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Chapter 2

Seed Science and Technology: Principles and Applications in Crop Improvement

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Abstract

Seed science and technology constitute the backbone of modern agriculture and crop improvement. Quality seed is the most critical input determining crop establishment, productivity and profitability. This chapter elaborates the fundamental principles of seed science, seed production systems, seed quality attributes, processing, storage, certification, and recent advancements pertaining to technology. Emphasis is placed on the application of seed science in crop improvement, hybrid seed production, stress tolerance along with sustainable agriculture. The integration of advanced seed technologies with plant breeding has significantly enhanced the dissemination of improved varieties and contributed to food and nutritional security.

Keywords: Seed quality, Seed production, Crop improvement, Hybrid seed, Seed storage, Seed certification.

1. Introduction

Seed is the basic and most vital input in agriculture, representing the genetic potential of a crop. The success of crop improvement programs highly depends on the availability and use of high-quality seed. Even with optimal agronomic practices, poor-quality seed can result in low yields and crop failure.

Seed science and technology encompass the study of seed development, quality maintenance, production, processing, storage and distribution. In India, the organized seed sector has played a crucial role in increasing crop productivity by ensuring the timely supply of improved varieties and hybrids to farmers.

2. Principles of Seed Science

The principles of seed science focus on maintaining seed quality from production to utilization.

Genetic Purity

Genetic purity ensures that the seed conforms to the varietal description. It is essential for maintaining yield potential, resistance traits, and uniformity.

Key practices:

- Maintenance of isolation distance
- Roguing of off-types
- Use of approved seed sources
- Proper seed multiplication stages

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Physical Purity

Physical purity refers to freedom from inert matter, weed seeds, and seeds of other crops. High physical purity improves sowing efficiency and crop uniformity.

Seed Viability and Germination

Viability indicates the ability of seeds to germinate and produce normal seedlings. Germination percentage is a standard indicator of seed quality.

Seed Vigour

Seed vigour reflects the capacity of seeds to establish seedlings under a wide range of environmental conditions. Vigorous seeds ensure rapid emergence and uniform crop stand.

Seed Health

Seed health deals with the presence or absence of seed-borne pathogens. Healthy seed minimizes disease spread and enhances crop establishment.

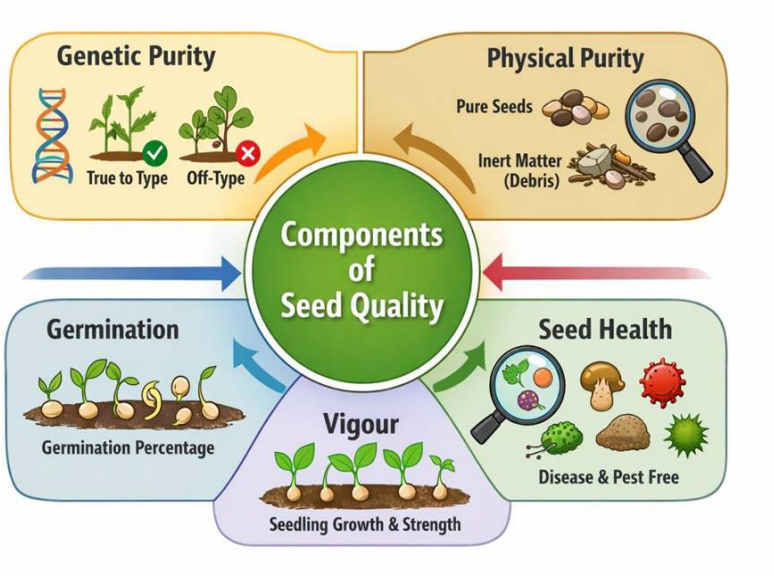

Figure 1: Components of Seed Quality

Schematic representation showing genetic purity, physical purity, germination, vigour and seed health as integrated components of seed quality.

3. Seed Production Systems

Seed production follows a systematic multiplication process to preserve genetic purity and quality.

Classes of Seed

The seed multiplication chain ensures quality maintenance.

Table 1: Classes of Seed and their Purpose

Seed Class	Source	Purpose
Nucleus Seed	Breeder	Maintenance of original genetic material
Breeder Seed	Nucleus seed	Production of foundation seed
Foundation Seed	Breeder seed	Production of certified seed
Certified Seed	Foundation seed	Distribution to farmers

Principles of Seed Production

- Selection of suitable agro-climatic region
- Maintenance of isolation distance
- Timely sowing and advanced crop management practices

- Regular field inspections
- Proper harvesting and post-harvest handling

Flow diagram showing Nucleus → Breeder → Foundation → Certified seed

Figure 2: Seed Multiplication Chain

4. Seed Processing and Storage

Seed Processing

Seed processing improves seed quality by removing impurities and grading seeds.

Table 2: Major Seed Processing Operations and Their Functions

Operation	Function
Cleaning	Removal of inert matter
Grading	Uniform seed size
Drying	Reduction of moisture
Seed treatment	Protection from pests and diseases
Packaging	Safe handling and storage

Seed Storage

Seed storage aims to preserve viability and vigour until the time of sowing.
Important factors:

- Seed moisture content (%)
- Temperature ($^{\circ}C$)
- Relative humidity
- Protection from storage pests

Harrington's thumb rules are widely followed which is targeted to enhance seed longevity.
Diagram illustrating moisture, temperature, humidity, and pests affecting seed longevity

5. Seed Certification and Quality Control

Seed certification ensures that seeds meet prescribed standards of quality and genetic purity.

Objectives

- Maintaining varietal identity
- Ensure minimum quality standards of seeds
- Protect farmers from obtaining spurious seed

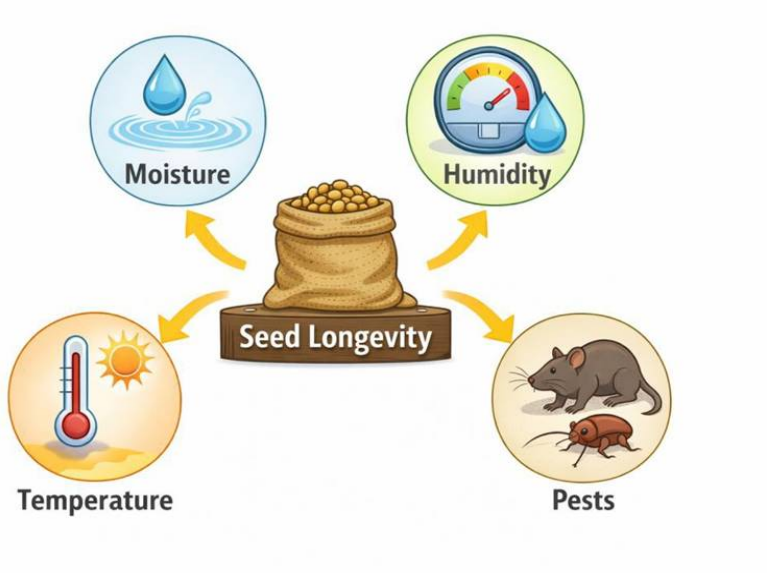

Figure 3: Factors Affecting Seed Storage Life

Table 3: Minimum Seed Certification Standards (Indicative)

Parameter	Certified Seed Standard
Physical purity (%)	≥ 98
Germination (%)	$\geq$ 75–85 (crop-specific)
Moisture (%)	< 12
Inert matter (%)	≤ 2

Seed Testing

- Seed testing laboratories evaluate:
- Germination percentage (%)
- Physical purity of seeds
- Moisture content (%)
- Seed health

6. Applications of Seed Science in Crop Improvement

Dissemination of Improved Varieties

Efficient seed systems enable rapid multiplication and distribution of improved varieties developed through breeding programs.

Hybrid Seed Technology

Hybrid seed production exploits heterosis for higher yield and homogeneity. Seed science ensures:

- Synchronization of parental lines
- Controlled pollination (especially in cross pollinated crops)
- Maintenance of genetic purity

Diagram showing male and female parent lines, isolation and controlled pollination

Seed Treatment and Enhancement

Seed treatments improve germination, vigour and protection against pests and diseases.

Table 4: Seed Treatment methods and its benefits

Treatment Type	Purpose
Chemical	Disease and pest control
Biological	Eco-friendly protection
Seed priming	Improved germination
Seed coating	Nutrient and pesticide delivery

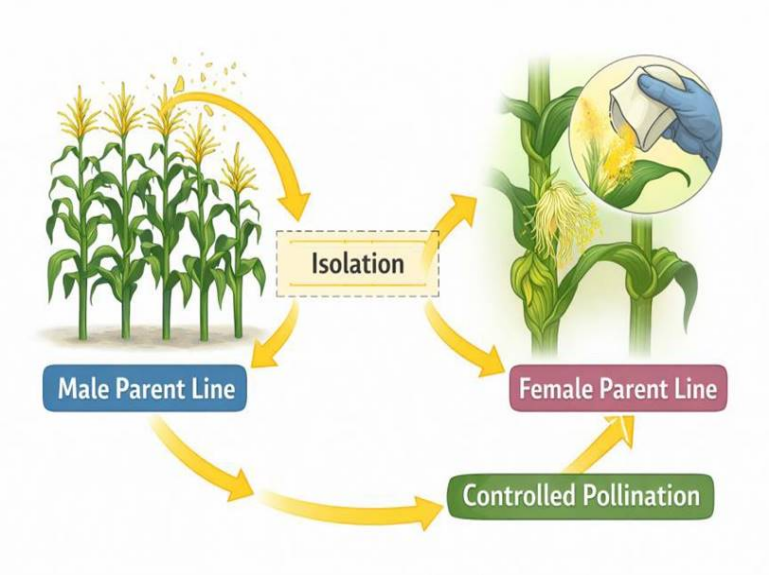

Figure 4: Hybrid Seed Production System

Stress Tolerance and Climate Resilience

Seed priming and coating technologies help crops withstand drought, salinity and temperature stress, improving field establishment.

Recent Advances in Seed Science

- Molecular markers were used efficiently for genetic purity testing
- Seed pelleting and film coating
- Cryopreservation of germplasm material
- Digital seed traceability
- Integration of biotechnology in seed quality improvement

Constraints and Challenges

- Climate variability affects the seed production
- Seed deterioration is possible during storage
- Limited availability of quality seeds of different crops in remote areas
- Presence of spurious seed in markets

Future Prospects

Future seed systems will integrate genomics, nanotechnology, precision agriculture as well as digital tools. Strengthening public & private partnerships and improving seed delivery mechanisms is very much essential for sustainable crop improvement.

7. Conclusion

Seed science and technology are indispensable for realizing the genetic potential of improved crop varieties. Quality seed will definitely act as a catalyst for enhancing productivity, profitability and also sustainability in agriculture. Continued advancements in seed technology and effective regulatory frameworks plays a crucial role in ensuring global food security in near future.

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