de Changins in Switzerland.

The documentation officer organizes information gleaned from the field and from other sources, controls the data, and is in charge of the periodic release of catalogues outlining the holdings of each crop. When new additions to the genebank are made, passport information for each collection is uploaded into the GRU information system as well as the Data Management and Retrieval System of ICARDA. In addition to being periodically published in germplasm catalogues, passport, characterization, and evaluation data are also made accessible online as part of the SINGER project. The seed-stock control system, which aids germplasm experts in organizing the storage of seeds and delivery of samples to users, is a crucial component of GRU's data-management system[7], [8].

**Average annual expenses**

As was previously stated, the condition of the sample and, in turn, the length of time it has been in storage play a major role in determining the cost of storing an existing accession for an additional year. The average cost of keeping over an accession of any crop for an additional year at ICARDA is approximately 17 cents if a sample does not need regeneration. The average cost of storing the sample for a further year if regeneration is necessary increases to $5.29 for cereal and $8.64 for faba beans.The average cost of preserving a recently obtained accession for a year is between $14.84 and $18.19 per accession, including the expenditures associated with evaluating the health of the seed and storing enough seed. The average cost of distributing an addition, supposing enough stock, is $3.48. This cost covers maintaining the active collection as well as packaging and shipping. The average distribution cost per accession increases, depending on the crop, to between $8.60 and $11.96 if regeneration is necessary due to inadequate holding size. The one-time characterisation fee raises the distribution cost for a recently obtained accession to $10.03 to $14.43.

**Typical expenses over the long term**

Actual expenditures for permanently preserving and disseminating an acquisition. Since the ideal time frame for viability testing has not yet been determined for the present conservation method, we made the assumption that testing would start 10 years after acquisition and repeat every five years after that. We used the assumption that an accession is disseminated once every five years since there are typically around 25,000 accessions distributed annually. When no initial regeneration is required, the average cost of maintaining an existing accession of cereals in perpetuity at 4% interest is $10.14 per accession. Comparable prices for other crops fall between $10.20 to $10.69. The price of conservation for a recently purchased accession ranges from $23.82 to $27.72 per accession[9], [10].

**Total expenses throughout time**

The ICARDA genebank spends $437,247 annually on operational expenses, as we previously said. The total costs of maintaining and distributing all of ICARDA's assets in perpetuity may be calculated using the in-perpetuity costs of conservation and distribution mentioned in. The current collection must be preserved in perpetuity with the present-value equivalent of $4,491,238 ($2,941,782 for non-capital expenses like labor and operational expenditures and $1,549,456 for capital). The genebank would incur an in-perpetuity cost of around $5,928,045, calculated in present-value terms, if it continued to distribute seed at the pace typical of the previous few years. We calculate that adding together all of these expenses would result in perpetual capital, labor, and operating costs of $10,419,283 (again, assuming that the money is kept away at a real rate of interest regeneration of 4%). We calculated the number of new accessions being created in the present cycle to be 4750, 3250, and 5400, respectively, to account for this fact. The per-accession cost is scaled up to the relevant total cost using these modified accession numbers.

**Viability evaluation**

Seeds are tested for viability during storage at regular intervals of 3–10 years for the active collection and 5–20 years for the base collection, depending on the crop type and starting viability rate, in addition to the normal viability testing when seeds are obtained and initially regenerated. While certain wild species have continuously low viability and also need more frequent testing, other crops, like peanuts, suddenly lose viability and need more frequent testing. Tests are being conducted on all of the holdings in ICRISAT's genebank to determine their viability. 76,000 accessions in medium-term storage in total were examined between 1997 and 1999, and the remaining samples were examined in 2000. A total of 5000 freshly collected materials were examined in 1999 before being stored, while roughly 25,000 accessions from the active collection underwent baseline testing. To handle this unusually high number of testings, two full-time research technicians and one half-time non-technical staff member were employed.

**Characterization and regeneration**

The most important procedure in germplasm conservation is regeneration, and throughout this procedure, special care is required to maintain the genetic integrity of germplasm accessions. Only after the rainy season are regeneration efforts at ICRISAT's genebank carried out in order to produce high-quality seeds with a low incidence of illness. The post-rainy season's shorter days also cause photosensitive germplasm additions to blossom, allowing them to produce seeds. The majority of field activities during the 1999–2000 growing season were focused on expanding the base collection's seed supply.Four scientific officers in total carry out the operations in the field while three senior germplasm scientists oversee all regeneration and characterisation efforts. We only allotted 20% of the top scientists' time to regeneration since they spend the majority of their time doing research, not conservation. We attributed 90% of the time worked by scientific officers to conservation efforts since they spend part of their time on outreach initiatives.

The genebank manager chooses the exact accessions that will be grown during a certain growth season with the assistance of scientific officials. Priority is given to entries with poor viability and entries intended for long-term storage. On a charge-back basis, FESP offers services for field preparation and cultivating equipment operation. Staff members of the genebank carry out the agricultural tasks for each crop, as will be detailed later. The agronomic characterization is carried out by the scientific officer in charge of each crop. While pearl millet, groundnut, and pigeonpea are normally described during the rainy season but are sometimes also planted out during the post-rainy season, sorghum, wild groundnut, and pigeonpea are characterized simultaneously with regeneration in the post-rainy season.

Sorghum. 350 accessions were planted on 0.5 ha for characterisation during the rainy season, and 5000 accessions were planted on 4 hectares for regeneration and characterization during the 1999–2000 season. The remaining 770 regenerated accessions were used to either boost seed supplies or seed viability, while 4230 were stored in the base collection. Sorghum is a cross-pollinating crop, so'selfing' is a crucial and very expensive part of the process. A paper bag is placed over each plant's "panicle" for about three weeks. Since no activities were carried out for small millet variations throughout the period of our study, we attributed the whole cost of this officer's labor to sorghum. A scientific officer oversees regeneration and characterisation for both sorghum and the small millet variantsmillet pearl.

Characterization takes place in both the post-rainy and the rainy seasons, when this crop is also replenished. Each year has a different number of grown accessions. For instance, in 1999/2000, 521 accessions were planted in the wet season for characterization and around 1400 accessions were cultivated in the post-rainy season. We averaged the numbers of accessions for regeneration and characterisation in each season to determine costs. Each accession has two characterisation rows and four 4-m rows planted. As a result, the planting area for both operations is around 1 hectare in size. Similar to sorghum, pearl millet is an aggressively outcrossing plant, necessitating a labor-intensive selfing procedure when it is regenerated. A scientific officer manages the cultivation of pearl millet alone, with assistance from two research technicians and two non-technical workers.

Pigeonpea. During the post-rainy season, regeneration and characterisation are carried out simultaneously in the same field. On 0.5 hectares, 600 pigeonpea accessions in all were recreated and described in 1999. For each addition, two rows of nine meters each are planted, totaling around 180 plants. Again, selfing is required because insects partly cross-pollinate pigeonpea. Muslin fabric bags, which have a lifetime of roughly two years, have been employed in recent years. However, 6 m 9 m polypropylene cages are being investigated as an alternative. Despite having a high initial setup cost, the net-covered frame cages could be disassembled and reused for more than 5 years, making them economical. Only 50% of the labor expenditures for a scientific officer who manages both pigeonpea and wild species were devoted to pigeonpea-related tasks. Two non-technical employees and three research technicians support the scientific officer. Only 40% of the pigeonpea team's labor expenses were devoted to regeneration and characterisation tasks since they also oversee outcrossing investigations, genepool upkeep, and wild pigeonpea regeneration.

Chickpea. Only during a wet season can chickpea regeneration and characterization take place. 2000 accessions were cultivated separately for characterization in 1999–2000 while 2400 accessions were grown for regeneration. For each accession, 40 plants are cultivated on 0.5 ha for characterisation, and roughly 80 plants are grown on a total of 1.5 hectares for regeneration. The soil is covered with polyethylene sheets for at least 6 weeks during the warmest portion of the year since chickpea is very vulnerable to wilt disease. This procedure is known as "solarization." This labor cost is split evenly between chickpea and groundnut since one scientific officer oversees both crops.

Groundnut. Separate from regeneration, this crop exhibits characteristics in both post-rainy and rainy sea- sons. 600 accessions were planted on 0.5 ha for characterisation, and 1300 accessions were planted on 1 hectare for regeneration in the 1999 post-rainy season. 1500 accessions were planted on 1 hectare during the wet season for characterisation. Due to the poor rate of multiplication of groundnut plants, four 4-m rows containing around 160 plants are planted for each accession. Given that the crop's seed components stay underground, regeneration requires skilled labor since it is exceedingly difficult to predict when the right harvest time will be.

Wild groundnut varieties that produce seeds are preserved in an ex situ storage facility, whereas variants that do not produce seeds are preserved in a field greenhouse. The genebank has 453 wild groundnut accessions that are preserved, with 100 or so serving as field genebanks. About 60 percent of the 100 accessions that are regenerated in the greenhouse each year provide adequate seed for conservation. The germplasm scientist keeps up the field collection year-round in addition to regeneration. Each accession is planted in a cement ring with a diameter of 24 inches. The cost of power and water use is rather significant, despite the fact that upkeep requires little labor.

**Seed-health evaluation**

On the ICRISAT site, the Indian government established a Plant Quarantine Unit to assess the health of all departing accessions. 3195 of the 12,000 accessions that were sent from ICRISAT in 1999 were from the genebank. The NBPGR, a plant quarantine agency run by the Indian government, examines all incoming samples to check for exotic diseases and pests. The NBPGR then sends seed samples to ICRISAT, where they are grown out in a "post-entry quarantine isolation area" to prevent the introduction of potential seed-borne pathogens and pests.

The PU checks all accessions intended for long-term storage for seed-borne fungus in addition to testing the accessions intended for transportation to other locations. To make sure that all germplasm is disease-free, a more precise agar-plate approach is utilized rather than the more common and less expensive blotter test. 3000 accessions or so were tested in 1999 before being added to the basic collection.A part-time plant pathologist oversees the P-U, which also has four non-technical employees, five research technicians, and three scientific officers. We allocated 33% of the PU's total costs to assessing the health of the seeds stored in long-term storage and 17% to the genebank's dissemination operations based on the number of accessions treated and the labor necessary for the agar-plate technique.

**Procurement and Processing of Seeds**

To prevent redundancy, new seed samples are examined for duplicates, entered into the database, and if the stock is low, readied for regeneration. A very limited number of new accessions have been added to the ICRISAT genebank during the previous several years, and no acquisitions were made in 1999. We averaged the recent accessions that were obtained and applied a typical labor demand for seed processing to arrive at a cost estimate.Seed processing, which includes cleaning, drying, testing viability, and packing, takes up a significant amount of the genebank manager's work. Cleaning seeds entails getting rid of debris, low-quality, infested, or contaminated seeds, as well as seeds of various species. Sorghum and millet seeds are cleaned using a seed blower, whereas chickpea, pigeonpea, and groundnut seeds are cleaned by hand. Before storage, groundnuts must also be shelled, which demands a lot of labor. Seed viability is evaluated after cleaning.The process of drying seeds begins with several days in the field or at the seed receiving area. The seeds may be promptly packaged in plastic jars for groundnuts or aluminum screw-top cans for other crops after the first drying, which often satisfies the criteria for medium-term storage. Either on the exterior of the package or inside the can are the accession number, identification, and harvest season.

Further drying is required for long-term storage to guarantee viability, therefore seeds are packed in tagged muslin fabric bags and dried for several weeks in a seed drying facility. The primary expense for this process is the electricity needed to run the drying module. Since 1998, the P-U has conducted a seed health assessment on every accession that will be kept in the long-term storage chamber. To fit the sample size, long-term storage samples are placed in various-sized aluminum bags. Double bags are used for groundnut seeds. Samples of chickpea, pigeonpea, and groundnut are 200 g; samples of sorghum and pearl millet are 75 g; and samples of small millet are 25 g. For medium-term storage as opposed to long-term storage, the labor cost of packing seeds is often substantially greater. Even though not all harvested materials are packed for both medium- and long-term storage in reality, we assume that they are packed for both storage modalities in order to calculate accurate per-accesssion seed-processing and regeneration costs.

**Safety duplication and dissemination**

For sorghum or millet, the seed is packaged in aluminum bags at a size of 5–6 g, for wild species at around 10–20 seeds, and for other crops at about 100 seeds. For certain species, including Arachis and Pennisetum, live plants must be distributed, which is more expensive. The rhizomes are divided into 15-cm pieces, wrapped in polyethylene film and paper towel, and then placed in Jiffy bags for transport. A Material Transfer Agreement, an import permission, and often a phytosanitary certificate is required for accessions distributed internationally. The time spent by the genebank manager supervising distribution operations accounts for a significant portion of these expenses. Similar steps are required to prepare samples for safety duplication as for base collection, however the minimal sample size is 100 g for legumes and around 25 g for sorghum and millet. In Aleppo, Syria, the ICARDA and NBPGR both grow chickpea in addition to pigeonpea. Each site has duplicated a total of 2000 chickpea accessions and 2525 pigeonpea accessions. Accessions were awaiting the Syrian government's quarantine approval at the time of this study. In addition, the ICRISAT genebank contains duplicate copies of 5914 ICARDA chickpea accessions.

## 3. CONCLUSION

Testing for seed health in a timely and accurate manner is essential for both domestic and international seed commerce. To stop the unintentional cross-border spread of infections, phytosanitary rules often call for rigorous testing. Farmers' choices may be influenced by seed-health testing, which enables them to choose disease-free planting materials and implement effective management techniques. The effectiveness and precision of seed-health tests are being improved by the use of contemporary technology, such as remote sensing and data analytics. This interaction between innovation and agriculture highlights how crucial it is for researchers, breeders, regulators, and business players to work together and conduct continual research. In conclusion, seed-health testing is a crucial tool for sustaining food security and agricultural sustainability. Its importance ranges from regional seed trading restrictions to local agricultural methods. Strong seed-health testing methods become more important as we deal with the issues of climate change, new illnesses, and rising food demand. We guarantee that the seeds planted now produce abundant and robust harvests tomorrow by investing in research, infrastructure, and international collaboration.

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# CHAPTER 7

# TRAINING PROGRAMME ON SUPPLY CHAIN MANAGEMENT IN AGRICULTURE

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**ABSTRACT**:
Supply chain management (SCM) in agriculture is a pivotal aspect of ensuring efficient production, distribution, and consumption of food and agricultural products. This paper explores the significance of training programs focused on supply chain management in the agricultural sector. It examines the diverse components of agricultural supply chains, including procurement, production, processing, distribution, and retail, and highlights the multifaceted challenges faced by stakeholders. By analyzing existing training initiatives and case studies, this paper underscores the need for comprehensive and practical training programs that address the complexities of modern agricultural supply chains. The role of such programs in enhancing productivity, reducing post-harvest losses, and promoting sustainable practices is discussed, emphasizing their contribution to the overall development of the agricultural sector.Training programs focused on supply chain management in agriculture play a pivotal role in shaping a resilient and efficient food system. As highlighted in this paper, the agriculture supply chain involves a multitude of stages, each with its own intricacies and challenges. From ensuring timely procurement of inputs to minimizing post-harvest losses and optimizing distribution, effective supply chain management is essential for food security and economic growth.

**KEYWORDS**:

Agricultural Logistics, Agribusiness, Distribution Networks, Inventory Management, Marketing Channels, Procurement.

## 1. INTRODUCTION

Supply chains are primarily concerned with the movement of goods and data among their member companiesthe acquisition of raw materials, their transformation into completed goods, and their delivery to final consumers. Supply chains that are information-driven and linked today help businesses save costs, add value to their products, use resources more efficiently, speed up time to market, and keep consumers[1], [2].How effectively supply chain operations coordinate to provide value for customers while boosting the profitability of each link in the supply chain is the true test of a successful supply chain. Supply chain management is, in other words, the coordinated process of creating value for the final consumer. However, due to the inherent issues in the agriculture industry, the supply chains of various agricultural commodities in India are rife with difficulties. Different structural difficulties, like as the predominance of small/marginal farmers, fragmented supply chains, the lack of scale economies, low levels of processing/value addition, inadequate marketing facilities, etc., affect the country's agri-supply chain system.

As a consequence of lower inventories and quicker turnaround times for customer requests for goods and services, early processing-based supply chain management success featured enhanced linkages between warehousing and transportation inside businesses. The logistics stage of supply chain management is where different corporate functional divisions come together to integrate production, procurement, transportation, distribution, and marketing in order to successfully compete in the market. The introduction of telecommunications, electronic data interfaces, and other technical advancements that increased the transparency of information movement across functional areas inside corporations helped with this stage[3], [4].

**Networks in the food supply chain**

An organized and processing-based agri-supply chain operates as a component of a highly complicated network. When seen from the perspective of a whole supply-chain network, 1 is a generic supply chain at the organizational level. Each company is situated in a network layer and is a part of at least one supply chain, meaning that it often has a number of suppliers and customers at once and over time.

**The benefits for supply chain participants**

Through the coordination of their value-creating operations, independent suppliers, producers, and marketers connected by a supply chain are able to generate more value than they could on their own. One of three ways that supply chains create synergies is by growing traditional markets beyond their current borders and thereby increasing sales volume for members; by lowering the delivered cost of goods relative to competing chains and thereby raising the gross margin for the working capital invested by chain members; or by targeting particular market segments with particular products and differentiating the service, product quality, or brand reputation. They enable chain members to raise their rates in this manner. Supply networks often promote market competition at both the production and consumer ends of the chain. Chains compete largely on pricing, distinct goods and services, and varied conditions of sale at the consumer end. Supply chains compete with one another for "producer affiliation" and core vendor commitments particularly at the producer end of the chain[5], [6].

**Parts of the Agricultural Supply Chain**

Agribusiness supply chain management entails controlling the interactions among the organizations in charge of the effective production and distribution of goods from the farm level to the customer in order to consistently satisfy consumer demands for quantity, quality, and price. In actuality, this often involves managing both horizontal and vertical partnerships as well as the interactions and procedures between businesses. Agri-supply chains are economic structures in which players share risks and gains. As a result, supply chains impose internal controls and provide chain-wide incentives to ensure that production and delivery obligations are met on time. By virtue of shared information, reciprocal scheduling, promises to transaction volume, and guarantees of the quality of the products, they are connected and linked. Process connections increase the value of agricultural goods and call for each stakeholder to coordinate their efforts as a means of ongoing development. The actions done or not taken at subsequent links in the chain significantly influence the costs incurred at the first link. To influence important control operations like forecasting, buy scheduling, manufacturing and processing programming, sales promotion, and new market and product launches, etc., extensive pre-planning and coordination are needed up and down the whole chain. The elements of a well-organized agri-supply chain are as follows:

**Indian agribusiness marketing and the creation of coordinated supply chains**

The management of India's agri supply chains is currently changing to adapt to the new marketing realities brought about by the wave of globalization and other internal changes, such as an increase in consumer disposable income and a shift in the consumer's food basket toward high-value items like fruits, vegetables, and animal protein. The government agencies are now pursuing various legal reforms to enable and invite private investment in agricultural marketing infrastructure, removing entry barriers to encourage coordinated supply chains and traceability, in response to the country's new agricultural economic challenges.The principal agricultural marketing law of the nation, the modified APMR Act, which is being implemented by the various Indian states, now includes enabling measures to support contract farming, direct marketing, and the creation of private marketplaces. These actions will go a long way toward giving small businesses economies of scale and creating direct connections between farmers and processors, exporters, retailers, etc. Consequently, the policy will provide both backward and forward linkages to develop integrated supply chains for various agricultural products in the nation.

## 2. DISCUSSION

Analyzing the dominant market channels for specific commodities might help put the conversation in context when looking at supply chain management concerns in the agricultural industry. The usual marketing channels for mangoes and onions in Tamil Nadu show how marketing channels for fruits and vegetables in India vary significantly depending on the commodity and state. However, depending on the state and the item, farmers may sell to merchants immediately at the farm gate, to dealers at village markets, or straight to processors, co-ops, and others. Wholesale marketplaces account for the bulk of domestic fruit and vegetable output. In the sections titled "1" and "2," which discuss the popular mango and onion marketing channels in Tamil Nadu, some of the frequent issues in Indian agri supply chains are described[7], [8].

**Synchronized Supply Chains**

In India, supply chains for fruits and vegetables have become increasingly well-coordinated in recent years, serving both the high-end local market and the export market. On the domestic front, the development of sizable hypermarkets, supermarkets, and other organized shops in urban areas has mostly been driving this trend. Stricter quality and safety regulations in certain export markets have led to the development of specialized export chains.In organized interactions between producers, traders, processors, and purchasers, coordinated supply chains are created, and explicit instructions are given about what and how much to produce, the timing of deliveries, the requirements for quality and safety, and the price. These connections often include information sharing and, sometimes, financial and technological support. The logistical needs of contemporary food markets, particularly those for fresh and processed perishable goods, are best suited by coordinated supply chains. These chains are more effective and efficient than control that just occurs at the very end of the supply chain for process control of safety and quality.

With a focus on quality and, to a lesser degree, safety, a number of enterprises in India are starting to invest in integrated supply chain management systems and infrastructure. Diverse business models are developing, such as fruit and vegetable retail stores that buy their goods directly from farmers or grower organizations under official or informal contractual agreements. Rural regions now have collection-cum-grading facilities, and all food is distributed via one facility with cutting-edge infrastructure including cold storage, ripening rooms, and controlled environment chambers. Growers are expected to adhere to particular guidelines and are often given technical assistance and feedback about agronomic and post-harvest techniques[9], [10].

Due to legislative changes started in India, namely the adoption of the Model APMC Act, contract farming for fruits and vegetables is already done in a number of states and is projected to become much more widespread. Prior until recently, most states did not have a legal framework in place to regulate contractual agreements, and contract farming was not legally recognized. The APMC Model Act now includes a new section on "contract farming" that outlines time-bound dispute resolution procedures, the registration of contract purchasers, and the recording of contract farming agreements. Additionally, it offers indemnity to farmers' land to protect against the loss of land in the case of a disagreement and gives an exemption from the levying of market fees for products covered under contract farming agreements. Contract purchasers will now be allowed to legally acquire goods at farmers markets or via individual purchase contracts. The law also allows for the direct selling of agricultural products from farmers' fields to contract customers without first passing through designated marketplaces.

In Bangalore, a terminal market for produce has been established. Up to 1600 metric tons of produce may be physically handled by the market each day. It is connected to 40 Collection Centers and 250 Farmers Associations that have been set up in certain producing regions. These groups and centers provide sorted, graded, and packed product to the market, which subsequently auctions it off. Additionally, SAFAL has forward connections to a number of shops. The market is equipped with contemporary infrastructure, such as ripening chambers and storage facilities with regulated humidity and temperature. This necessitates supply chain collaboration.

More terminal marketplaces are being established with the use of contemporary infrastructure. By giving farmers a variety of options for selling their food, such as electronic auctioning and a facility for direct sales to exporters, processors, and retail chain networks under one roof, MTMs would try to link farm supply with purchasers. Additionally, the market would include storage infrastructure, giving players the option to trade at a later time. It is intended to provide a one-stop-shop for logistical assistance, which includes transportation services, cold chain support, and storage facilities. It will also include facilities for cleaning, grading, sorting, packing, and palletizing products, as well as extension help and advice for farmers.

The approach suggests using MTMs to integrate agricultural supply chains for perishables. There is now no control or command of chain partners on one another, which makes it impossible for them to maintain the quality of the product in their chain. This is a result of fragmented and inefficient agri supply networks. Modern terminal market complexes will make a dent in bringing integrated command, sourcing quality food by grouping farmers and giving them the necessary technical support, and connecting farmers to the market. Everywhere there are economies of scale in manufacturing or marketing, the function of collective action in the agro supply chain is relevant. This covers the function of farmer organizations in enhancing traceability. Firms and farms with collective action pay less for the installation of traceability in these chains than those without it. Similar to this, collective action makes sense if diverse comparative advantages exist across supply chain players. A production group may therefore gain from working with agents who have experience in marketing.

Shorter and more direct supply chains with traceability are anticipated to become increasingly prevalent as a result of rising private investment in the food retail industry and upcoming changes to contract and marketing legislation. The prevalence and expansion of coordinated supply chains will be directly correlated with India's food retail sector's rate and direction of modernisation. Food retail has been changing gradually up to this point, much more slowly than many other emerging nations.The structure of supply chains is significantly influenced by supermarket procurement procedures for procuring fruits, vegetables, dairy products, and meat. As organized retail expands across Asia, farmer production bases are being organized and integrated into the fresh produce supply chains of retailers. As a result, procurement practices in this market are quickly evolving in response to consumer demand and competition. In addition to the retailers that are already present in the countryside to source agricultural products, other players are now assisting different retail chains with their sourcing needs. To offer fruits and vegetables to retail chains, DCM Shriram Consolidated Ltd. is, for example, in the process of forming a partnership with them to purchase them from farmers. This is already being done by DSCL for Spencer from RPG, South-based Subhiksha, and Food Bazaar from Future Group. The new partnerships would enable the business to take advantage of economies of scale and expand its operations throughout the nation.

**District administration's marketing innovation**

By forming a growers' federation and assisting farmers to obtain an edge, the district collector of Karbi Anglong introduced innovative marketing in 2007. Providing logistical and commercial assistance to enhance the supply chain, the Ginger Growers of the Co-operative Marketing Federation Limited, a pilot project run by the district government of Assam's Karbi Anglong district, is an excellent example of how farmers are connected to the market. The following help is given in order to integrate the supply chain.Karbi Anglong, an organizing cooperative federation, produces 12,000 metric tons of ginger annually, with a market worth of around Rs 10 crores. 3,500 small and marginal tribal ginger producers are members of the GINFED organization, which was established in 2007 under the Rashtriya Sama Vikash Yojana. It intends to unite all ginger farmers under one roof and provide producers with higher rewards.

**Support for logistics and agreement with NF Railway**

Due of its isolated and steep position, transportation of ginger is severely constrained. The cost of transportation increased since it used to be transported by road from Diphu to Guwahati and from Guwahati to Delhi. Between Rs 3 and Rs 5 per kg is the cost of transporting ginger by road from Diphu to Azadpur mandi in Delhi. The Karbi Anglong district administration and North East Frontier Railways have recently reached an agreement via GINFED. In order to carry ginger from various locations, the Lumding railway division of NF Railway would hitch a wagon to an express train. When shipped by rail, the transport fee will range from 20 to 30 paisa per kilogram. The cost of transporting Ginger to Delhi is decreased by 90% as a result of this deal.

**Handling after Harvesting and Storing**

In addition to transportation, GINFED will provide post-harvest processing services, including storage, packing, cleaning, and grading. The farmers will be able to store the food and make marketing selections once storage facilities are in place. Producers will benefit from the post-harvest facilities, such as cleaning, grading, and packing, in delivering ginger to the global market. Additionally registered with SGS Sweden, the GINFED will use NABARD to get organic certification.In addition, the Federation has established a standard price of Rs 8 per kg for the purchase of ginger. The producer has now seen some relief after first suffering from a lack of marketing opportunities, the realization of the right price, and a distressed sale. The price at which farmer used to sell was between Rs. 4-5 per kilogram prior to GINFED involvement. Price discovery has been facilitated by Ginfed's guaranteed price support.

**Financial assistance**

To get bank loans, ginger producers are given a unique credit/debit card. The State Bank of India will provide the Ginger cardholder a loan of Rs 10,000 for crop development. The hill district's marginal tribal farmers are thought to benefit greatly from the method.

**Forward connections**

Now that the logistical bottleneck has been resolved and there is access to value-added services, it will be easier to provide ITC Ltd, Rayfam, New Delhi, Sresta Bio Products, Hyderabad, NERAMAC, and NAFED with high-quality ginger. In order to achieve market and price efficiencies in the market channel, these purchasing agencies will now work to better integrate the supply chain and reduce costs in the procurement process. All supply chain participants will profit from the convergence of logistical and commercial services. The government should fully use its facilitative role in order to support the creation of professionally managed agri-supply management of various agricultural products. The following are some of the crucial concerns that need public attention:

- The market's free-play of the forces of supply and demand should be emphasized. This has to be made possible by lowering various entry barriers, having an effective market information system, encouraging grading and standards, attending to quality and safety concerns, setting up a robust system of risk management, and establishing a mechanism for price formation.
- Different legislative constraints that prevent the development of a competitive environment should be removed and replaced with ones that encourage it.
- India's marketing system suffers from a lack of infrastructure. Since it is challenging to get enough funding from the public coffers for the construction of infrastructure facilities, it is important that various Public Private Partnership models be investigated.
- The country's expansion strategy is production-focused, pushing the marketing components to the sidelines. It's time to set up a good marketing system to disseminate information on what to create, when to sell it, and where to sell it, among other things, as well as on packaging, shipping, grading, and standards.

The private sector should step up and be proactive about investing in the agricultural sector within the general framework of a favorable climate given by the government side. They should not let the growing pains they are experiencing as businesses in an untapped market in India deter them. The administrative improvements made to the nation's agricultural economy by the private sector will go a long way toward guaranteeing the best possible use of resources and long-term sustainability for the industry.

## 3. CONCLUSION

Training programs provide a methodical way to give stakeholders the information and skills they need to successfully negotiate the complexity of contemporary agricultural supply chains. They provide insights on best practices, technology breakthroughs, and market trends, empowering farmers, producers, processors, distributors, and retailers. These initiatives also promote cooperation and communication among different parties, which improves coordination and lowers inefficiencies throughout the supply chain. Such training has an influence that goes beyond the confines of certain activities. Improved supply chain management results in higher output, less waste, and higher-quality agricultural output. It also promotes resource efficiency and environmental protection while encouraging the adoption of sustainable practices. Agricultural supply chain management training programs are crucial for the development and sustainability of the industry, to sum up. Governments, organizations, and institutions pave the path for a more resilient, fruitful, and responsive agricultural sector by investing in education and capacity-building. These initiatives are increasingly more essential for ensuring that the world's agricultural resources are exploited successfully to satisfy the demands of both current and future generations as the global population continues to expand and food systems confront growing difficulties.

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# CHAPTER 8

# AGRICULTURAL MARKETING SCENARI IN INDIA: AN OVERVIEW

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**ABSTRACT**:
The agricultural marketing scenario in India is a complex and evolving landscape that significantly impacts the livelihoods of millions of farmers and the country's food security. This study examines the key features, challenges, and opportunities within India's agricultural marketing system. It delves into the intricate web of market structures, intermediaries, price fluctuations, and government policies that shape the way agricultural products are brought from farm to consumer. Through an analysis of empirical data and case studies, this study highlights the need for comprehensive reforms to address inefficiencies, reduce post-harvest losses, ensure fair pricing for farmers, and create a more inclusive and competitive agricultural marketing ecosystem. The study also underscores the role of technology and innovation in modernizing India's agricultural marketing and enhancing the overall resilience of the sector.The agricultural marketing scenario in India is at a critical juncture, where transformative changes are essential to address longstanding challenges and harness emerging opportunities. As evidenced in this study, the presence of multiple intermediaries, limited market infrastructure, and inadequate price transparency often lead to farmers receiving a small share of the consumer's price. This perpetuates the cycle of poverty and hinders the sector's growth potential.

**KEYWORDS**:

Cold Chain Infrastructure, Crop Pricing, Farmer Producer Organizations (FPOs), Food Processing Industry, Government Policies, Price Support Mechanisms.

## 1. INTRODUCTION

The country's agricultural marketing environment must be included in any discussion of agri-supply chain management. The provides a thorough overview of the nation's agriculture marketing system and how it relates to supply chain management challenges. It should be obvious that the marketing and manufacturing of agricultural products are closely related to one another. A country's agricultural economy is primarily driven by an efficient agriculture marketing system via cost-effective supply chain management in the post-WTO era. An efficient marketing system works to ensure that producers get fair compensation at low marketing costs and that consumers have consistent access to goods at fair rates. A variety of governmental interventions have sometimes been made in order to safeguard the interests of the many players in the supply chains of agricultural commodities within the country's agricultural marketing system. The nation's current agricultural marketing system, however, needs substantial improvement. The mechanism for selling agricultural goods is riddled with flaws. To address these challenges, the administration has already started implementing certain reform measures, and more are on the way[1], [2].

### Traditional agricultural marketing system characteristics

The government has long given the issues with agricultural marketing its attention. The Royal Commission on Agriculture had noted that the system in place at the time did not match the criteria of the ideal selling mechanism as early as 1928. The following are some of the crucial features of the conventional marketing system for agricultural commodities that have been covered: Although there are still many of these, improvements are being made[3], [4].

**Villages sell a lot of agricultural products**

The majority of farmers in India get minimal returns on their product since they sell a substantial portion of it in the communities. The price that is in effect at each level of marketingthe village, the main wholesale market, the secondary wholesale level, and the retail levelvaries.

The volume of village sales varies by region, by product, and also by the standing of the farmer. Food grains make up 20 to 60 percent of the village sale, followed by cash crops, 35 to 80 percent, and perishable goods, 80 to 90 percent. Even now, this practice is fairly widespread. The following causes contribute to village sales:

- Farmers have debts to landlords, dealers, or moneylenders in the community. They are often compelled to sell the product to them at cheap rates or engage into advanced selling contracts.
- Many settlements still lack access to highways. Even in rural areas with good access to highways, there are insufficient transportation options. The product is tough to transport in bullock or camel carts to marketplaces since they are sometimes located far away.
- Due to the majority of farmers' tiny holding sizes, there is only a modest amount of market surplus.
- Farmers often have to sell their products in the villages because they are strapped for cash and must pay their social and other commitments.
- The majority of perishable goods must be sold in the villages due to their poor "keeping" qualities and the lack of speedy transit options.
- Many farmers despised city marketplaces primarily due to their ignorance of standard market norms, the risk of theft or robbery while in transportation, and the challenges they encountered while trying to sell their products there.
- Farmers do not have easy access to information about the prices that are currently being offered in the local main and secondary wholesale marketplaces [5], [6].

**Farmers' Post-Harvest Immediate Sales**

The majority of growers often sell their crop as soon as it is harvested at the cheap rates that are in effect at the time. In the post-harvest season, Indian marketplaces are overstocked due to significant supply. Traders often use this circumstance. In the first quarter of the harvest season, between 60 and 80 percent of the food grains are still sold. In addition to the aforementioned issues, the nation's agricultural supply chain management system has the following shortcomings.Institutional marketing infrastructure is inadequate, and there aren't enough producers' organizations

- The variety of market fees
- The existence of marketing system abuses
- A lack of trustworthy and current market information
- A low market surplus of a wide range of products
- Lack of produce grading and standardization
- Lack of Fast Transport Methods
- The market's oligopolistic structure is caused by unhealthful unionization of merchants and market workers.

**Government marketing agencies**

As an equivalent to the Central Marketing Department, marketing departments were established in the United States. From a fully-fledged department to a cell within the Agriculture Department, the organization of the State Departments differs from State to State. To address the farmers' marketing issues, every State now has a marketing department or cell. State and Union Territories established State Agricultural Marketing Boards in response to the growing importance of agricultural marketing to the state's economic growth and the rising activity of market regulation. These State Agricultural Marketing Boards oversee market regulation and provide a high degree of coordination in how the regulated markets operate at the State level. After the State Agricultural Marketing Boards were established, the plan for market control gained speed. In several states, boards and agricultural marketing departments were combined. However, the National Commission on Agriculture once again advised in 1976 that each state create a separate Directorate of Agricultural Marketing[7], [8].

## 2. DISCUSSION

**Regulation of Agricultural Marketing**

Agricultural marketing has been regulated in several places around the nation as a result of characteristics including excessive marketing costs, unlawful deductions, and the occurrence of numerous malpractices. The creation of regulated marketplaces has greatly improved upon the shortcomings of the conventional marketing system. However, when it comes to village sales, these issues still exist.

**Regulated Market**

A controlled market tries to prevent intermediaries from taking advantage of farmers and to ensure that food is weighed accurately and that farmers are paid promptly. A regulated market is one that attempts to do rid of unhealthy and dishonest behaviors, cut marketing expenses, and provide producer-sellers in the market facilities. The main objective of a legislative proposal to control the marketing of agricultural products is the creation of controlled marketplaces.

Regulated marketing's goals are as follows:

- To stop the exploitation of farmers by assisting them in overcoming the barriers to selling their goods.
- To improve the effectiveness and efficiency of the marketing system so that farmers may get fair prices for their products and the commodities can be purchased by consumers at an affordable price.
- To provide farmers incentive pricing to encourage them to boost output in terms of both quantity and quality.
- Enhancing infrastructural facilities to encourage the orderly selling of agricultural products.

**Reforms**

The State Governments enforce the "Agricultural Produce Market Regulation Act," which is the principal law governing the market. The country's marketing system is supported by a network of more than 7100 regulated markets and over 28000 rural primary markets, 15% of which are also regulated. Initial market control goals included ensuring accurate weighment, rapid payment of farmers for their goods, and preventing intermediaries from taking advantage of farmers. However, the marketplaces that were initially created to shield farmers from the clutches of middlemen's exploitation instead stifled the free development of market forces and put farmers' interests on the back burner[9], [10].

The APMC Regulation prohibited exporters and processors from purchasing directly from farmers, which discouraged the processing and export of agricultural goods. Just the State Gov. may establish markets, hindering the private sector's ability to do so and make investments in marketing infrastructure. The government established the Inter-Ministerial Task Force. In 2002, the government of India estimated that the infrastructure needed for agricultural markets would need investments totaling Rs. 12,400 crores by 2012. For our farmers, the growing emphasis on liberalization, privatization, and globalization presents both a difficulty and an opportunity. However, significant internal improvements in the nation's agricultural marketing system are unavoidable if we want to provide our farmers the chance to capitalize on foreign chances.

**Reforms to regulations implemented**

Government has been in place since 2003. India has already started implementing a number of agricultural marketing changes, and more are on the way. The government has a significant project. developed the Agricultural Produce Marketing Act, 2003, a model law. To implement the necessary changes in the sector, all the States/UTs have agreed to alter their individual State APMR Acts in accordance with the Model Act. The Model Act's key characteristics include establishing markets in the private and cooperative sectors, rationalizing market fees, promoting contract farming, direct marketing, and grading and standards, including the creation of a Grading and standards Bureau in each State/UT. In relation to three areas, namely contract farming, direct marketing, and the establishment of private markets alone, the states have changed their Acts.

Since agriculture is a state matter, the States must take the initiative to implement the needed changes and advance the nation's agricultural marketing system to the pinnacle of perfection. It's time for the States to undertake changes in other areas beyond the three already mentioned, such as creating a State-level Bureau of Standards and Grading, fostering marketing expansion, and creating a responsive market information system, among others. These changes would significantly increase processing, create an integrated supply chain management system, and encourage private investment to the industry.The Indian government has started the following reform-related initiatives:

There is now a warehouse Development and Regulation Authority. This is in charge of the agricultural industry's negotiable warehouse receipt. A Food Safety Regulatory Authority has been established to handle the concerns relating to food safety and quality, and this will go a long way toward protecting the farmers from the distress sale of their goods. It is planned to change the FCR Act in order to strengthen the Forward Markets Commission. The introduction of the Rural Godown Scheme and the Infrastructure Program has significantly increased the amount of private investment in the agricultural marketing industry. The Government of India's Market Research Information Scheme has been effective in distributing data on prices and arrivals from practically all of the wholesale marketplaces in the nation. The government's plan for a terminal market has the potential to encourage the establishment of a hub-and-spoke network of PPP marketplaces around the nation.

**Horticulture Supply Chain Management**

In the first, we spoke about case studies of organized supply chains for several horticulture products. However, a thorough investigation of the problems with India's horticulture product supply chain management is required. The covers an all-India horticulture industry situation before moving on to a case study of supply chain management problems in Andhra Pradesh since the scenario is essentially the same across the whole nation.India is the world's fruit and vegetable basket. It boasts a large output of both fruits and vegetables and produces a wide diversity of both. After China, India is the world's second-largest producer of both fruits and vegetables. India is the world's sixth-largest pineapple grower, seventh-largest producer of apple, and the country that produces the most bananas, mangoes, and papaya. It is the second-biggest producer of brinjal, cabbage, cauliflower, onion, and potato in the world, the greatest producer of okra, and the third-largest producer of tomato. The accompanying graphic shows the quantity and productivity of fruits and vegetables produced in India during the last three years.

The enormous horticulture produce production base provides India with a wealth of export prospects. India exported fruits and vegetables worth Rs. 5730.85 crores in 2012–13, of which Rs. 2467.40 crore was for fruits and Rs. 3263.45 crore was for vegetables. The majority of fruits exported from the nation are mangoes, walnuts, grapes, bananas, and pomegranates, while the majority of vegetables are onions, okra, bitter gourd, green chilles, mushrooms, and potatoes.Malaysia, the United Kingdom, the Netherlands, Pakistan, Saudi Arabia, Sri Lanka, and Nepal. India's share of the world market is still just around 1%, but its horticulture products are becoming more and more popular. This has happened as a result of parallel advancements in modern cold chain infrastructure and quality control procedures. Several Centers for Perishable Cargoes and integrated post-harvest processing facilities have been established around the nation with the help of APEDA, in addition to significant investments made by the private sector. Initiatives to increase capacity among farmers, processors, and exporters have also helped this endeavor.

**Both domestic and international trade**

In India, families consume close to 17% of their food and consumables from fruit and vegetable-based goods. Indian consumers are used to purchasing fruits and vegetables in their raw state and processing them at home. Before preparing meals, households spend time cleaning, sorting, and chopping. Nearly 80% of fruits and vegetables are eaten in their basic form with minimal value enhancement. Confectionery goods and potato chips make up the majority of tertiary items. India still has a low level of consumer expenditure in areas like canned food, jams, pickles, and other processed ready-to-eat goods, which indicates significant development potential. Players have the chance to sell tertiary processed goods that may replace items produced at home, such as canned goods, ready-to-eat meals, and soups.

**A case study on horticulture in Andhra Pradesh**

As a result of its diverse climatic conditions, which include tropical, sub-tropical, and warm temperate zones, Andhra Pradesh has the highest production of some of the nation's horticulture crops. The case study that follows examines the horticulture scenario and supply chain management issues of horticultural commodities of Andhra Pradesh. Andhra Pradesh produced 11.4 million mt of fruit in 2008–09, the most of any Indian state and representing 19% of the nation's overall fruit output. Of all the Indian states, Andhra Pradesh has the second-largest area dedicated to fruit growing. It generates around 5% of the nation's total vegetable output, which places it eighth overall. It produces roughly 29.5% of the nation's total spice output and ranks first in both production and area under key spices. The state is the top producer of certain spices, including coriander, ginger, tamarind, turmeric, and chilies. Andhra Pradesh is the nation's top producer of citrus, papaya, and spices. It comes in second for mango and tomato output, third for pomegranate, and fourth for banana, grape, grapefruit, and okra. In Andhra Pradesh, fruit output rose from 6.2 million mt in 2001-02 to 12.2 million mt in 2007-08 before falling to 11.4 million mt in 2008-09. As in the neighboring state, vegetable output in the state climbed from 2.6 million MT to 5.3 million MT in 2008-09.

**Processing of horticultural products: Andhra Pradesh's current situation**

Compared to other states in the nation, processing of horticultural goods is superior in Andhra Pradesh. But it falls well short of the promise for processing fruits and vegetables.According to data from the Food goods Order, 2.35 lakh tons of fruit and vegetable goods worth Rs. 821 crores were produced in 2007. This accounts for almost 18% of the total fruit and vegetable products produced in India. Of all the Indian states, Andhra Pradesh processes the most fruit and vegetables, followed by Tamil Nadu and Maharashtra. However, the state comes in second place behind Maharashtra in terms of the value of processed fruits and vegetables.

There are 296 licensed Fruit Product Order fruit and vegetable product production facilities in the state as of January 1st, 2009. In the state, there are 54 house scale units, 44 cottage size units, 117 large scale units, and 37 small scale units. In addition to this, there are several unlicensed small-scale companies operating in the unorganized sector that produce fruit and vegetable products. Only 2.35 lakh of the state's roughly 17 million tonnes of fruits and vegetables that were produced in 2008–09 were processed by registered processors. Even if we assume that the organized and unorganized sectors are each twice as large, the state still only processed 2.76% of the total fruits and vegetables produced in the nation.

The Chittoor area is home to the majority of the state's fruit and vegetable processing businesses, which are predominantly mango pulping facilities. The cluster has 65 active units, 50–55 of which are engaged in mango pulp canning, and 15 of which have aseptic packaging capabilities. The Chittoor cluster's specifics have been reported individually. Additionally, the cluster includes 2 IQF factories that prepare various vegetables for export. Many of the facilities also process, although in lesser quantities than mango, other fruits including guava, papaya, tomato, etc. In addition to the Chittoor mandarin-pulping cluster, the East Godavari and Vijayanagaram districts also have a significant mandarin-jelly cluster. In East Godavari, there are about 800 mango jelly units, the majority of which are minor unorganized units. According to estimates, the cluster processes a total of around 0.12 lakh metric tons annually.There are around 58 significant registered units that process and produce chili powder. These units are mostly found in Hyderabad, Warangal, and Guntur. The majority of the 40 registered turmeric processing facilities in the state are found in the Nizamabad and Medak districts. The remaining horticulture product processing facilities are dispersed around the state.

**Horticulture crops in A.P. supply chain**

The supply chain for fruits, vegetables, and spices in the state involves several middlemen and handling, which may sometimes result in significant physical loss and/or value loss of the commodity. The key participants in the majority of the horticulture product supply chains are the farmer, post-harvest contractor/aggregator, commission agency, wholesaler, retailer, and end consumer, even if the supply chains may differ from one crop to another. Some of the main crops' supply and value chains are shown as examples.

**Banana supply chain**

When the fruit is ready to be picked, the farmers go to the banana supplier or commission representative and ask for the price of the day. The farmer then asks the commission agent to come to the farm to check on the fruit's quality. The pre-harvest contractor in the farmer's village or neighborhood is sent by the commission agent to the farm to inspect the fruit and report on its quality. The farmer may initiate this chain of events by asking the pre-harvest contractor in his community to visit his farm, who would then get in touch with the commission agent to inquire about the cost and requirements for the day.

The commission agent communicates with the wholesalers in the consuming marketplaces, and these wholesalers make orders based on market demand. As soon as the wholesaler confirms an order, the commission agent contacts his pre-harvest contractor to visit the farm, match supply and demand, and set up harvesting. Markets and regions have different commission rates for the commission agent. The commission agency further assesses the buyer with various service fees. The service fees are unrelated to the going rate in the marketplace. The farmer is responsible for covering the costs of harvesting, loading onto the truck at the main road, weighing fees, and pre-harvest contractor costs. In some marketplaces, the weight of the stalk is not deducted from the total weight.

## 3. CONCLUSION

To build a marketing environment that is more effective, transparent, and competitive, extensive changes are required. Supply chains can be made more efficient, infrastructure can be improved, and technology-driven solutions may be adopted to assist decrease waste, boost value addition, and provide farmers access to more markets.

Furthermore, by gaining more power via cooperatives, producer groups, and contract farming agreements, farmers may be able to bargain for better rates and conditions. Government policies have a significant impact on how the agricultural commercial environment is shaped. A sensitive approach is needed to strike a balance between the interests of farmers, consumers, and dealers.

Fair trade practices, price stabilizing mechanisms, and market information transmission should all be encouraged by policy actions. It is impossible to exaggerate the importance of technology in modernizing India's agricultural markets. Real-time price discovery is made possible by digital platforms, e-commerce, and mobile apps, which may close information gaps and link farmers with customers. These technologies have the potential to alter the way agricultural goods are acquired and sold as connection and digital literacy increase throughout the nation.

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# CHAPTER 9

# SUPPLY CHAIN OF CHILIES IN GUNTUR: A COMPREHENSIVE REVIEW

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**ABSTRACT**:

The supply chain of chillies in Guntur, India, is a significant and intricate network that plays a crucial role in the region's economy and global spice trade. This study examines the dynamics, stakeholders, and challenges within the chilli supply chain, from cultivation to distribution. Guntur's reputation as a major chilli-producing region makes it an ideal case study to explore the complexities of agricultural production, post-harvest processing, marketing, and export. Through a combination of field research, market analysis, and stakeholder interviews, this study provides insights into the unique characteristics of the chilli supply chain in Guntur. It also highlights the potential for value addition, improved infrastructure, and market linkages to enhance the efficiency and competitiveness of the supply chain, benefiting both farmers and the broader economy.The supply chain of chillies in Guntur is a testament to the intricate interplay of agricultural practices, market dynamics, and global trade. As revealed in this study, the region's reputation as the "Chilli Capital of the World" stems from a long tradition of chilli cultivation and trade. The supply chain encompasses various stages, from seed selection to cultivation, harvesting, drying, grading, packaging, and ultimately reaching consumers worldwide.

**KEYWORDS**:

Agricultural Markets, Chili Processing, Cold Storage Facilities, Export Industry, Guntur Chilies, Local Markets.

## 1. INTRODUCTION

Farmers, commission agents, wholesalers, processors, and retailers are just a few of the many participants in the supply chain. The farmer gathers the crop, dries the peppers, and transports it to the APMC mandi. The product is auctioned off at the mandi. An example auction is held first. Normally, chili sales and purchases start around seven in the morning. The market yard's arrival of chiles is noted in the arrival register. The stock is organized for sale by grower at the commission agents' stores. Chilies are bought at open auction by traders and wholesalers after each lot is examined for quality standards. Although open auction is the preferred form of selling, it is seldom used instead mutual negotiation is used to complete the sale and purchase. Multiple types of chilies are cited as a practical barrier to the use of the auction method[1], [2].

The commission agents now charge farmers a 2.5% commission. The fee, however, varies from 2% to 8% depending on a number of other parameters, such as the credit given by the commission agency to the producer. There are also additional handling fees of between Rs. 10 and 20 each bag. The payment is due on the 13th day after the sale of the product; else, the commission agent must pay the seller interest at a rate of 24% per year. It's interesting that despite the enormous output, there isn't much value added. Trade estimates that only around 5-7 percent of the crop is being added value to, with about 70 percent of the harvest being marketed as dried, unground red chillies and 20 to 25 percent as ground chilli powder. Chilies are often processed at the processor level to create various products. There are three categories for dried peppers used commercially.  very pungent Chillies slightly to moderately pungent Chillies Paprika may have a sweet or somewhat pungent flavor. Additionally, all three varieties are extracted using solvents to create oleoresins and mixtures of crushed peppers and chilies.

**Chittoor's mango supply network Cluster for mango processing**

The majority of farmers sell their goods to commission salespeople working in the neighborhood APMC market yards/mandis. The majority of processors either get their products via commission agents or the neighborhood mandi. Some processors purchase straight from substantial farms. But according to trade sources, fewer than 10% of all purchases are made directly from farmers. Pulp and concentrate are sent to secondary processors of juice, squash, jam and jelly, confectionery and ice cream producing units after processing in order to add value. The variations are delivered to key consuming markets in Bangalore, Chennai, Kolkata, and Hyderabad by dealers and commission agents, and then by retailers to final customers. Only a small percentage of processors export the pulp directly; the majority do so via export houses or export corporations[3], [4].

**Value Chain of Peppers**

Similar to the example above, 63% of the final rupee of the selling price of chili powder at the processor level goes to the chili grower. However, processing suffers from considerable loss, which reduces the processor's realization.

The cost of processing is a substantial additional expense in the value chain. 2.5% of the commission is charged to the farmer by the agency. His commission is Rs 100 if the price revealed is Rs 4000. If you buy directly from farmers, you may easily eliminate this expense. According to a value chain analysis, the cost of value addition is approximately Rs 275 per quintal, the cost of value addition is approximately Rs 800 per quintal, the cost of taxes is approximately Rs 200 per quintal, the total gross margin of the chain is approximately Rs 2000 per quintal, and the cost benefit for the farmer, trader, and processor per unit.

**Cluster of fruit processing in the Chittoor district:**

The Chittoor area is home to the majority of the state's fruit and vegetable processing businesses, which are predominantly mango pulping facilities. The cluster has 65 active units, of which 50–55 is engaged in the canning of mango pulp and 15 have aseptic packaging capabilities. Additionally, the cluster has two IQF factories that prepare various vegetables for export. Many of the facilities also process other fruits, although in lesser quantities, such as guava, papaya, tomato, etc., except from mango, which is only accessible for around two months.

During the season, the typical capacity of canning and aseptic packaging units is respectively 1500–2000 MT and 400–5000 MT of mango pulp. The majority of the cluster's units fall into the modest size category. Totapuri, which grows widely in the area and is suitable for processing, is the primary mango variety that is processed.

The second kind, Alphonso, is likewise processed; it is more expensive but has a superior taste, making it ideal for blending. The cluster produces pulp that is sold to numerous major domestic brands, such as Coco-Cola, Parle, and Pepsi Co India, for around 85% of its exports. Middle Eastern nations are the biggest consumers of pulp, followed by Germany, the United Kingdom, Singapore, and Thailand.

## 2. DISCUSSION

**Challenges related to supply chain in A.P**

The lack of post-harvest infrastructure at the farm level is a significant gap in the state's supply chain for horticulture commodities. Sorting, grading, washing, packing, and other crop-specific post-harvest operations are almost nonexistent at the farm-proximate level; farm level collecting facilities are mostly missing. This causes more losses and lesser value realization by those involved in the value chains, particularly the producers[5], [6].

**Shoddy Packing Techniques:**

The majority of produce transit to the mandi/units lacks suitable packing, buffering, and insulation, resulting in significant losses in the form of waste. Produce is often thrown on the ground in the market yards for weighing and price haggling. Before being dumped back into the conveying truck for further transit, some hand sorting and grading is done at the market yards. Higher waste is produced by this handling.

**Lengthy and Complex Supply Chain**

Numerous small farmers are unable to successfully negotiate a higher price in the wholesale markets, both for products to fulfill the demands of the fresh market and for the processing sector. Small farm size combined with inefficient wholesale markets leads to a lengthy chain of middlemen, multiple handling, quality losses, and a widening price difference between producers and consumers. A disproportionate amount of consumer costs is consumed by intermediaries and systemic inefficiencies. The customer is forced to pay for the inefficiencies in the marketing chain due to the high overhead created by the large number of small shops, each of which deals in little amounts.Lack of facilities for scientifically ripening crops like bananas and mangoes:

Traditional techniques of handling bananas after harvest result in finger injuries. Farm level collecting centers and pack buildings are also lacking. De-handling is done at the marketplaces where the product will be sold, and the center stem must also be transported with the bunch. Due to the previously described numerous factors throughout the value chain, 25–30% of the fruits are wasted for these reasons[7], [8].

New, cutting-edge ripening facilities are required at the state's key consumption hubs for several fruits, including banana and mango. The ripening chambers now in use employ antiquated technology. They are upgradeable with things like automated temperature control, palletization facilities, ethylene generators, and ethylene scrubbers. This will guarantee improved fruit quality and a longer shelf life, resulting in greater price realizations for the producers and better product for the end user.

**Lack of cold chain infrastructure**

For horticultural goods in the state, integrated cold chain infrastructure is not very prevalent. Even for very perishable goods, refrigerated vehicles are only sometimes used. Horticulture crops including apples, oranges, chillies, turmeric, and tamarind are held in the state's current cold storage facilities, but new cold storage facilities are required close to the key consumption centers. Additionally, many cold shops use antiquated technology, which results in poor energy efficiency. Additionally, the state lacks sufficient educated human resources for technical administration and operations in cold warehouses. With so many new cold shops opening up, business owners are having trouble finding and keeping the most qualified human resources[9], [10].

**Processing-related difficulties**

**Power source**

Fruits and vegetables are processed mostly during the peak season for arrivals of the particular commodity. The typical annual operating period for the fruit and vegetable processing plants is just 120–150 days. Since the majority of processing is done during the busiest period for arrivals, a lack of electricity during this time increases processing costs since the processors rely on fossil fuels to generate their own power. Furthermore, the problem is made considerably more significant by the perishable nature of fruits and vegetables in comparison to other agricultural goods like rice and oil seeds.

**Demand minimum fees**

The fruit and vegetable processing business is very seasonal, as was already said, and as a result, the year-round need for electricity is not constant. Several processors stated during the field survey that processing units must pay minimum demand costs depending on connected load regardless of utilization, adding to the cost of the processed product.

**Laws pertaining to labor resources**

Due to the seasonal nature of the business, the units must operate throughout all three shifts while the raw materials are available for processing. The processors are finding it difficult to adhere to labor standards regarding the weekly off and the working hours for female employees.

**Labs for quality control and assurance**

While the processing plants are situated in the hinterland, the majority of the quality assurance laboratories that are recognized by the customers are found in major cities like Hyderabad, Bangalore, and Chennai. The processing plants have basic quality laboratories on site, but samples must be transferred to distant cities for complex testing like checks for pesticide residues, which adds to the cost and turnaround time.

**Typical facility/incubation centers**

There are no common facility centers set up to assist new entrepreneurs in setting up processing units, lowering the initial cost of installation and freeing up resources for creating new products or new markets. There are no incubators in the state to assist businesses in creating new goods or coming up with fresh answers to issues they are currently facing.To handle all the issues and difficulties mentioned in the preceding part, a multifaceted approach must be developed. However, addressing all of the difficulties, particularly those that are production-related, is beyond the purview of this research since they lie within the authority of several departments. The following interventions are recommended based on our evaluation of the applicability of interventions connected to the Department of Food Processing/Department of Industries.

**Interventions Connected to Infrastructure**

1.fostering integrated value chains for all possible state goods throughout all areas. IVCs would provide the necessary infrastructure at all levels of value to serve all of the key horticultural crops in the areas. Depending on the needs of the major crop in each prospective area, the hub will feature primary processing facilities such cutting-edge pack houses, ripening chambers, and cold warehouses. An example of the facilities for an IVC for bananas is shown below: At the major banana production clusters in the area, modern pack houses may be built to accommodate the bananas cultivated nearby, which need a truck to drive for two to three hours to reach the pack house.

**Dairy Supply Chain Management**

With an annual output close to 130 million MT and a growth rate of over 5%, milk production in India is the biggest in the world and accounts for 5% of the GDP.A village's farmers pump milk into a collecting facility every morning and evening. Farmers or other producers who are members of the cooperative refer to it as the Village Level Cooperative Society, which is owned. It is known as the Village Level Milk Pooling Point in Reliance. Accordingly, each farmer pours milk into a measuring cup, which is then weighed and analyzed to determine the proportion of fat and saturated fat (SNF). Once every week or every ten days, farmers get compensated.

**BMC/MCC village collection centers**

Raw milk obtained from cows or buffalo is very bacterial and also nutrient-rich. As a result, at room temperature, bacteria quickly begin to thrive and spread, making milk very prone to spoiling. Milk obtained from farmers at the village collecting point is sent to a nearby Bulk Milk Chilling Centre or Milk Chilling Centre to prevent spoiling. Milk is removed from numerous VLC or VLPP using vehicle or truck. Milk is refrigerated to 4 degrees Celsius at BMCC or MCC because at this temperature germs cannot multiply further, keeping the milk safe and allowing for eventual transmission to a processing facility distance from the original village collecting station. A BMCC's installed capacity may range from 2000 to 5000 liters depending on the need, but an MCC's capacity can range from 6000 to as much as 30 to 40 thousand liters. Therefore, via a variety of channels, each BMCC or MCC offers a cooling facility to hundreds of communities that are mapped under it.

**Dairy tanker**

Insulated milk tankers are used to deliver chilled milk from BMCC and MCC to the processing plant. Temperature is maintained throughout the often 30- to 40-hour travel to processing by an insulated tanker. It is necessary to properly clean and sanitize the inside chamber before filling the milk tanker. For the examination of Fat and SNF, one sample is taken from the full tanker. Along with the tanker to the processing facility, a paper containing information on the milk's amount, fat, SNF, acidity, etc. is sent. Lactic acid serves as a milk quality indicator. It is crucial to note that inbound logistics plays a key role across the whole supply chain, even if what has been described so far only represents a portion of the dairy SCM. The difficulty is in coordinating with various VLC/VLPP with BMC/MCC and securely transporting the raw material to the processing facility while keeping its quality. Therefore, in addition to quality and other factors, the logistic problem is how to maintain the cost of shipping as low as feasible.

**Manufacturing Unit Processing**

A whopping 46% of all milk is eaten as liquid milk, with 27% going to ghee. Butter contains 6.5%, while curd has nearly 7%. For the conversion to milk powder, around 4% is used. The remainder is used to make cheese, khoa, and other foods.

Cheese is a high-value commodity, and consumption is rising as the high-income urban population's lifestyles change. The manufacturing processes for the various products described above vary and are within the purview of dairy technologists working in this area. But here's an illustration of how to make the milk pouches:

In order to make the milk safe for human consumption, the milk that has been obtained from the BMC or MCC is once again cooled and kept in the silos until it is put through a procedure called pasteurization. Pasteurization involves killing the harmful bacteria present in the milk. However, milk is regulated to ensure that it meets the PFA's basic requirements. For instance, Toned Milk must have at least 3.0% Fat and 8.50% SNF. Milk that has been standardized and pasteurized is sent for packaging into polythene packets. Packed milk is stored at 4 degrees Celsius in the cold storage, and from there it is delivered by insulated vans to the agents dispersed around a certain region. Dairies typically dispatch at night, however in certain markets they may do it in the day.

**Sales, Promotion, and Distribution**

Distribution methods, logistics practices, and marketing strategies are all heavily influenced by the kind of product. India is the world's third-largest producer of eggs and fifth-largest producer of chicken meat. About 2 million people are employed by the poultry sector in India, which also makes up 1.1% of the country's total GDP. In contrast to the general meat industry growth rate of 5% per year, chicken meat is seeing the greatest growth rate of all meat categories, at over 15% per year. About 25% of the nation's total meat output is now made up of poultry. Over the last three decades, the poultry sector has grown quickly. A number of advancements in poultry science and technology have produced genetically better birds with high production rates even in unfavorable hot climates. Production of cutting-edge poultry equipment, premium poultry feed, medicines, and healthcare items including vaccinations are some of the key elements influencing increased productivity. The private sector still makes up the bulk of the poultry producers in this business, and between 25 and 250 birds are often raised in backyards by these farmers. Additionally, processed meat makes up a very small portion of the entire value of meat production.

**Both opportunities and threats**

Despite being one of the world's top producers of chicken goods, India has one of the lowest rates of per capita egg and poultry meat consumption. Around 40 and 1 kilogram of eggs and 10.8 kg of chicken meat are consumed annually per person in the nation, respectively, as per the Nutritional Advisory Committee's recommendations. Low per capita income, high pricing, and sociocultural and religious issues are all blamed for the poor consumption of chicken products. High pricing are a result of high feed costs, a poor meat yield, inefficiencies, diseconomies of scale, and a lack of state-of-the-art processing facilities. Feed expenses are around four times as costly as those in other nations, such as Brazil, and make up between 70 and 75 percent of the whole cost. Low yields of feed materials like maize are a major contributor to these high prices. The exclusivity of this market to small-scale operations is another factor keeping feed prices high. These businesses have inadequate economies of scale and often lack the funds to make investments in cutting-edge technology. Indian breeds produce less meat per animal than varieties utilized in Western nations because they have lower Feed Conversion Ratios. The FCR in India is normally 1:2, which means that for a broiler to gain 1 kg, 2 kg of feed must be given. In the majority of industrialized nations, the FCR is 1:1. Obviously, greater total costs arise from poor FCRs. Lack of research on genetics to create high-yielding kinds, nutrition and environment for healthy broiler development, and a lack of contemporary methods for raising chicken are other factors that contribute to poor meat production. In addition, since the majority of poultry producers are small-scale farmers in the unorganized sector, as was already indicated, they face inefficiencies and diseconomies of scale as well as a lack of resources to invest in new technology.

India's processed meat market is expanding relatively slowly. In affluent nations, practically all broilers are processed and marketed as value-added goods in the form of portions, boneless chicken, and other items that have undergone further processing. The majority of chicken sold is processed and branded, even in nations like Malaysia, Indonesia, and Thailand. However, chicken meat is only marketed in its processed and branded form in roughly 2-3% of the country's total production, making it a commodity product. The desire for live chicken among customers and their suspicion of processed chicken, as well as insufficient infrastructure such a lack of cold chains, are the two primary causes of this. Indian customers consider chicken to be fresh if it is live and chopped in front of them, even if it is done in a very unclean way. Customers prefer live chickens over processed chicken since the latter is seen as "not as fresh" and is thus readily accessible in marketplaces. Additionally, since processed chicken is more expensive than live chicken, it has only recently been available to those with higher incomes.

With advertising and education, the consumer perspective would progressively alter in favor of processed chicken. The quality of processed meat degrades as a consequence of the absence of cold chains from the processors to the retailers and the inadequate refrigeration facilities at the retail outlets, which eventually has an impact on consumer health. India consumes the majority of the chicken meat that is produced there. There is hardly any of this that is exported. Indian chicken products are uncompetitive on the global market due to their high manufacturing costs. Indian chicken meat costs more than 50% more than the global average. Due to inadequate infrastructure at the seaports and airports, exports have also suffered. However, there are a ton of potential for the Indian poultry industry. In addition to having a large live bird population, India also boasts the fastest-growing poultry industry among all meat categories since it is one of the best and fastest converters of plant sources into very biologically valuable food. Due to India's steady economic expansion, rising per capita income, expanding non-vegetarian population, and growing knowledge of the health benefits of chicken meat, demand for poultry meat is anticipated to increase more quickly. Along with rising health consciousness and higher living standards, the demand for processed meat is also anticipated to expand. The biggest vertically integrated chicken farm in India, Venkateshwara Hatcheries, launched processed meat under the name "Venky's" in the Indian market in 1986. Later, a lot of local chicken farms began selling processed chicken in lesser quantities.

There should be rules and streamlined processes to attract private investments in the poultry sector in order to accelerate the expansion of the Indian poultry industry. It is important to upgrade the infrastructure that is already in place, such as the roads and electrical systems, and to build new infrastructure that is sufficiently equipped, such as cold storage facilities, refrigerated transportation, and warehouses. Poor road conditions also cause live birds to weigh less before they are delivered to markets, which has a negative impact on the quality of processed chicken. Chicken that has been chilled or frozen requires a consistent power source to maintain the appropriate temperatures. To increase yield and food value, decrease lead times for the production of broilers, and ensure the preservation of meat product quality for longer periods, the government should invest directly in research on genetics, nutrition, automation, environment, and food safety. It should also encourage private investments in these fields.

In order to process the corn, maize, and other ingredients needed for chicken and broiler feed, contract farming must be encouraged. In order to boost crop yields that would not only guarantee a consistent supply of materials for chicken feed but also smooth out price swings, the private sector poultry farms might collaborate with the contract farmers. This is precisely what occurred in Thailand, where the once-fragmented and unorganized chicken business has evolved into a sector that is structured and composed of major integrated farms like Charoen Pokphand. These farms complement the limited government investments in R&D by working closely with crop farmers, feed producers, growers, hatchers, processors, fast food retailers, and the government to improve breeds of layers and broilers, look for alternative feed sources, and develop better disease control techniques and vaccines. They actively contribute to growing the export market and boosting local demand. Focus has to be placed on awareness initiatives to increase demand for processed chicken. Simplifying customs processes and putting in place suitable infrastructure at seaports and airports are necessary to enable the export of chicken. The elimination of agricultural product subsidies globally in accordance with WTO accords is projected to provide Indian poultry exporters access to new markets including those in Russia and Eastern Europe. The focus should be on vertically integrated poultry supply chains and industrial consolidation in India's poultry sector via mergers, acquisitions, and strategic partnerships. A farm may be lean, efficient, and competitive in price thanks to vertical integration, which also gives it total control over all supply chain components. The costs and quality of processed chicken would also become competitive on the global market thanks to scale economies achieved by the integrated farms.

## 3. CONCLUSION

The chilli supply chain in Guntur confronts a number of difficulties despite its significance. Ineffective post-harvest procedures, a lack of consistent grading and quality control, restricted access to financing and market data, and the predominance of intermediaries may result in lower farmer income and less competitiveness in international markets. There is, nevertheless, a great deal of room for development. The effectiveness and quality of the supply chain may be improved by introducing contemporary storage facilities, improving grading and certification procedures, and using digital platforms for market information distribution. Additionally, cultivating sustainable agricultural techniques, increasing value addition via goods like chilli paste and powder, and establishing direct market links may empower farmers and boost their revenue. The chilli supply chain in Guntur is representative of the agriculture sector's bigger prospects and problems. The area can strengthen its position in the international spice trade, enhance the lives of chilli farmers, and contribute to regional economic development by solving the infrastructural, technology adoption, and market access constraints.

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# CHAPTER 10

# GENEBANK STANDARDS FOR PLANT GENETI RESOURCES FOR FOOD AND AGRICULTURE

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**ABSTRACT**:

Genebank standards for plant genetic resources for food and agriculture (PGRFA) are critical guidelines that ensure the effective conservation and utilization of the world's plant diversity. This paper examines the significance of genebank standards in maintaining the genetic diversity essential for food security, climate adaptation, and sustainable agriculture. The study explores the principles and components of genebank standards, emphasizing their role in preserving the viability and integrity of stored seeds and germplasm. Through an analysis of international agreements, case studies, and best practices, this paper highlights the global effort to harmonize genebank operations, data management, and access and benefit-sharing mechanisms. It underscores the collaborative nature of genebank standards and their contribution to securing agricultural resilience and biodiversity conservation.Genebank standards for plant genetic resources for food and agriculture constitute a foundational framework that underpins global efforts to safeguard agricultural biodiversity. As evident from this study, these standards play a critical role in ensuring the quality, safety, and accessibility of genetic resources held in genebanks around the world.

**KEYWORDS**:

Conservation Methods, Diversity Indexing, Germplasm Collection, Genetic Resources Management, International Treaty, Quality Control.

## 1. INTRODUCTION

These genebanks are used to conserve plants that generate non-orthodox seeds, also known as recalcitrant or intermediate seeds, and/or are propagated vegetatively. These plants need different ex situ preservation techniques since they cannot be preserved in the same manner as conventional seeds, i.e., at low temperatures and humidity[1], [2].The most popular technique for non-traditional seed producing plants is field genebanking. Additionally, it is employed for plants that produce a small number of seeds, are vegetatively propagated, or need a lengthy life cycle in order to supply breeding and/or planting materials. The process also involves keeping live plants in pots or trays in greenhouses or shade houses, even though the phrase "field genebank" is used. For the administration of germplasm collections kept in field genebanks, technical guidelines and training materials are provided.Plant germplasm may be preserved in vitro by slow growth for short- or medium-term storage, or it can be preserved through cryopreservation for long-term preservation. The earlier technique involves maintaining cultures on synthetic culture medium under growth-restrictive circumstances. The growth rate of the cultures may be slowed down by a variety of techniques, such as decreasing the light intensity, raising the temperature, or altering the culture media by adding growth inhibitors or osmotic agents.

Storage of biological materials at very low temperatures, typically liquid nitrogen at -196 °C, is known as cryopreservation. These circumstances cause the majority of physical and biological processes to cease, allowing for the long-term conservation of materials. For safe, effective, and cost-effective conservation, these techniques of conservation must be used in conjunction with other modes. Cryopreserved lines, for instance, may be kept as a backup for field collections, as reference collections for a population's genetic diversity, and as a source for upcoming novel alleles.For each kind of genebank, the following requirements are given:Orthodox seeds must meet the following genebank standards: collection of germplasm, drying and storage of seeds, viability monitoring, regeneration, characterisation, assessment, documentation, distribution, safety duplication, and security/staff.Standards for Field Genebanks include site selection, germplasm gathering, field collection installation and administration, regeneration and propagation, characterisation, assessment, documentation, dissemination, security, and safety duplication[3], [4].

**Genebank Standards for In Vitro Culture and Cryopreservation**

Collection of germplasm, evaluation of water content, vigor, and viability, hydration of seeds that are resistant to germination, in vitro culture and slow-growth storage, cryopreservation, documentation, distribution, and exchange, and security and safety duplication. Genebanks all throughout the world have a lot of the same fundamental objectives, although their missions, resources, and the systems they work within often vary. As a consequence, curators must optimize their own genebank systems, which calls for management approaches that may vary greatly across institutions while pursuing the same goals. Plant genetic resources are retained for a variety of reasons, which are explained by underlying concepts. These principles serve as the foundation for creating the norms and standards necessary for a genebank to run efficiently. There is a description of the main guiding concepts for conservation.The identity of seed sample accessions preserved in genebanks should be carefully ensured to remain intact throughout the different procedures, from acquisition to storage and dissemination. Careful preservation of data and information about the material is necessary for accurate identification of seed samples preserved in genebanks. This starts with documenting passport information and, if necessary, gathering donor data. When feasible, this data should also be kept on file for earlier genebank collections whose passport information has not yet been captured or is insufficient. Seed reference collections and herbarium voucher specimens are often crucial for the accurate identification of seed samples. It is crucial to identify accessions in the field since poor labeling may cause significant genetic degradation. Field layout designs should be used in conjunction with field labeling and be carefully recorded to guarantee accurate accessions identification in field genebanks. Field labels may be lost as a result of many outside circumstances, such as harsh weather. Modern methods may substantially simplify the administration of germplasm by lowering the chance of mistake and further verifying the identification of accessions, such as accession labels with printed barcodes, RFID tags, and molecular markers[5], [6].

**Preservation of Viability**

The ultimate goal of genebank management is to preserve the viability, genetic integrity, and quality of seed samples stored in genebanks and make them accessible for usage. As a result, it is crucial that all genebank procedures follow the requirements set out in order to maintain appropriate levels of viability. Standards for germplasm procurement, processing, and storage need to receive special attention if this goal is to be accomplished. This is determined by visual examination for absence of damage, as well as by rate and totality of germination, for recalcitrant and other non-orthodox seed types. However, the presence of bacteria and fungus that are macroscopically imperceptible may degrade the quality of the seeds. In general, seed samples accepted into seed genebanks should be highly viable and, to the greatest extent feasible, conform to the requirements for the acquisition of germplasm. In order to preserve the maximum physiological seed quality, it is best to collect the seeds as soon as they are ready but before they naturally disseminate. Avoid collecting dispersed seeds from the ground or seeds that are dirty and may contain saprophytic or pathogenic fungus or bacteria. In order to prevent sample quality from being harmed, genebanks should, to the greatest degree feasible, guarantee that the germplasm they have gathered is genetically representative of the original population. They should also account for the quantity of active propagules. Depending on the anticipated seed lifespan, a monitoring system has to be in place to assess the viability state of stored samples at suitable intervals. If the proper attention is given to post-harvest treatment, drying, and storage, the frequency of regeneration may be decreased. Propagability is more important in the context of field genebanks than viability, which precisely refers to a seed's ability to germinate and generate a plantlet. Field genebanks are susceptible to environmental influences from things like weather, the prevalence of pests, etc. The severity of these affects will vary depending on the species and development cycle of the species, such as annual, biennial, or perennial. The need to a priori determine seed responses before to implementing any germplasm storage strategies is another consideration in the case of species whose seeds exhibit uncertain post-storage behavior[7], [8].

**Preservation of Genetic Integrity**

Maintaining the viability and variety of the original obtained sample is crucial for maintaining genetic integrity. The preservation of genetic integrity depends on each and every genebank step, from collection and acquisition through storage, regeneration, and dissemination. Maintaining viability in accordance with the requirements aids in the preservation of genetic integrity. In particular when samples are returned from cryostorage, a variety of molecular approaches are required to determine if genomic stability has been preserved, including assessments of potential epigenetic alterations that may or may not be reversible. In plants that need a lot of time between planting and reproductive maturity, seed regeneration in the field would be very difficult to do. When there are indications that a population's vitality and viability are waning, a resample of the original population should be collected. For germplasm preserved in vitro, maintaining genomic integrity is just as crucial, particularly given the possibility of somaclonal variation. This is the major justification for avoiding indirect somatic embryogenesis when producing types of germplasm that should be maintained. As far as is possible, sufficient quantities of high-quality, adequately representative seed samples should be acquired during acquisition. It is understood that the sample may not be representative of the original population when the goal is to gather certain qualities. Following established protocols1 for regenerating seed accessions with as few regeneration cycles as feasible, sufficiently high effective population sizes, balanced sampling, as well as pollination control is crucial for minimizing genetic loss. The significance of safety duplication in addressing potential dangers in genebank facilities is highlighted here.

**Protection of the Genetic Diversity**

Genebanks have to make an effort to guarantee that the seeds they are storing and disseminating are free of controlled pests and diseases that may be transmitted via seeds. Surface disinfection techniques may often be used to efficiently remove external surfaces. Genebanks often lack the ability or resources needed to conduct tests to determine if samples obtained in any other way, as well as samples taken from regeneration and multiplication plots, are free of seed-borne illnesses and pests. This is especially true for material that was obtained from outside sources. Recalcitrant-seeded species conservation presents additional challenges. Only when resistant seeds are kept in short- to medium-term hydrated storage or when explants made from seeds are put in tissue culture can pollutants that are internally-borne become apparent. The only approach to guarantee uncontaminated germplasm is to now unsatisfactorily dispose of any contaminated seed or explant. To assure the quality of samples received, it is crucial that seed material be accompanied by the relevant import and phytosanitary certifications when germplasm is exchanged. While some infected/infested samples may be simply cleaned, others may need more complex cleaning techniques.

## 2. DISCUSSION

The physical infrastructure of the genebank facilities where germplasm is preserved must meet acceptable standards to protect the materials from any external causes, including natural catastrophes and human-caused harm. This is a fundamental tenet of germplasm conservation. To guarantee that genebank cooling equipment, backup generators, and equipment to regulate power outages are in excellent working order and that monitoring devices are accessible to track crucial parameters over time, adequate security mechanisms are needed. LN supplies must always be accessible since cryogenic storage demands it. It is crucial to maintain LN levels regardless of whether the LN freezers or customized storage vats are filled or topped up manually or mechanically. Making ensuring materials are securely replicated in other places is another crucial security concern for genebanks. By doing this, material may be recovered from duplicate sets in the event that a collection is lost for whatever reason[9], [10].

### Germplasm availability and usage

The preserved content must be accessible for use now and in the future. Therefore, it is crucial that every step of the administration and functioning of a genebank advances this objective. It will be necessary to have enough seed and information on the accessions on hand. Field genebanks have a limited ability to distribute to users since there are only a few individuals of each accesssion; nonetheless, the genebank should have a plan in place to swiftly multiply any germplasm for distribution.

### Information accessibility

Essential, thorough, accurate, and up-to-date information, including historical and current information, especially in relation to the management of individual accessions following their acquisition, should be recorded in electronic databases to ensure communication of information and accountability. This information's accessibility, availability, and sharing should be given top importance since they promote better and more thoughtful conservation. Phenotypic assessment data from search-query interactive databases may help germplasm customers tailor their requests for germplasm, and in turn, feedback of more evaluation data increases the value and usability of the collection. It will improve the usage of preserved germplasm if information about it is made freely accessible and available. Furthermore, by properly planning their multiplication and regeneration tasks, the genebank curators will be able to maintain enough supplies of their accessions. It is advised to use an interactive search-query database for these genebank-based information systems. A notable illustration of the importance of this kind of information is the Millennium Seed Bank's Seed Information information 2 at Kew. While EURISCO4 is a web-based library that offers information on European ex situ plant collections, BRAHMS 3 is a system designed for the objectives of curation and germplasm data management.

### Proactive control over Gene Banks

Active management of saved germplasm is necessary for the efficient and sustainable conservation of genetic resources. For germplasm to be effectively protected and made promptly and sufficiently accessible for use by plant breeders, farmers, researchers, and other users, proactive management is essential. It places a focus on the significance of protecting and disseminating information linked to the material as well as the content itself, and it establishes a practical plan for managing human and financial resources for a logical system.

In an attempt to protect biodiversity, it promotes partnerships with outside parties to provide services to genebanks and includes a risk management plan. It should be noted that field collection upkeep is expensive, hence every attempt should be made to create supplemental in vitro or cryopreservation collections. Compliance with national and international legal and regulatory frameworks is required, particularly with regard to access, availability, and distribution of resources as well as the health of plants and seeds. For crops under the Multilateral System of the ITPGRFA, a Standard Material Transfer Agreement should be employed where suitable. In order to stop the introduction and spread of plant pests and diseases, the IPPC laws establish the basis for quarantine and health restrictions. In terms of the availability of human and financial resources, there is a need for the organizations holding genebanks to commit long-term and continuously.Additionally, proactive management tries to implement the Genebank Standards to the greatest degree feasible under locally-prevailing circumstances and fosters the application of real-world experience and knowledge to fresh germplasm in a genebank. This might sometimes imply that, even when a specific criterion isn't fully followed, precautions are made to protect the fundamental principles of managing genebanks.

**Genebank Requirements for Religious Seeds**

Acquisitions are done in line with relevant international and domestic legislation, such as phytosanitary and quarantine rules, ITPGRFA or CBD access laws, and national laws for access to genetic resources. Following Standard 4.1.1 will establish the management and distribution regime, permit the export of seeds from the nation of origin/donor and the import into the country of the genebank.Maximum seed quality must be maintained, and immature seeds and seeds that have spent too much time outside must not be preserved. Seed quality greatly depends on how they are managed after collection and before being placed in controlled environments. During the post-collection phase and during transportation to the genebank, unfavorable high temperatures and humidity might lead to a quick decrease in viability and shorten lifetime after storage. The genebank's post-harvest management follows the same rules. The circumstances endured prior to storage inside the genebank have an impact on the seed quality and lifespan. It is advised that a germination test be carried out right away after processing and before to pre-storage in order to assess the caliber of the seed gathered.It is crucial to make sure that each accession's passport data is as comprehensive and well-documented as possible throughout the acquisition process, particularly georeferenced data that may be used to find collecting locations. Passport information is essential for categorizing and identifying the accession and will serve as a starting point for choosing and using the accession.

**Specialized Elements**

In the multilateral framework of the International Treaty, SMTAs are required in order to get access to PGRFA. According to the national legislation for access to genetic resources of the country where the collection will take place, the acquirers must adhere to the relevant rules of the ITPGRFA or the CBD and must have the authorized person sign an MTA. Additionally, access must be subject to prior informed permission from the country as needed by the nation offering the service. The appropriate national authorities of the recipient country must be consulted for phytosanitary laws and any other import restrictions.

Freshly plucked seeds from the field may have a high-water content, and ventilation is necessary to stop fermentation. They should be put into appropriate containers that allow for proper air circulation, guarantee the contents don't become wet from insufficient air exchange, aren't mixed up during collection and transport, and don't get damaged. Maintaining seed quality will include keeping an eye on the temperature and relative humidity to make sure that seeds are not subjected to circumstances exceeding 30 °C or 85 percent RH after collecting and transporting as well as throughout post-harvest processing. To lessen the danger of degradation, technical guidelines for the specific or related species should be used while processing and drying completely developed seeds in the field.

Data collected should be recorded using appropriate forms. These forms ought to contain details like the sample's initial taxonomic classification, the location of the collection site's GPS coordinates, a description of the plants' habitats, the number of plants that were sampled, and other pertinent information that is vital for effective conservation. The FAO/Bioversity multi-crop passport descriptors should be utilized, if at all practicable. When seed is gathered from farmer fields or shops, farmer interviews may provide very important extra information, such as cultural practices, prior generations of seed history and origin, usage, etc. The collector should be aware of the dwindling numbers of the wild population they are targeting while they are collecting. The collection handbook for the European Native Seed Conservation Network advises against taking more than 20% of the total seeds present in a population. To optimize the collection of genetic diversity that may be present at different times, it may be helpful to repeat sampling from a certain place.

At least one copy of 95% of the alleles that occur in the target population with a frequency higher than 0.05 should be present in the collecting sample. To accomplish this goal, a random sample of 59 unrelated gametes is sufficient; in a species that reproduces entirely at random, this translates to 30 people, but in a species that exclusively selfs, this aim needs 60 individuals. Therefore, depending on the breeding strategy of the target species, the sample size to capture 95% of the alleles might range between 30 and 60 plants. In order to prevent frequent regeneration, sufficient amounts of seeds should be gathered and distributed. We should be aware, nevertheless, that depending on the availability of seeds for harvest, this goal could not always be reached.

If seeds are donated, along with any accessible passport information, the taxonomic classification, donor, donor's identity number, and names should be included. You should ask the donor for adequate details regarding how the germplasm you obtained was kept, including pedigree or lineage information and, if available, chain of custody information.

The validity of the seed sample should be ensured by giving each batch of seeds a unique identification number that they carry with them at all times and connects to their passport information and any other information gathered. When feasible, a herbarium voucher specimen should be obtained from the same population as the seed samples, and the technique and justification for collection should be documented.

**Contingencies**

Rarely are field-collected seeds in such quantity or in such good shape as to automatically assure long-term preservation. It is advised in this situation to multiply under controlled circumstances with the explicit goal of long-term conservation.Whenever there is a high percentage of immature seeds or fruits in collections, steps should be taken to promote post-harvest ripening.

Usually, you may do this by keeping the material in an environment that is well-ventilated and dry. As soon as it is determined that the gathered seeds are more developed visually, the material should be transported to controlled drying conditions. For wild and endangered species, where seeds would not be readily accessible in sufficient quantities or under ideal circumstances, allowances in terms of the higher requirements will need to be made.

**Standards for measuring seed viability Standards**

After the accession has been cleaned and dried, or at the latest within 12 months of the sample being received at the genebank, the first seed viability test should be carried out. The majority of seeds from farmed crop species should have an initial germination value greater than 85%. A lower proportion could be acceptable for some accessions, wild species, and forest species that do not often achieve high germination rates. Depending on the species or particular accessions, viability monitoring test intervals should be set at one-third of the period projected for viability to decline to 85%1 of original viability or lower, but no more than 40 years. The interval should be ten years for species with long lifespans and five years or fewer for species with short lifespans if this degradation duration cannot be calculated and accessions are being stored in long-term storage at - 18°C in hermetically sealed containers. Depending on the species or particular initial viability accessions, the viability criterion for regeneration or other management decisions like recollection should be 85% or lower.

Germplasm viability is maintained by ideal seed storage conditions, however even under these ideal circumstances, viability decreases with time. Therefore, it is essential to frequently evaluate viability. Before the seeds are packed and placed in storage, the first viability test should be carried out as soon as feasible. Subsequent tests are carried out at regular intervals during storage. If the first viability test cannot be performed prior to storage due to workflow and efficiency concerns, it should be performed as soon as feasible and no later than 12 months after receipt. In multi-species genebanks, a variety of germination regimens may be necessary, and samples from the same species may be evaluated collectively once a year.

Viability monitoring seeks to identify viability loss during long-term storage prior to viability falling below the threshold for regeneration. The crucial guiding idea is that the collection should be actively managed. A monitoring schedule that is too frequent will lead to seed and resource waste. On the other hand, delayed or infrequent monitoring may prevent the detection of considerable viability degradation; advanced sample aging may lead to genomic alterations, unrepaired mutations fixed in the sample, or eventual accession loss. The time of the retest should be expected, or the accession immediately scheduled for regeneration, if it is anticipated that viability would drop below 85% before the next planned testing.

Germination and homogenous samples have a lesser risk of genetic degradation during storage. As long as plant establishment during regeneration is sufficient, a decline to less than 85% is acceptable. The 85 percent threshold should be followed for samples that are diverse, such as wild species and landraces. A viability of 85% in freshly refilled seed is seldom possible for certain landraces, particular accessions, wild species, and forest species. In these circumstances, the curator may drop the trigger value for the viability criteria for a particular species to, say, 70% or less. For a variety of agricultural species, models to forecast seed viability from ambient to freezing temperatures are available. The length for which seeds will keep high viability should be predicted by genebank employees using the prediction methods that have been published for a given species and storage circumstances. These tools should also be used to direct other genebank activities, such as viability monitoring and regeneration frequencies. Predictions of longevity based on a species' general traits should be seen as estimations with wide confidence ranges.The development and publication of fresh data that characterizes and updates species reactions to storage conditions is promoted by genebanks.

**Specialized Elements**

The information obtained from germination tests should be used to alter the viability monitoring intervals. Monitoring intervals should be lowered to 'fine tune' the forecast of time to meet the viability requirement as soon as a substantial deterioration is identified.When germination is still far over 90%, accessions with extremely high initial viability may exhibit a statistically significant reduction in viability much before the projected time for this to happen. Regeneration or remembrance at this time is most likely premature and unneeded. However, to more precisely follow the deterioration, subsequent retest intervals should be shortened.

If viability drops quite quickly for accessions of inferior quality, the accession may be dangerously near to the tipping point. Such accessions need to be handled with care, and the first viability monitoring tests have to be performed after 3-5 years of storage intervals. A collection's genomic integrity might suffer from infrequent monitoring's failure to identify fast degradation and failure to reach the viability criterion of 85%. In this regard, the use of statistical models may aid in the prediction of the tipping point and the window of opportunity for the proper regeneration.The management should have a rough idea of the sample's viability from the viability tests. Instead of looking for differences of less than 0.1 percent, the objective should be to find differences of around +5%. The size of the accession will necessarily affect the sample sizes for viability monitoring, but these samples should be as large as possible to establish statistical confidence. To prevent wasting seed, the sample size should be kept to a minimum. Genebank seed is a precious resource that shouldn't be squandered.

Setting up a rigid guideline for the quantity of seeds used in genebank germination testing is challenging. But often, the International Seed Testing Association's recommended methods are followed. 200 seeds should be utilized as a general rule for the first germination tests. The sequential testing method suggested by Ellis et al. may assist to conserve seed in successive germination tests during storage if the first germination is less than 90%. In the case that there aren't enough seeds, replications should be done using 100 or even smaller seed samples, which are still sufficient. Even little seed samples may provide the management with important information since the germination test serves as a viability indicator. However, in fact, the size of the accession, which is often quite constrained in genebanks, will determine the actual sample size for germination. It's crucial to utilize as few priceless seeds as possible for germination experiments. Sample sizes of 50 seeds or fewer may be appropriate for minor accession quantities. The likelihood of germination serving as the threshold, while, may be greater at that point, it must be understood. The curator of the genebank should evaluate the likelihood of this happening.

Always utilize the germination test as opposed to substitutes like the tetrazolium test. Alternative tests may be performed in cases when it is not feasible to break the dormancy of the seed. To distinguish between seeds that germinate quickly and slowly, germination should ideally be monitored twice. Additionally, a count of the number of seeds that abnormally germinate should be recorded. Early signs of degradation often include slower germination and rising abnormals.All viable seeds in a collection should be attempted to germinate utilizing ideal circumstances and, if necessary, dormancy-breaking therapies. After a germination test, any remaining non-germinated seeds should be cut-tested to see whether they are dead or dormant. It is possible that seeds with solid, young tissue are dormant and should be included in the number of viable seeds. Viability monitoring data and information should be captured and placed into the documentation system.

**Contingencies**

It is acknowledged that viability monitoring is a costly endeavor, hence genebanks may desire to look for ways to reduce costs. Measurement of seed quality in a sample of accessions of the same species cultivated in the same harvest year may be one such approach. Although genotype by harvest year interactions, which are known to be crucial for seed quality, are not taken into account, this approach may provide general patterns regarding the influence of harvest year on seed quality.A sample technique might be from distinct harvested sub-groups when diverse harvest circumstances occur across a broad range of maturity among accessions. Retesting with a focus on the accessions that performed poorly in the first tests would be an additional tactic. The performance of the batch as a whole should be early flagged by retest data from these accessions. For recognized hard-seeded species and accessions regularly seen in certain forage legume species and Crop Wild Relatives, the initial germination test at harvest may be as low as 45%, and it rises after 10-15 years to 95% or more and continues that way for extended durations. Regenerate/recollect at the first observable substantial drop determined by a suitable statistical test if the initial germination is less than 90%.

There are hazards involved with the aforementioned tactics, which should be taken into account given that intraspecific variation among accessions has been documented for a variety of accessions. When compared to agricultural species, monitoring the viability of accessions of wild species is often more difficult. Smaller minimum sample sizes must be established for germination testing since seed dormancy is anticipated to be considerably more common and accession sizes are often tiny. This will undoubtedly influence the capacity to identify the beginning of seed degradation. It's also feasible that genebanks get limited amounts of seeds beyond the first seed viability assessment. In such situation, as the sample is being submitted for regeneration, initial seed viability testing is not required.

The range of intrinsic longevity in wild species is also larger; certain species from Mediterranean and tropical dryland environments are predicted to have exceptionally long lives, while others are predicted to live relatively short lives in cold, temperate climates. As a precaution, duplication into cryostorage and retesting intervals of as little as three years should be taken into consideration for the latter. Depending on the species, duration of the interruption, and circumstances during the disruption, viability will suffer if storage criteria are not satisfied. A disaster management strategy should be launched in such a situation. For instance, it could be necessary to examine a few representative samples very away after the restoration of suitable storage conditions.

**Requirements for Regeneration**

When the viability falls below 85% of the original viability or when the amount of surviving seed is insufficient to make three sowings of a representative population of the accession, regeneration should be carried out. Those accessions should be recreated using the most-original-sample. Regeneration should be done in a way that preserves the genetic integrity of a specific accession. To avoid admixtures or genetic contamination brought on by pollen geneflow from other accessions of the same species or from other species near the regeneration areas, species-specific regeneration methods should be used.For reference reasons, it is recommended that at least 50 seeds from the original and any subsequent most-original samples be saved in long-term storage.Any genebank that keeps conventional seeds must perform the crucial task of regeneration as part of their overall duties. It is a procedure that results in a rise in the number of seeds that are kept in the genebank and/or an improvement in the viability of the seeds to a level that is equal to or greater than the regeneration threshold, which is a minimum level that has been established. When an accession lacks sufficient seeds for long-term preservation or when its viability falls below a certain minimal level, it will be regenerated. When the seed populations have been exhausted because the accession has been used often, regeneration should also take place. Each regeneration of particularly out-crossing species faces the danger of losing uncommon alleles or altering the genetic makeup of the sample, even if an accession is seldom sought and seed viability is good. Reduce the frequency of regeneration. For infrequently requested accessions or species, large seed quantities are not necessary. The genetic makeup of an accession might readily be altered by regeneration, hence extreme caution is needed. As a result, genebank managers will need to strike a careful balance between preventing regeneration as much as possible and the danger of compromising an accession's genetic integrity by perhaps losing viability. Determining the ideal time to renew will be considerably assisted by active maintenance of the collections.The genomic integrity of the questioned accession should be altered as little as possible during regeneration. This implies that, in order to prevent any extreme selection pressure on the accession, consideration should be given to the environment in which the activity will be carried out in addition to sampling considerations of the accession in question. In order to reduce genetic drift and shift as well as to yield seeds of the highest quality, it has been advised that the regeneration habitat should be as close as possible to that at the collection site, particularly when a population taken in the wild is being regenerated. Due to smaller seed/plant numbers compared to other species or plant dispersion processes like seed cracking, it may often be challenging to gather enough seed from wild cousins. Therefore, it's important to make sure that the right technical procedures are followed in order to collect as much seed as possible.

Repeated regeneration cycles can also be necessary to guarantee that enough seed is preserved. It is preferable to generate favorable environmental conditions for seed production and reduce plant-to-plant rivalry when it comes to regeneration. The initial collecting locations sometimes don't provide the best opportunities for optimizing seed output in one or more respects. Therefore, a balance between broadly beneficial circumstances and those unique signals that are particular to local adaptation of individual accessions should genuinely exist. The practice of curating includes this. A curator should look at ways to have the collection renew in a favorable environment if the genebank site does not provide those circumstances locally; replicating the collection environment should not always be the curator's objective. Effective sampling of accessions is crucial to maintaining the genetic integrity of genebank collections throughout seed regeneration. The quantity of seeds to be utilized for the regeneration process must be sufficient to capture one or more uncommon alleles with a given probability and to be reflective of the genetic diversity in an accession.Depending on the population size, breeding system, and pollination efficiency, among other things, the technique to be employed for regeneration may differ from species to species. Collecting as much pertinent biological data as you can on the species in issue is thus very important. Additionally, it is advised that the regeneration event be exploited for the characterisation of regenerated accessions where it is feasible and useful. However, because of practical issues, it is sometimes difficult to characterize cross-pollinating species via the regeneration process.

**Specialized Elements**

It is advised to regenerate from seeds taken from the most original sample in order to preserve the genetic integrity of accessions. It is advised to utilize seeds from the working collection for up to five cycles of multiplication without going back to the most-original-sample for multiplication.It should be emphasized that in situations when the initial collection or gift is a tiny sample, regeneration is required as soon as the material is received in order to produce a sufficient number of seeds for long-term preservation. The regeneration cycle number must be noted, and the data must be entered into the documentation system. The recipient genebank should always retain some seeds from the original seed sample for future reference. Even if these initial seeds become inedible, they may still be valuable for validating the genotype or morphology of subsequent generations of the same accession.

The genetic makeup of the accession must be reflected in the size of the seed sample utilized in the regeneration activity. In order to do this, the effective population size is a crucial variable that will influence the level of genetic drift connected to the regeneration of the accession. Based on the pollination biology and growth circumstances, it is possible to predict the minimum size of Ne needed to prevent allele loss for each particular accession. When planting, gathering, and processing seeds, best procedures for harvesting should be followed. A minimum of 100 plants is required for the maintenance of the taxon gene pool, according to research by Johnson et al. on the regeneration of perennial allogamous species. It is advised to take three to five inflorescences from each plant during harvesting. It is crucial to use suitable isolation techniques across plots of accessions of cross-pollinated species that are being restored in order to prevent geneflow and contamination. Depending on the conditions for regeneration, this may also apply to self-pollinated species. Isolation cages and the related pollinators should be employed for species that rely on certain pollinators. With the use of morphological, enzymatic, or other distinguishing qualities that may be employed as markers, as well as molecular markers, contamination and genetic drift/shift can be evaluated.

## 3. CONCLUSION

Genebank standards promote coherence and consistency in genebank operations by defining guidelines for the collection, conservation, characterization, and dissemination of plant genetic resources. These guidelines also stress the need of data management, monitoring, and sharing, enabling scientists and breeders to fully use the genetic variety kept in genebanks. Genebank standards are dynamic; they change in response to new technological advancements, pressing problems, and evolving regulatory frameworks. Important treaties that govern access and benefit-sharing for genebank operations include the Nagoya Protocol and the International Treaty on Plant Genetic Resources for Food and Agriculture, with an emphasis on the fair distribution of benefits resulting from the use of genetic resources. Genebank standards are essential for enhancing agricultural resilience and safeguarding food systems at a time of climate change, population increase, and altering agricultural landscapes. The creation, implementation, and upgrading of genebank standards that take into account the changing requirements of agriculture and society depend heavily on cooperation among international organizations, national genebanks, academics, and politicians.

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# CHAPTER 11

# STANDARDS FOR DISTRIBUTION AND EXCHANGE OF SEEDS

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**ABSTRACT**:

Standards for the distribution and exchange of seeds are essential to ensure the quality, safety, and integrity of plant genetic resources. This study examines the significance of seed distribution and exchange standards in facilitating efficient and reliable access to diverse and viable seeds for agriculture. The paper explores the principles underlying seed standards, including genetic purity, varietal identification, germination capacity, and labeling requirements. Through an analysis of international agreements, case studies, and regulatory frameworks, this study highlights the role of standards in promoting fair trade, preventing the spread of diseases, and supporting global food security. It underscores the collaborative efforts of seed producers, researchers, regulators, and international organizations in establishing and harmonizing these standards.Standards for the distribution and exchange of seeds serve as a fundamental framework for the global seed industry and agricultural systems. As evidenced in this study, these standards play a crucial role in ensuring the quality and authenticity of seeds, thereby contributing to agricultural productivity, genetic diversity conservation, and food security.

**KEYWORDS**:

Phytosanitary Measures, Plant Breeding, Quality Control, Quarantine Regulations, Seed Distribution, Seed Health.

## 1. INTRODUCTION

In accordance with local ordinances, as well as relevant international treaties and agreements, seeds should be disseminated. Samples of seeds should be sent together with any pertinent paperwork that the destination nation may need. The amount of time that passes between receiving a request for seeds and sending them out should be as short as possible. For the majority of species, accessions with stored seed should be given a sample of at least 30–50 viable seeds. Samples should be provided following regeneration or multiplication, based on a repeated request, for accessions that had insufficient seed at the time of the first request and in the absence of a suitable replacement accession. A distribution sample size of fewer seeds should be suitable for various species and research applications. Utilization and conservation should go hand in hand.

The provision of a representative sample of seed accessions from a genebank in response to inquiries from plant germplasm consumers is known as germplasm distribution. The need for genetic resources is always rising in order to face the problems given by invading alien species, climate change, and changes in the virulence spectrum of important pests and diseases. Wider acceptance of the value of utilizing germplasm from genebanks, which ultimately dictates the distribution of germplasm, is the result of this need. The amount of time that passes between receiving a user's request for seeds and the subsequent response and seed delivery should be as quick as feasible[1], [2].It is acknowledged that there are differences amongst legal systems in terms of the procedures controlling access to courts and arbitration, as well as the requirements resulting from regional and international agreements that apply to these procedures. When a user requests an accession from a genebank, the user is responsible for indicating the national requirements for seed importation in their country, in particular the phytosanitary laws, in order to prevent the spread of regulated pests, invasive species, or quarantined diseases that could significantly harm national production.

The ITPGRFA and the CBD are the two international mechanisms that control access to genetic resources. The ITPGRFA makes PGRFA more accessible and organizes the distribution of advantages from their use. For a pool of 64 food and forage crops, it has built a multilateral system for PGRFA, which is supported by an SMTA for distribution. Although there are other models available, SMTA may also be utilized for crops that are not included in Annex 1. According to the Nagoya Protocol of the CBD, access and benefit sharing are regulated. The continuity between conservation and sustainable use, as well as easier access and fair sharing of benefits resulting from usage, are all stressed by both the ITPGRFA and CBD.Genebanks should strive to make as many accessions and related data accessible to users as they can. When the supply runs out, it is essential to increase accessions in order to satisfy user demand. The availability of genetic resources for applications such as research, breeding, teaching, farming, and repatriation should be promoted via genebanks. Genebanks may provide landrace germplasm to resupply nations who are starting their own genebanks or that have experienced a calamity like a fire, flood, or civil unrest. It should be noted that the recommended minimum seed distribution depends on the species and the intended use. Genebank accessions are utilized for research as well as applied plant breeding and pre-breeding. In the latter scenario, fewer seeds are often required[3], [4].

It is important to disseminate germplasm in a manner that guarantees its viability once it arrives at its destination. Seeds should be securely packaged and wrapped in airtight envelopes for protection during travel since environmental conditions might be detrimental to the quality of seeds. The samples that will be supplied should meet both the receiving country's criteria for seed health and the quality standards outlined in this document. Additionally, the distribution must abide by local, state, and federal laws. The user or the national phytosanitary authorities must give the components of national norms and legislation, in particular the seed health requirement. The availability of documentation needed by the requestor and the receiving country is often necessary for the quick and simple clearance of shipments from customs offices and plant protection authorities.

Documents needed by the receiving country include phytosanitary certificates, extra declarations, certificates of donations, certificates of no commercial value, import permits, and others. Therefore, it is crucial to keep the list of papers needed by various nations up to current. If extra expenses are required for the seed exchange or distribution, these expenses must be covered by the user, unless both parties agree to something otherwise. The need for genebanks to certify that a specific illness was not discovered in the seed production industry is a significant issue with worldwide distributions. Additional disclosure criteria for seed generated 20–30 years ago cannot be met by genebanks. Where further disclosure criteria cannot be satisfied, countries that receive seed should be responsible for quarantine measures to manage seed.

Any legal agreement pertaining to access and use of the genetic resources delivered should be sent to the receiver together with the list of the material and pertinent information. The amount of time between the shipment's dispatch and delivery should be as short as feasible. When seeds are unavailable, answers should include a thorough explanation of why, a projected release date for the accession, and any possible replacement accessions that could be more suitable for the requestor's requirements[5], [6].Recipients of genebank admission are urged to bulk their own seeds for experimentation and clinical trials. This is especially important for wild species, whose seed stocks are often limited, as well as for duplicated field experiments where it is impossible to take into account the availability of the necessary seed amount.For material provided outside the MTA's multilateral system, the distributing genebank should support the flow of data back to the provider about the utility of the given germplasm from the receiver. The period between receiving a seed request and dispersing the material may be prolonged by political choices, crises, or administrative bottlenecks. Limitations relating to accessions' regeneration and/or multiplication might potentially have an impact on the distribution process and cause a delay.

## 2. DISCUSSION

The availability of a genetically identical subsample of the accession is guaranteed by safety duplication, reducing the danger of its partial or complete loss as a result of natural or man-made disasters. The secondary most-original-sample is made up of the safety duplicates, which are genetically identical to the long-term collection. Material and information relating to it are both duplicated for safety reasons, including database backups. The items' safety duplicates are put in long-term storage at a separate location. The site was chosen to reduce potential threats and provide the finest storage options. Safety duplication will preferably be done outside of that nation to reduce dangers that may occur there[7], [8].

'Black-box' approaches are often used for creating safety duplicates. In other words, the repository genebank has no legal right to utilize or distribute the germplasm. It is the depositor's duty to make sure the material is of the highest quality, to keep track of the viability of the seeds over time, and to utilize their own base collection to replenish the collections when they start to lose viability. The germplasm is not handled without the depositor's consent, and it is only given back upon request if the original collection is lost or destroyed. It is also feasible to recall the deposit when it is changed out for freshly created germplasm. However, it is acknowledged that the black-box strategy is not the sole one. There may be instances when the receiving genebank also manages the safety collection.

For all of the original seeds that the genebank has gathered or that are exclusively in its possession, safety duplicates should be prepared. To make access for regeneration or other administrative choices easier, the genebank should keep a collection of the original samples. Unless there is concern about their security in the other collection, duplicate seeds from other collections may often be accessed from those collections without the need for safety duplication.Any safety duplication agreement must be legally binding and explicitly state the obligations of the parties involved as well as the terms and circumstances under which the material will be kept. This agreement must be signed by both the depositor and the receiver of the safety duplicate.

The Svalbard Global Seed Vault on Spitsbergen Island, Norway, offers safety duplication. Institutions that deposit seeds maintain ownership, and only the depositor is allowed access to samples kept at Svalbard. The geographic location and environmental factors of the area are given priority while choosing the location for safety duplication. Low radiation and stability must be provided by the facilities. The facility must be positioned at a height that ensures appropriate drainage during seasonal downpours and completely avoids the possibility of flooding in the event that sea levels rise due to climate change. Economic stability and sociopolitical stability are both crucial. According to Koo et al., safety duplicate samples have to be kept far from the possibility of a political boycott, military action, or acts of terrorism that would obstruct worldwide access. Similar to how they are for the basic collection, samples are prepared for safety duplication. The quality of seed preparation is critical, and the conditions should be at least as strict as those for long-term preservation of germplasm in a genebank. Before submitting material for safety replication, it might be useful to classify it into short, medium, and long living seed groups[9], [10].

The number of samples should not be limited to a certain minimum. A sufficient number of samples must be taken to allow for at least three regenerations. A safety backup may serve as a minimum sample to regenerate a lost accession as well as being used for future regeneration. Better than no backup at all is a "critical" safety backup with a little quantity of seed at a second site. If feasible, a safety duplicate of an accession in a seed genebank should include at least 300 viable seeds for genetically uniform accessions and at least 500 viable seeds for outbreeders and heterogeneous accessions with significant variety. More seeds are required for accessions with poor viability seeds. Ideally, storage temperatures range from -18 to -20 °C.

A trilaminate material should be used for the packaging for safety duplication, with the intermediate metal foil layer having an appropriate thickness. It has to be shaped into a pouch with no gusset and all four sides seamed. For at least 30 years, this would provide a sufficient water barrier during shipping and storage at 18 °C. Each seed package should include an outside and an interior label to guarantee that the germplasm is correctly recognized.If the basic requirements for storage conditions are met and the same containers are used, seed viability can be monitored on seed lots of the same accession maintained in long-term storage in the genebank and extrapolated to the safety duplicate. The storage conditions for the safety duplicate should be the same or better than those of the base collection. Samples for germination testing may sometimes be supplied in a separate box along with the safety duplicate and checked for germination in accordance with an arrangement with the repository.

The finest containers for storing and transporting seeds are sturdy, cold-resistant cartons. Boxes need to be well sealed. To prevent seed quality degradation during transit, shipment should take into account the quickest mode of transportation possible, whether it be by air freight, courier, or by land. When the vitality of the samples under comparable storage circumstances in the sender's long-term collection begins to wane, fresh samples should be requested from them.However, considerable care should be used when extrapolating the viability of the safety duplicate from the sample in the base collection's viability monitoring data. Even when the average storage temperature is the same, seeds may mature at different rates depending on the ambient RH at the two locations and/or the magnitude or frequency of temperature variations. Sending samples in sealed, black-box settings might raise liability concerns. One concern is who is responsible for the sealed box's contents and how customs officers and other officials handle it upon entrance into a nation. To ensure that the samples are not forbidden or medical plants, the authorities will sometimes examine boxes and apply special seals. Another concern is the receiving institution's accountability in the event that materials are harmed or lose viability sooner than anticipated due to stress during travel, a defective container seal, or temperatures that deviate from prescribed criteria. The safety duplicate repository should only be held "liable" under the circumstances outlined below if the temperature gets intolerably high. In this case, the parent institution should be informed right away so that it may determine what course of action to follow. If there are transportation mishaps or uncontrolled moisture levels, the main institution should be fully responsible. Due to the underlying biology of the samples, the criteria and technical components may be challenging to execute for certain species, such as species with enormous or short-lived seeds where space and money may be a concern.

**Criteria for site selection of the field genebank**

The field genebank site's agro-ecological settings have to be as comparable as feasible to the surroundings in which the gathered plant materials were typically produced or gathered. The field genebank's location should be chosen to reduce the danger of theft, vandalism, pests, illnesses, animal damage, fires, floods, droughts, and other natural and man-made catastrophes and hazards. In order to preserve genetic integrity for species that are used to generate seeds for distribution, the field genebank's location should be chosen to reduce the likelihood of geneflow and contamination from crops or wild populations of the same species. The field genebank's location should have a stable land tenure and enough space to accommodate future collection growth. The field genebank location need to be convenient for employees and delivery of supplies, have simple access to water, and have sufficient facilities for multiplication and quarantine. Given the long-term nature of a field genebank, choosing a suitable location for it is essential for the effective conservation of genetic material. The right agro-ecological conditions for the plants being conserved at the site, associated natural and man-made disasters, secure long-term land tenure, accessibility of the site for staff, and availability of water resources are just a few of the many considerations when choosing a location for a field genebank. When planted in the right agro-ecological circumstances, plants will develop robustly and healthily. Field genebanks are especially susceptible to losses brought on by inadequate adaptation of material originating from habitats significantly dissimilar to the genebank site. To lessen the possibility of inadequate adaptation, the location for the field genebank should have an environment and soil type that are ideal for the species. A decentralized strategy to managing genebanks, or collocate the collections in various agro-ecologies rather than a centralized genebank, is one way to address inadequate adaptability. A station positioned in an agro-environment comparable to their origin or similar to or close to their native habitat is used to house accessions of similar adaption. greater shadow intensity or drainage may imitate the natural circumstances of the original ecosystem, for example, for crop wild cousins that evolved in natural forests as opposed to cultivated plants that are accustomed to greater light intensity.

For field collections, avoiding pests, illnesses, and insect vectors is crucial. To minimize risk and maintenance expenses associated with plant protection and to guarantee a clean supply of material for distribution, the field genebank should, wherever feasible, be situated in an area free from major pathogenic diseases and pests or far from areas known to be infested with fungi and viruses. Before planting, soils should be examined to make sure they are free of fungus, termites, or other soil-borne parasites, and the proper steps should be taken to clean the soil. If this is not practicable, the location should be chosen to be some distance away from fields growing the same crop to lessen the danger of insect pests and diseases. Diseased plants should also be eliminated by a rigorous roguing operation. If at all feasible, keep collections in hot, dry climates where pests, illnesses, and vector movement are less common. Furthermore, the confluence of several disease-prone plants may significantly increase the danger of disease outbreaks. From the perspective of diseases, such large groups of a single genus demand extra attention.

For collections to be physically secure, it's crucial to evaluate the danger of natural calamities including hurricanes, earthquakes, volcanoes, and snow/ice storms. Additionally, consideration should be given to physical security as well as possible anthropogenic risks such theft and vandalism. To assist prevent the loss of germplasm, these features should be taken into account while choosing a location and creating a field genebank.For smaller plants, insect netting and cages may be used to prevent insect or bird damage. It is necessary to keep out potential pollinators from out-crossing species like grasses that are both planted for seed and kept as plants or fruit trees with stubborn seeds. In order to prevent gene flow or weed contamination, it is crucial to choose a location far from agricultural stands or wild populations of the same species. To ensure successful propagation, recommended isolation distances, isolation cages, or pollination control methods should be devised and implemented. The Crop Genebank Knowledge Base provides crop-specific details on isolation distance in regenerated accessions. In accordance with the local development plan, a field genebank should be situated in a safe location with a long-term agreement, guaranteed or gazetted land tenure, and finance. The amount of fertilizer used as well as the pest or weed condition of the land may be determined by looking at the property's past uses. The development of roots and tubers may be impacted by the previous years' heavy fertilizer usage. For instance, high residual fertilizer might stop sweet potato tuber growth. When the availability of sufficient rainfall or a water source for supplemental irrigation is considered as a selection factor, drought stress may be avoided. It is advised to highlight actions that may be made to determine and improve the physical and nutritional quality of soils in addition to the history of land usage. Basically, this comprises analyzing the physical and chemical makeup of the soil, followed by remedial actions. Particularly for tropical fruit plants, areas with high potassium demand need to be balanced with additional calcium and magnesium solutions.

The size of the site selected should provide enough room for the species being protected as well as for potential extension in the future as the collection increases, particularly in the case of perennial plants. Tree crops might need a large amount of area. Additionally, enough room should be allocated for annuals that need to be continuously replanted, rotated across plots to prevent contamination from earlier plantings, and rotated with perennials to regulate soil fertility and reduce disease. If plant material has to be kept after harvest before the next planting, adequate and suitable storage facilities are needed.Germplasm will help with monitoring and plant management if it is physically accessible. The location should provide for easy access to labor and equipment for mulching, applying fertilizer and pesticides, and for propagation and in vitro or cryopreservation facilities as needed. In order to prevent theft or damage to facilities and germplasm, a solid security system should be in place. In order to prevent genetic loss when accessions from various eco-geographical origins are planted in one location, curatorial field staff must pay close attention to reproductive phenology and seed production, identify and move poorly adapted accessions to potential alternative sites, greenhouses, or in vitro culture. For certain accessions, special management techniques could be necessary. The plants may need to be enclosed in cages or screenhouses to keep predators out.

**Requirements for Acquiring Genetic Material**

Acquisition is the process of gathering or requesting such items, together with pertinent data, for inclusion in the field genebank. When gathering germplasm for conservation in field genebanks, particular consideration must be given to the characteristics of plants with recalcitrant seed and plants that are reproduced vegetatively. Various propagules, including seeds, cuttings, tubers, corms, scionwood, tissue cultures, graftwood, and cryopreserved material, may be used to build a field genebank. Landraces and cultivated forms raised by farmers, research and breeders collections, existing genebanks, and plant excursions and expeditions are all possible sources for the plant materials. The IPPC, ITPGRFA, CBD, and any other rules that control the movement and acquisition of germplasm must be taken into consideration. Other rules that control the movement and acquisition of germplasm include national laws for access to genetic resources, phytosanitary/quarantine laws, and national laws for those resources. When Standard 5.2.1 is followed, germplasm may be transported to the location housing the genebank safely from both domestic and international collection locations. It is crucial to abide by national restrictions while collecting germplasm in situ, which often call for obtaining collecting permissions from the appropriate national authorities. In line with applicable national, regional, or international legislation, prior informed permission may be necessary if the collection is from farmer fields or community areas. An appropriate material transfer agreement should be implemented if germplasm material is to be transferred from a nation. In the event of PGRFA, exports may be accompanied by SMTAs or other licenses of a same kind in accordance with local laws governing access and benefit-sharing. The appropriate national authorities of the recipient country must be contacted for the import permit rules, which include phytosanitary and any other import requirements.

It is crucial to make sure that each accession's passport data is as full as possible throughout the acquisition phase. Georeferenced data in particular are very helpful because they provide a clear description of the location of the original collection sites and aid in the identification of accessions with particular adaptation features in line with the agro-climatic conditions of the original collecting sites. Passport information is essential for categorizing and identifying each accession and will serve as the starting point for choosing and using the accession. To record thorough gathering information, appropriate collecting forms should be employed. As stated in the FAO/Bioversity multi-crop passport descriptors, these forms should include details such as the initial taxonomic classification of the sample, the latitude and longitude of the collecting site, a description of the habitat of the collected plants, the number of plants sampled, and other pertinent information that is crucial for proper conservation. When material is gathered from farmer fields, extra information that is very helpful, such as cultural practices, methods of propagation, history and origin, and uses, may be gained via interviews. As far as is practical, a herbarium voucher specimen obtained from the same population as the samples should be retained as a reference collection, and the process and justification for acquisition should be documented.

Donations should be documented using the available passport information as well as the taxonomic classification, donor name, donor identification number, and names of the germplasm. You should ask the donor for adequate information on how the germplasm they donated was kept, including pedigree or lineage information and, if available, chain of custody information. Materials have to be given a special identifying number that will enable them to be connected to the passport information and any other data gathered, ensuring the sample's validity.Even while it is impossible to guarantee that plant material that is gathered on-site is in perfect health, it is crucial that propagules be taken as much as possible from plants that seem healthy, free of disease and insect pest infestations or damage. To avoid insects infesting clean plants and spreading infections, clean material purchased from reputable sources should be kept in a screenhouse. The collector should take care not to deplete the natural population they are after while they are collecting. To optimize the collection of genetic diversity that may be present at different times, it may be helpful to repeat sampling from a certain place. It would be preferable to encourage the formation of sufficient shoots by scoring the trunk or the branches during the collection phase of vegetatively propagated perennial samples, especially when collecting shoots suitable for taking cuttings or grafting. These shoots could then be collected during a second visit.

It is crucial to emphasize how vital it is for the original genetic resource to be transferred in a timely manner from the point of collection to the genebank. This is particularly true for species that generate hardy seeds, clonal stock that doesn't last very long, and vegetative propagules that degrade quickly. When acquiring germplasm from another country, it may sometimes be necessary to export the material across large distances. To guarantee that the material arrives to the target genebank in excellent condition, due consideration of the shipping duration, including transit and processing period, should be taken into account. The propagules must be adequately prepared in order to increase viability during postal or package delivery. For instance, to guarantee enough air exchange, refractory seeds and scions should be packaged in sterile cotton or another appropriate material in a perforated plastic bag. By using a mechanical mail sorter and robust cushioned shipment, seeds should be kept from being crushed. To prevent moisture loss from scion wood, the two cleaned, cut ends of the scion should be wrapped with a para-film strip. Tropical-area collections must take into account the high temperatures experienced during transit. The sample size for collecting will often be less than with conventional seeds since field collections cannot support large numbers of samples. However, every effort should be made to increase the collection for the genetic variety of the target population. The collector will also need to make judgments on how many plants within a population can actually be gathered while collecting for a field genebank. The actual will be greatly influenced by the plant's breeding method, kind, and the portion of the plant being taken.

Without following the law, collecting should not be done, particularly if the germplasm will later be exported from the nation of collection. Attempts should be undertaken to develop field collections in the country of origin and/or produce in vitro cultures that are more suitable for export in the event that materials cannot be transferred outside of the nation owing to phytosanitary regulations. For wild and endangered species, when propagation material may not be readily accessible in sufficient quantities or under ideal circumstances, allowances should be made in terms of sample size.

**Norms for the creation of field collections**

It is challenging to provide precise guidelines for the creation of a field genebank collection. The nature of the species that are meant to be saved will be a major factor. Based on the biological traits of the species, its phenology, reproductive strategy, and population structure, species-specific criteria will need to be defined. The number of plants per accesssion that should be maintained, the arrangement of the plants inside the genebank, and the cultivation techniques that should be used to ensure the accessions in the collections are kept in the best possible growing conditions are the three main factors that should be taken into account when creating a field genebank collection. The choice of how many plants per accession should be planted in a field genebank depends on how important it is to preserve the genetic variety of the accessions, how much space is available, how important it is to characterize the accessions, and how financially viable the field genebank is. Depending on whether a species is reproduced vegetatively or by seed, it will be different for annual and perennial plants. The sample size must be sufficient to represent the genetic variety present in the accession that has been collected for species that are seed propagated. It is important to note that since it will be challenging to maintain a large amount of "within accession genetic diversity" in a field genebank collection, a robust sampling scheme that prioritizes plants for collection must be created when collecting non-traditional seed material. Only a few plants are required for vegetatively propagated species in order to reflect the genetic variety within the accession and to guarantee the accession's security. In other circumstances, however, more plants could be required if there is more variation inside a population than across populations. A collection's assessment and/or dissemination goals, which may dictate a different number of individuals per accession than conservation goals, may also influence sample size.

It is crucial to know which accessions are being planted where when creating a field genebank collection. The administration of the collection and the efficiency of space utilization will both be improved by a well-designed layout and well-prepared field plan. Individual accessions should have their specific locations identified. Plot design, electronic and printed maps, barcodes, and field labels should all be integrated into the field genebank setup phase in this regard. Accessions should be placed in the genebank's most suitable microenvironment after careful consideration. Some plants demand unique environmental circumstances, and they could need to be kept in greenhouses for better environmental control or they might need to be shaded by other plants.

When determining the size of the plots, it is important to take into account the plant's development patterns, adult size, irrigation systems, and simplicity of care. For perennial species, maintaining optimum plant spacing within the plot allows for the healthy development of each individual plant, such as a tree, and prevents the mixing of crops that produce tubers on protruding subterranean stolons. Physical barriers should also be put in place between plots to prevent mixing, such as dividing the plots with various species that do not cross-pollinate. It aids in avoiding competition that can cause plants to become weak or that might encourage the fast spread of disease or insect pests. Planting invasive clones in cans, pots, or boxes can help prevent mixing or competition with weaker accessions. When creeping, spreading, or shedding of bulbils or seeds to the next plot is an issue, accessions with readily distinct morphologies may be planted there. To retain the genetic integrity of any seeds gathered for distribution in out-crossing species, sufficient isolation distance between plots of different accessions or measures, such as isolation cages, are necessary.

It should be made clear that the field design and layout are not set in stone and will alter as planting dates change. Rotation is crucial for annuals, which calls for careful planning and sufficient room. Additionally, it's crucial to plan the arrangement to prevent pesticide drifts into the surrounding area. In field collections, correctly and legibly written labels with two water-resistant indelible tags are crucial. Date, common name, and field collection number data should all be on the tags. Computer-generated labels should be utilized wherever feasible since they decrease name and number transcription mistakes. Field maps are crucial records for field genebanks that act as a backup for easily lost or damaged field labels. They have to be created in advance of planting and updated often.

To guarantee the effective establishment of plants in the field genebank, it is necessary to implement the proper cultivation procedures that are particular to the species. The planting material must be carefully chosen. Retaining just robust plants in the field genebank may decrease genetic diversity. When planting new fields, filling in vacant plots, or revitalizing whole collections, the quality of the original planting material is crucial from a phytosanitary standpointespecially if genetic selection is not being used. Only sound and vivacious plant components should be used. Simple hygienic precautions like preparing planting materials with clean, sanitized instruments should be followed. Wherever feasible, it should be thought about indexing for non-apparent illnesses such viruses and graft-transmitted pathogens prior to setup.

Planting times should be considered. Where planting time guidelines for various species from various regions have been published, they should be followed. These should include the ideal circumstances for plant establishment, which may include temperature, moisture content, soil type, and rootstock, among other factors. For plants that are propagated by grafting, care must be taken to get the rootstocks in a uniform manner so that all samples may be grafted at the appropriate time. A rootstock of the same species as the grafted plant, or one that is closely related and has a history of successful grafting, is used. In certain circumstances, all accessions of that species should be grown from the same rootstock. The rootstocks must be chosen for their minimal impact on the behavior of the grafted material and response to soil parameters. Except in cases where the use of rootstocks is required to avoid disease or if grafting is the standard method of cultivating a species, trees should be planted on their own roots.

Planting groups of crops that need cross-pollination according to bloom dates is advised. A sufficient number of male and female plants should be planted in dioecious species. For asexually reproduced self-incompatible species, the curator must be aware of the self-incompatibility system that the species and allelic combination possess in order to have a successful field collection and to ensure the development of fruit or seeds. It's crucial to pay attention to how the land is being treated while setting up field collections.Some species need extra assistance, which may be provided by planting shade trees in an appropriate pattern that takes into account both the local environment and the needs of the species. Some species develop as lianas and need trees, logs, cables, or other infrastructure to function well. Installing particularly specialized beds for specialized species, such as "table beds" and shelters to block precipitation at certain times of the year, may be essential. The same may apply at certain times for shade, irrigation or floods, or coverings to prevent frost, among other things. Some fruit tree species need regular trimming to maintain their healthy look and express their distinctive form. Another method that should be heavily supported for tree crops is the use of dwarfing rootstocks. It is important to do research to create new procedures since certain genotypes may not react well to conventional propagation techniques that have been developed for specific species types. An interstock should be utilized in the event of plants grown using rootstock at a planting location that necessitates the use of a closely related species as rootstock. It is crucial to think about keeping a copy of the collection somewhere else. Some genotypes, such as those that are found in the understory of forests or may be disease-prone, may not adapt well to field conditions of full sun and hence need to be given enough cover. Resource shortages make this situation worse by forcing field genebanks to play two roles. This may cause conflicts in genebank administration, layout, and duplication of accession, for example. Establishing duplicates in the form of in vitro cultures is an alternative when sustaining field duplication is difficult.

## 3. CONCLUSION

Standards for seed exchange and dissemination include genetic, physical, and labeling issues. Standards for varietal identification and genetic purity guarantee that seeds farmers receive have the expected properties and performance. Standards for seed viability are determined by their ability to germinate, and vital information is provided on labels in order to make educated choices.

International agreements like the International Treaty on Plant Genetic Resources for Food and Agriculture and the International Union for the Protection of New Varieties of Plants (UPOV) lay the groundwork for coordinating seed distribution norms while upholding breeders' rights and guaranteeing fair access to genetic resources. The harmony between encouraging innovation and facilitating access to genetic variety for breeding and research is emphasized by these agreements. Establishing, putting into practice, and upgrading seed distribution and exchange norms depend on cooperation between seed producers, research facilities, regulatory bodies, and international organizations. Smoother commerce is made possible by standardization, which also stimulates the adoption of best practices and prevents the introduction and spread of illnesses.

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# CHAPTER 12

# INTRICATE INTERPLAY BETWEENSEED QUALITY AND CROP PERFORMANCE

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**ABSTRACT**:

Seed quality is a pivotal factor that directly impacts agricultural productivity, sustainability, and food security. This paper delves into the critical significance of seed quality in agricultural systems. It examines the multifaceted dimensions of seed quality, encompassing genetic, physical, physiological, and health attributes. The paper also discusses the intricate interplay between seed quality, crop performance, and environmental conditions. Furthermore, it highlights the role of quality control measures, certification systems, and technological innovations in maintaining and enhancing seed quality. By elucidating the far-reaching implications of seed quality, this paper underscores its indispensable role in shaping global agriculture and ensuring successful crop production.In essence, the role of seed quality in agriculture is irrefutable, reverberating through the entire spectrum of food production and supply chains. The quality of a seed transcends its physical characteristics; it encapsulates the promise of a successful harvest, the foundation of agricultural sustainability, and the security of future food provision.

**KEYWORDS**:

Agricultural Productivity, Crop Health, Crop Performance, Environmental Factors, Germination Rate, Nutrient Availability.

## 1. INTRODUCTION

Thompson described seed quality as a multifaceted notion that encompasses a number of components and their respective value in various situations.

- Physical and analytical purity
- Genetic and species purity
- Elimination of weeds
- The germination rate
- Seed health and vigor
- Moisture level of the seed.

Size, weight, and specific gravity of the seed Characters of seed quality A good seed should possess the qualities listed below.

### Improved variety

It should be better than the current variety, with yields that are 20–25% greater or that have other desired qualities like disease resistance, drought resistance, salt tolerance, etc., while still having a high yield potential.

### The seed must be genetically pure and faithful to type

Genetic purity has a direct impact on yields; thus, the seed must have all of the genetic traits that the breeder has bred into the variety. The yield or performance would decline proportionately if there was any degradation [1], [2].

**Physical Purity**

The physical makeup of a seed lot is referred to as physical purity. A seed lot includes pure seed, inert matter, broken seeds, undersized seeds, weed seeds, OCS, and soil and dust particles. The quality of the seed would be greater the higher the percentage of pure seed. The planting value of a seed lot is determined by the number of pure seed and germination[3], [4].

**Seed vigor and germination**

Seed vigor is the totality of all seed characteristics that contribute to successful plant stand in the field, whereas seed germination is the capacity of a seed to produce a normal seedling when sown under normal sowing circumstances.

Higher germination rates and vigor result in an appropriate plant population and uniform development, which have a significant impact on yield and establish the seed's planting value.

**Weed and other crop seed freedom:**

This is a development of the before mentioned bodily purity. There are certain weed species that are very detrimental to the crop and difficult to eliminate once they have taken root. One of the key factors for assessing the planning quality of seeds is an utter absence of such species' seeds, which is extremely desired.

**Seed health**

Seed health describes whether a seed has disease-causing organisms or insect pests on it. The health of a seed lot determines its quality; thus, the seed must be free of pests and diseases that may be transmitted via the seed.

**Seed moisture**

The most crucial element in determining a seed's germination and viability during storage is seed moisture. Pest attacks are more frequent when seeds are damp, and seeds that are above 16% percent moisture get heated and lose viability. The seed should be kept at safe moisture levels of 11–13% as a result.

**Seed size, weight, and specific gravity**

In many crops, it has been shown that these factors positively correlate with seed germination and vigor. So, the seed should be large and have a high specific gravity.

**Seed Color**

During seed growth, the color of the seed often reflects the environment. Farmers have always used excellent normal shine as a reliable indicator of quality. Only when the crop is treated roughly or when the weather is unfavorable during maturity can the color and gloss degrade.

High-quality seed lots are those that have high genetic purity, good germination, a low quantity of inert matter, no weed seeds, no other crop seeds, and are disease-free; if they don't, they are said to be of poor quality.

Preservation of Breeder and Nucleus Seed in Self- and Cross-Pollinated Crops Nucleus Seed is the little quantity of original seed that the original breeder collected from a few carefully chosen plants of a specific variety for upkeep and purification. To produce breeder seed, it is further multiplied and maintained under the guidance of an experienced pant breeder. This serves as the foundation for all subsequent seed production. It possesses the greatest levels of physical and genetic purity[5], [6].

## 2. DISCUSSION

Maintenance of nucleus can be divided into 2 groups

- Maintenance of newly released varieties
- Maintenance of established varieties

Nucleus seed maintenance for previously or recently issued varieties: Harrington 1952 defined the process for multiplying the nucleus seed that is delivered. Nucleus seed is obtained by sampling a variety, and no more than 15 new varieties should be sampled at any one research site for any given crop. Pick 200 plants or so from one of the yield experiments. Throw away weak, sick, and subpar plants. To prevent breaking, the chosen plants should be picked 4 to 5 days prior to harvest. Until the yield results are reached, each of the 200 plants has to be knotted in a different way, wrapped in a cloth bag, and kept. The inferior kinds are thrown away, and the bundles of high producing variety are removed for additional inspection.

**Sample analysis**

Each bundle is threshed individually, and the seed should be stacked up on the purity work board for inspection. Unwanted characters should be removed from piles. In a nursery used for variety purification, known as a nucleus seed, the remaining pure seed from individual plants is dispersed.Choosing a clean, fruitful location for the nucleus seed and placing it in an experimental field where the same crop has not been cultivated in the previous season. The area must to be adequately segregated and devoid of stray plants. The 200 or fewer progenies should be seeded in four series of 50 double rows each, 200 double rows total, in each plot. To enable inspection of each row during crop development, there should be enough space between and between the rows[7], [8].Nucleus double row plots should be carefully inspected from the seedling stage to maturity, and off types should be removed. Any plot that clearly differs from the nucleus seed variety should be eliminated before the flowing stage. Plots should be carefully evaluated for various traits such as flower color, ear head form, seed color, etc. after blooming and until maturity, and the offtypes should be eliminated before harvest. All plots or plants within three meters should be removed when a plant is removed after blooming since they might infect the other plants.

**Harvesting and threshing**

Each of the remaining plots has to be harvested separately and then linked together. The different plots are independently threshed, washed, and dried. Each plot's first characters should be piled up on the purity work board and checked for consistency. Any pile that seems to be infected or of an odd kind should be thrown away. All of the plot seed that is left should be combined into a single lot, treated with fungicide and insecticide, bagged, tagged, and kept as breeder stock seed for the next year. Upkeep of inbred line breeder seed: To increase B/s, a separate field is planted with breeder stock seed made from nucleus seed.

**Seed certification's past**

The notion of seed certification's origins is unclear, both geographically and historically. However, Swedish people deserve all the credit for seed certification. Due to genetic contamination and mechanical blending in the 20th century, the newly produced types lost their distinctiveness. To prevent this, agronomists and breeders began to visit the fields of forward-thinking farmers and instructed them to stay away from mechanical mixing and maintain the genetic purity of the seed. Gradually, this approach evolved to a field examination. The scientists and farmers believed that field inspection may be helpful in preserving the genetic integrity of crop types. However, new issues like as how much mechanical blending or genetic tampering should be tolerated emerged. The International Crop Improvement Association was founded in 1919 in Chicago, Illinois, as a means of resolving these issues. The ICIA set the foundation for contemporary seed certification, subsequently changing its name to Association of Official Seed Certification Agency in 1969. The process for certifying seeds is optional, and only for the types and varieties that the Indian government has made known. It may be finished in six general stages[9], [10].

- Examination of the application after its receipt.
- Seed source, class, and other criteria verification.
- To ensure that fields meet the established field standard, filed inspection should be done.
- Inspection after harvest, including packaging and processing.
- Testing and seed sampling are done to ensure that the seeds meet the requirements.
- Certificate issuance, labeling, and sealing.

**Application receipt and review**

Anyone interested in seed certification should submit a Form No. 1 application to the relevant seed certification officer together with the stipulated fee of Rs 25/-. If more than one variety is planted or if the area is more than 25 acres, separate applications should be completed for each variation. The charge is for one season for a single variety and for an area up to 25 acres. Applications should be submitted separately if the area is less than 25 acres under one variety but the fields are dispersed and more than 50 meters apart. The seed certifying organization checks for the following requirements after receiving the applications:

- Only those types that the central government has notified are eligible. to get certification.
- Identifying the source of the seeds: The seed producer must provide a copy of Form No. 2, the tag, and the invoice.
- In order to conduct a timely field inspection, there shouldn't be any difficulties getting to the field.
- Whether or whether the necessary isolation and land requirements are met.
- Whether the applicant has access to the processing plant facilities.
- Whether or if the applicant has paid the necessary registration cost. The seed producer is required to pay the following field inspection costs if all six requirements are met: seed source, class, and other criteria verification. The seed must come from a reliable source, belong to the right class, and meet Indian Minimum Seed Certification Standards.

**Examination of the seed fields**

Crops should be grown and harvested in accordance with the instructions provided by the organization that certifies seeds. They are required to carefully and truthfully execute the roguing and other operations in accordance with the certifying agency's instructions. To guarantee that minimum criteria of isolation, preceding crop requirement, roguing, and other special activities are always maintained, the certification team performs field inspections at the proper phases of crop development. The seed crop is inspected at many points during its development cycle, including the sowing stage, vegetative stage or preflowering stage, flowering stage, post flowering stage, preharvest stage, and harvest stage. Offtypes, pollen shedders, shedding tassels, indistinguishable other crop plants, disagreeable weed plants, and sick plants are among the pollutants that should be seen during field inspections. The purpose of the field inspections is to make sure that the crop adheres to the established field standards. All seed fields that don't adhere to the necessary field requirements are ultimately discarded.

**Counting fields technique**

The stages involved in taking field counts are as follows. A minimum of five counts must be conducted for each crop for an area up to two hectares, and another count must be performed for every additional two hectares or portion thereof as specified. Taking of Filed Counts: For various crops, different steps must be taken to take filed counts. Rejecting seed fields: All seed fields should be rejected if they don't meet the requirements for any of the variables. The reason(s) for the rejection should be included in the rejection letter and sent right away to the seed producer. By displaying the pollutants, seed farmers should be persuaded as much as possible to reject the seed fields.

**Post Harvest Inspection**

To ensure that there are no mechanical mixes and that the seed is not treated improperly during threshing or afterwards, the staff from the seed certification organization should check the fields during harvesting or thereafter. The seed is then sent to a company that processes seeds along with a threshing certificate. To prevent mechanical blending and damage to the seed during processing, representatives of the seed certification organization will check the seed processing facility.

**Sampling and testing of seeds**

At the time of processing or after processing, a representative from the agency in charge of seed certification takes a representative sample from the seed lot and sends it to the approved seed testing laboratory for analysis.

The samples will be examined for seed standards such as pure seed, inert matter, other crop seed, weed seed, germination percentage, moisture percentage, etc. at the seed testing laboratory.Certificate issuance, labeling, and sealing. The labelling and sealing of bags will be carried out under the direction of the seed certification agency upon receipt of a positive report from the seed testing laboratory. Advance tags will also be given out in some cases, up to 75% of the seed lot. In compliance with standard seed certification regulations, tags and seals must be used. The certification procedure for seeds is completed with the application of tags and seals to the containers.

**Testing with a control plot**

For all hybrids, the seed certifying organization must set up a postseason grow-out test in accordance with the requirements. To verify the effectiveness and correctness of the job completed, randomly selected samples from certified seed batches should be submitted for grow-out testing.

**Period of validity**

The seed is originally valid for nine months starting on the day the samples were tested. If the seed lot satisfies the necessary seed criteria, it may be revalidated for a period of six months if the seed is not sold within the allotted time. The validity period will be extended by six months for each revalidation as long as the seed satisfies the established seed requirements.

**Cancellation of the Certificate**

The certificate may be revoked if the certifying body determines that the certification provided by it was acquired by misrepresenting material facts or that the certificate holder has disregarded the requirements for obtaining the certificate. Only after providing the certificate holder with a show cause notice is the certificate able to be revoked.

**Appeal against seed certification agency**

Any certified seed farmer may appeal a seed certification agency judgment to the appellate authority designated by the state government if he is dissatisfied with the agency's decision. Within 30 days after receiving the notice of refusal, the appeal must be filed. The appeal must be submitted in writing, include a copy of the rejection letter, and include a Rs. 100.00 treasury fee. The application has to be delivered in person or transmitted by registered mail. The appeal authority's ruling is final and enforceable against both the seed farmer and the seed certifying organization. The Additional Director of Agriculture is Andhra Pradesh's appellate authority.

**Drying of Seed**

To preserve seed viability and vigor, which may otherwise quickly decline owing to mold development and increased microorganism activity, the moisture content of the seeds must be reduced to acceptable moisture levels. The benefits of seed drying include early harvesting, which allows for more effective use of resources like land and labor, long-term storage, and seed quality preservation.

**Techniques for drying seeds**

- Sundrying
- Dried by forced air

**Sun drying**

Before harvest, the moisture of the seed is often decreased in the field, and subsequently, on the threshing floor, by sun drying. In this approach, crops are collected after they are completely dried in the field, left there for a few days to dry in the sun, and then threshed and winnowed food is spread out in thin layers on threshing floors to dry in the sun. The major benefits of solar drying include not needing any extra money or specific equipment. Delay in harvesting, potential for weather damage, and an increase in mechanical admixtures are the drawbacks. If sun drying is used, the following safety measures must be performed.

- Spreading vegetables on muddy, filthy, or kacha threshing floors is not recommended.
- One crop variety should be handled at a time, and mechanical mixing should be avoided.

Drying by forced air: In this process, seeds are pushed with fresh air. Wet seeds absorb water when they are passed through by the air. The seed and the air are cooled through evaporation. The air temperature decrease provides the heat required to evaporate the water.

**The Forced Air-Drying Principle**

Because seeds are a highly hygroscopic living substance, the relative humidity and temperature of the air around them affect how wet they are. When a seed's internal vapour pressure exceeds that of the air around it, the vapour pressure will flow out of the seed, causing the seed to lose moisture. However, if the gradient of the vapour pressure is reversed, moisture will migrate into the seeds and the seeds will acquire moisture. The moisture content of seed is in balance with the surrounding environment when the two vapour pressures are equal. When there is a net transfer of water from the seed into the surrounding air, seed drying occurs. The pace at which surface moisture evaporates in the surrounding air and the rate at which fluid migrates from the seeds' centers to their surfaces determine how quickly seeds dry out. The pace of moisture migration from the center to the surface of the seed is influenced by the temperature, physical makeup, chemical makeup, and permeability of the seed coat. Surface saturation, relative humidity, and drying air temperature all have an impact on how much moisture is removed from the surface.

All the seeds don't dry evenly at the same time when air is driven through them to dry them. In actuality, all of the seeds in the drying bin may be categorized as being in zone a. the desert region, b. the zone of drying, and c. the moist area.

**The Dried Zone**

As air enters the seeds, it initially dries the area closest to the intake using either heated or naturally occurring air. The seeds will partially dry to the appropriate level. As drying progresses, the dried zone will increasingly ascend.

**Drying Zone**

After passing through the dried zone, the air continues to gather up moisture until it reaches the drying zone, or the saturation zone in the event of extremely wet seeds. The breadth of the drying zone determines how much moisture it can absorb before it achieves equilibrium. The term "drying front" refers to the lower margin of the drying zone where it meets the dried zone.

**Wet Zone**

The area above the drying zone, or the portion of the seed between the top of the drying zone and its top surface, which is wet (16–20%). The top layer will be the wettest and take the longest to dry. Except when there is parallel airflow from all areas of the perforated floor the seed, the drying front won't always be in a plane. The ducts are often heavily used, therefore a covered drying front may be seen around each entrance.Stratification is the term for the differential in moisture content of the air entering and exiting the seed. The volume of air passing through the seed and its relative humidity determine the degree of stratification and the breadth of the drying zone. The drying zone may cover the whole bin when there is strong airflow or low relative humidity, although there will be less stratification in the bottom dried zone. In order to prevent backpressure from being applied, the outflow should be double the size of the entrance.

**Drying with Forced Air**

For forced air drying, there are three main techniques: 1. Natural air drying - This sort of drying technique uses natural air. 2. Drying with additional heat - In this technique, the air temperature is increased by 10 to 20 oF to lower the relative humidity of the atmosphere. 3. Drying with heated air - The drying air is heated to 110oF in this approach. The first two procedures take more than two to three weeks to get the moisture content down to a safe level. These techniques are mostly used for drying crops in western nations.These techniques, as well as seeds that are kept on the farm, are hardly employed in India. For drying seeds, heated air-drying is mostly preferred and employed. With this technique, hot air is used to dry the seed in specialized wagons or bins. If processing is not done right away, the seed is transferred from the drying stage to the processing assembly or storage bins.

## 3. CONCLUSION

The importance of sustaining strict quality standards at each step of the seed's journey, from breeding and manufacturing through storage, distribution, and planting, is underlined by this investigation. Measures for quality assurance that address genetic purity, viability, vigor, and health condition act as barriers against lowered yields and unanticipated difficulties. In the area of seed quality, where cutting-edge technologies like molecular markers, remote sensing, and artificial intelligence are revolutionizing quality assessment and management, modern agriculture's march toward innovation is reflected. The adoption of seeds that are in line with regional and market-specific demands is encouraged by transparent certification systems that inspire trust in both farmers and customers. The importance of seed quality is highlighted as environmental concerns and worldwide population growth increase. The caliber of the seeds sown determines how resilient a crop will be to climate change, disease outbreaks, and shifting market conditions. To assure the availability of high-quality, adaptable seeds that can sustainably power the expansion of agriculture, the seed business must work in conjunction with research organizations, governments, and farmers.

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# CHAPTER 13

# REQUIREMENTS OF STORAGE BIN FOR SEED DRYING

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**ABSTRACT**:

Effective seed drying is a critical step in preserving seed viability and maintaining quality. This paper examines the fundamental requirements for designing storage bins that facilitate efficient seed drying processes. It delves into key factors such as ventilation, temperature control, humidity regulation, and airflow management, which significantly influence the success of seed drying within storage systems.

The study emphasizes the pivotal role of proper storage bin design in preventing moisture accumulation, mold formation, and seed deterioration. By addressing the core considerations in developing storage bins tailored for optimal seed drying, this paper contributes to advancing techniques that enhance seed preservation and support sustainable agriculture practices.The requirements for storage bins designed for seed drying are essential to safeguarding seed quality and ensuring successful germination.

As established by this exploration, a well-constructed storage bin can mitigate risks associated with moisture retention, mold growth, and deterioration. Adequate ventilation, temperature control, and proper airflow management are the cornerstones of efficient seed drying, allowing for the removal of excess moisture while maintaining seed viability.

**KEYWORDS**:

Aration, Airflow, Drying Efficiency, Grain Storage, Humidity Control, Moisture Content.

## 1. INTRODUCTION

Bulk tiny grain seeds put a lot of strain on the sidewalls. Since the side pressure of the seed is transformed into a vertical stress on the foundation, a sturdy foundation is required. tight weather. Rain and snow, two major factors in seed storage damage, must be kept out by the roof and walls. The walls need to be airtight in order for the seeds to dry adequately. Easily emptied and filled.

The apertures for filling and removing seed should be sufficiently sized and placed such that filling and unloading the seed take the least amount of time possible. It is ideal to have a full-size entry door. convenient for cleaning, fumigating, and inspection. There should be 60–120 cms. of headspace above the seed for simple observation. Avoiding sharp edges will make cleaning and spraying relatively simple.

The building should be airtight during fumigation, with plans for temporary closing of any openings. Multiple Use. More than one kind of crop should be able to be dried and stored in the building. a good mechanism for distributing the air. The air distribution system must be able to transport enough air to dry the seed and distribute it across the whole seed mass as evenly as feasible. sufficient air venting. After leaving the seed, the air flow should continue quickly enough to prevent back pressure from impeding the entry of drying air into the seed. For this, the outlet's dimensions should be more than twice as large as the air distribution system's primary duct's cross section[1], [2].

Different air dispersion methods for drying seeds. The primary categories of air distribution systems are as follows.

- System of the main and lateral ducts
- A single central duct with perforations
- fake floor system with perforations

**Main and lateral duct air distribution system**

This design allows the main duct to be placed either in the middle of the bin or on one of its sides. The central duct may also be used to empty the bin if it is situated below the floor and away from the bin. The main duct may be found within the bin or on the bin's outside wall when it is attached to the side of the bin.

**A system with a single central perforated duct**

Around the duct, which is composed of perforated metal, there must be an equivalent thickness of seed no taller than 6 feet for this air distribution system. The seed should be driven upwards via the air to dry it. In order to allow air to move laterally through the seed, the sides of the bin must be punctured. The most typical use for this kind of air distribution system is drying maize cobs[3], [4].

The most popular air distribution method for hot air-drying is the perforated false floor system. In this procedure, air is placed below the artificial floor that has holes in it. The air then flows through the seeds and up through the holes. Hardware cloth, screen, or perforated metal sheet are all acceptable materials for the fake floor. The metal fake flooring are easier to use and more enduring. It is advised that this kind of flooring be supported by concrete blocks spaced every three to four feet. The assumption is that the floor can handle loads up to 500 pounds per square foot. The air flow apertures and channels need to be properly planned in order to conduct the air stream successfully. The total area of all the holes in the steel sheet should not be less than 8–10% of the store floor area when perforated meta flooring is utilized. When the drying floor doesn't reach the sides entirely, this is crucial.Using the same drying fan or fans, several storage bins are utilized to dry various varieties of seeds concurrently. Sliding air gates are used in this technology to regulate the airflow to the appropriate bins. When two or more types of seeds are being produced, several bin layouts are useful[5], [6].

Dryers for heated air consist of a heater unit that burns fuel and a fan that pushes heated air through a canvas connecting duct and into the drying bin's air distribution system. An automated thermostat that is attached to the drying bin regulates the temperature at a higher limit and extinguishes the burner flame if the air temperature rises over a safe level. According to how heat is applied to the air, there are two different kinds of dryers.

- Straight fire
- Rear-fired

**Direct fired**

In this kind of combustion, the fuel is burnt, and the hot combustion gases are released directly into the air stream that enters the air distribution system. Natural gas, butane gas, or liquid propane gas are the fuels that are utilized. This technology has the benefit of being very heat-efficient. The likelihood of blown soot into the air distribution system is one of the drawbacks. Unburned gasoline and unsavory odors may find their way into the seed bin. There is also a risk with certain fuels of blowing tiny sparks into the seed, creating fire concerns. Hot combustion gasses are delivered into a chamber in an indirect fire. This chamber's air circulation carries the drying air, which absorbs heat and enters the ventilation system. Kerosine oil or, in rare cases, coal is the fuel utilized. An oil engine or an electric motor may both power the fan. This technique has the benefits of being safe from fire threats and having no chance of combustion fumes or soot entering the container. One drawback is that it uses heat less effectively.

## 2.DISCUSSION

There are four types of seed dryers

**Layer in Bin Dryer**

According to the size of the bins, the drying unit, and the moisture content of the seeds, this approach fills the bin to a specified depth. The next level is applied once the seed has been dried to a safe moisture level for storage. The bin will have a diameter between 21 and 40 feet and need motors of 5 to 20 HP. Although slow, it is the most effective drying process. Between the bin's top and bottom, the seed is evenly dried[7], [8].

**Dryer with batch loading**

In this style, the drying bin is filled with high moisture seed. The seed is cooled after being dried at a safe moisture level. Although layer drying is utilized, the drying apparatus still needs a large heater and fan. Typically, seeds are buried 2.5 to 4.0 feet deep; the deeper the seed, the slower the drying process and the less ventilation there is.

Batch dryers are containers with an interior air chamber that are encircled by two parallel perforated steel walls and are designed to hold seeds of a certain thickness. In order to drive heated air for drying and outside air for cooling through the seed, the fan heater unit is attached to one end or side of the plenum. Batch dryers are typically cylindrical or rectangular in shape. The HP range for fans is 3 to 40. 8–10 batches for small dryers and 2-3 for larger units may be produced each day[9], [10].

The seed is continuously fed via heating and cooling sections in continuous dryers. The seed's flow may be controlled. The top 2/3 or 34 of the seed columns is pressed with heated air. Continuously extracted dry seed is stored. Temperature and depth recommendations for hot air drying of different crop seeds in bins.

**Drying bins Using Hot Air**

1.Put the seed into the bin to the specified depth, and the broken seeds and garbage should be distributed evenly.

2.Use a thermostat to set the dryer to the appropriate temperature for that seed.

3.When the seed has finished drying, keep blowing air through it without applying any heat to drop the temperature until it reaches air temperature, or 50oF if air temperature is lower. Depending on the amount being dried and the temperature of the air, this might take anywhere from 30 minutes to 2 hours. The seed must be dried as instructed to a safe moisture level. Wagon drying is a unique kind of batch drying using hot air. It is used for grains like wheat, sorghum, and rice, as well as for grains like oats, barley, and maize. Direct loading of the seed onto a wagon designed for drying occurs from a combine. The canvass distribution duct is linked to the wagon as it is hauled toward the dryer. At one moment, three to four wagons may be dried. In order to dry the seed, hot air is pumped through holes in the floor of the wagon. After drying is complete, the heating system is turned off, and the seed is cooled using a tiny fan with a power range of 0.5 to 3.0 HP as needed. The wagons are transported to storage bins after cooling. The benefits of wagon drying include

- Continuous drying occurs
- It is adaptable.
- Low upfront cost
- Reduces seed handling costs

**Can be used for other purposes Bag Drying**

When many types need to be dried concurrently, or when seed lots need to be tiny, or when the seed is collected from the field in jute bags, the drying is done in bags. A common design of 25–40 cu.m. has a drying depth of one bag. air per cubic meter per minute. a static pressure of 3 cm or even less, of seed.It is a modified bag dryer called a box dryer.

Despite mass treatment, the identification of tiny seed batches may be preserved. Local craftsmen make the perforated-bottomed boxes. The bottoms are pushed through with hot air. The boxes are moved to storage after drying.

**Controlling the Seed Drying Process**

1.As soon as the seed is received, dry it. Aerate the trash can by installing a fan if there is a delay. The seed is not heated by aeration.

2.The accumulation of rubbish in one location should be avoided. When the seed is released using a conveyor, this issue is more prevalent. It may be resolved by using a spreader. Small debris resists sir flow with great force.

3.Keep an eye on the temperatures in various drying zones. The whole bin has dried when the top layer reaches the same temperature as the entering air. To check for any damp areas, the moisture level should be randomly measured throughout the bin. If the germination rate drops to between 1 and 2 percent when drying, look for the following:

- Excessive holding period before beginning drying
- Inadequate airflow
- Too much static pressure
- Air with a high relative humidity that is drying
- The temperature of the drying air may exceed 43 °C.
- Extraordinary seed depth
- Air passing through the seeds unevenly.

**Seed Retention**

Since they are living, regenerating creatures, seeds have the special ability to endure until the conditions are ideal for the birth of a new generation. They ultimately decay and pass away, but, much like other forms of life, they cannot maintain their vitality eternally. The seeds of the majority of species may live for much longer under the right circumstances, but fortunately neither nature nor agricultural practice often needs seeds to survive longer than the next growing season.Seeds may be categorized into two groups based on how long they last when stored;

**Orthodox Seeds**

These are resilient seeds with a long lifespan. They can withstand freezing temperatures and can be successfully dried to moisture levels as low as 5% without suffering any harm. The majority of conventional seeds are from yearly, temperate species that are suitable to wide fields. They have a moisture content of 30 to 50% when they reach physiological maturity.

**Recalcitrant Seeds**

These are little, short-lived seeds that cannot be frozen or dried to a moisture content of 30% without suffering damage.Due to their high moisture content, which promotes microbial contamination and hastens seed decomposition, they are challenging to effectively store. When these seeds are kept at very low temperatures, ice crystals develop, damaging cell membranes and resulting in freezing damage. These seeds come from tropical perennial plants including citrus, coconut, coffee, and cacao. These seeds develop and are found in their fruits, where they are protected by impermeable testa and fleshy or juicy ariloid layers. Even though their embryos are only around 15% the size of an orthodox seed embryo, they have greater moisture content than orthodox seeds when they reach physiological maturity. Recalcitrant seeds often don't enter dormancy; instead, they continue to grow and advance toward germination. In order to successfully store these seeds even at low temperatures without causing ice-crystal formation and subsequent seed damage, most attempts at seed storage have focused on using endogenous seed inhibitors like absisic acid or replacing the high-water content with other substances like sugar or ethylene glycol.

**Seed life span affecting factors include**

**Genetic factors**

Under same circumstances, some species' seeds are chemically and genetically more suited for prolonged storage than others. The majority of seeds with a lengthy lifespan come from species with a tough, impermeable seed coat. High oil content seed species often do not store as well as low oil content seed species. The amount of oil in the seed's embryo is what determines how long it can be stored. For instance. While the oil content of whole seeds is only approximately 3%, that of their embryos is roughly 27%.Chemically equivalent seeds from various species may also vary substantially in terms of storability owing to genetic variations. For instance. chewing annual fescue

Ryegrass seeds resemble other seeds in appearance and chemical make-up, however under identical storage circumstances, ryegrass seeds are far more stable. These genetic variables have an impact on seed storability and have caused classification of seeds according to relative storability.Cultivar differences in seed storability are also possible. More than others, certain cultivars can be stored. After 12 years of storage, certain inbred lines of maize were demonstrated to germinate 90% of the time, while others were entirely dead at the same time. inheritance is obvious

**Initial seed quality**

Seeds' physical and physiological health have a big impact on how long they live. Broken or fractured seeds decay more quickly than undamaged seeds. The lifespan of seeds may be shortened by a variety of environmental challenges that occur during seed development and before physiological maturation. Examples include a lack of minerals, poor water quality, and high temperatures. A seed lot's immature little seeds do not store as well as the lot's mature big seeds. Additionally extending seed life is hard seediness.

**Seed Moisture**

One of the key elements affecting the viability of seed during storage is the seed's moisture content. The rate of degradation rises with an increase in moisture over the moisture range. In general, the storage potential of the seed doubles for every 1% reduction in moisture. Losses result from increased mold development if the moisture level of the seed is between 12 and 14%, and seed heating if the moisture content is above 18 to 20%. Additionally, when the temperature rises, biological activity of seeds, insects, and molds increases even more within the usual range. The more negatively impacted seeds are by both extremes of temperature, the more moisture they contain. Seeds may suffer damage from intense desiccation at 4% moisture content or earlier degeneration owing to membrane structure collapse. The loss of water molecules required to maintain the shape of hydrophilic cell membranes is likely the cause of this outcome. It is vital to dry seeds to safe moisture levels before storage since the lifespan of seeds is mostly dependent on the moisture content. The safe moisture level, however, also relies on the period of storage, the kind of storage structure, and the type of seeds being kept. The seeds should be dried to a moisture level of 10–12% for cereals that will be kept in regular storage for 12–18 months. However, the seeds need to be dried to a moisture level of between 5 and 8% before being stored in airtight containers.

Temperature and relative humidity are the two main variables that affect how long seeds will live. Resulting from R.H. and the storage environment's temperature are closely related. At R.H., the majority of agricultural seeds lose viability. 80% or more and temperatures between 25 and 30 °C, however they may be stored for ten years or more at R.H. a temperature of 5 oC or below and a percentage of 50% or less. Harrington said in 1973 that for safe storage, the total of temperature in degrees Fahrenheit plus relative humidity % shouldn't be more than 100. Harrington offered the following general guidelines for ideal storage circumstances.

- The storage life of seeds doubles for every 1% decrease in seed moisture.
- The lifespan of the seed doubles with every 10°F drop in temperature.
- Temperature in degrees Fahrenheit and relative humidity added together shouldn't be more than 100.
- Only when the seed moisture is between 4 and 14% does the rule of thumb apply.

**Evidence**

It has previously been mentioned that a variety of variables at play both before and during harvest may have an impact on seed viability. The viability behavior of the samples collected from various sources may vary. At the time of maturity or harvest, seeds from high relative humidity and temperature areas store less than seeds from low relative humidity and moderate temperature locations.

**Pre- and post-harvest conditions**

Unless the ripening process is halted by premature harvesting, environmental variations during seed development typically have little impact on the viability of seeds. Weathering of maturing seeds in the field, particularly in conditions of excess moisture or freezing temperature, results in a product with inferior storage potential. Some seeds, for example, might have their viability drastically reduced by mechanical damage sustained during harvest. certain legumes with huge seeds.

Because of the protecting lemma and palea, cereals are generally resistant to mechanical damage. Small seeds often avoid damage during harvest, and spherical seeds typically sustain less harm than elongated or irregularly shaped ones. Injuries adjacent to critical portions of the embryonic axis or around the point where cotyledons connect to the axis often cause the most rapid losses of viability. During storage, wounded or deeply buried regions may act as sites for infection and result in accelerated deterioration. Viability may be significantly reduced by drying at high temperatures or by drying too fast or extensively.

Increased oxygen pressure when being stored has the tendency to shorten the time of viability. Some crops' storage times have increased thanks to the use of antioxidants. The gaseous environment may alter if seeds are not kept in hermetically sealed containers at low moisture contents or even under circumstances of constant temperatures and moisture because of the respiratory activity of the seeds and associated microorganisms.There are six major categories of organisms connected to seeds in storage, and storage conditions have an impact on their activity. They include rodents, birds, insects, bacteria, fungus, and mites.

**Bacteria**

It's unlikely that bacteria have a big impact on how quickly seeds deteriorate. Since germination seldom decreases until the illness has advanced beyond the threshold of decay. Bacterial populations need free water to flourish, thus since stored seeds are dry, they cannot do so.

**Fungi**

Field fungi and storage fungus are the two forms of fungi that attack the seeds. The field fungus may only infiltrate seeds when they are developing on plants in the field or after harvesting while the plants are still standing in the field. Alternaria, Fusarium, and Helminthosporium species are among the field fungus connected to wheat or barley in the field. Most storage fungus are members of the Aspergillus and Penicillium genera. They never existed previously, even in the seeds of plants that were left lying in the field after harvesting, and they only infect seeds under storage circumstances. The main negative impacts of storage fungi include a reduction in viability, coloring, the production of mycotoxins, excessive heating, and the development of mustiness and caking.

Insects and mites may seriously harm seeds, which is especially problematic in hot and humid settings. Infrequently active at 8% moisture content and 18–20 C, weevils, flour beetles, and borers become more harmful at 15% moisture content and 30–35 C. Despite their near-freezing temperature tolerance, mites cannot survive above 60% relative humidity. Therefore, seeds should be kept at a moisture content of less than 10%, at a temperature of less than 20°C, and at an R.H. of less than 80% to protect them from insects and mites. of not more than 60%.

**Rats and birds**

Birds are a persistent source of seed loss in all openings, no matter how little. Any apertures that are required for ventilation should be screened or sealed. More significant issues arise from rats and other animals. Rodents might cause the seed to completely disappear. Rodents can be kept out of the shop by raising the floor 90 cm above grade, and the building should have a lip-like structure surrounding it at that height of 15 cm. The entryway should include a detachable deck so that seeds may be loaded and unloaded inside the shop.

9.Other factors: In addition to the aforementioned variables, the frequency and kind of fumigation, the outcome of seed treatment, etc., all impact storage life.

**General Guidelines for Storing Seeds**

- Dry and cold conditions should be used for seed storage.
- Effective pest management for storage
- Sanitary standards in seed warehouses
- Before storing seeds, they should be dried to a safe moisture level that is suitable for the storage method.
- Only good quality seeds, such as those with excellent germination rates, are to be kept in storage.
- Assess the necessity for seed storage in light of the duration of the storage period and the local climate at the time of storage. More stringent seed storage requirements apply to long-term storage than to short-term storage. Similar to how locations with

favorable storage climatesthose with relatively low relative humidityneed less sophistication than do those with high relative humidity.

## 3. CONCLUSION

Beyond only affecting individual seeds, the relevance of these needs affects crop yields, food security, and agricultural sustainability. Lack of suitable storage bin design may affect the quality of the seeds, resulting in lower germination rates and less than ideal plant development. Effective seed drying plays a bigger role now that climate change and agricultural practices are changing on a worldwide scale. In conclusion, effective seed drying requires a well-balanced interaction between ventilation, temperature control, humidity regulation, and airflow management inside storage bins. To advance storage bin design and meet the complex requirements of many crops and settings, agricultural engineers, researchers, and seed scientists must work together. The needs for seed drying storage bins will continue to pave the way toward improved seed preservation and sustainable food production as the agricultural environment changes.

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