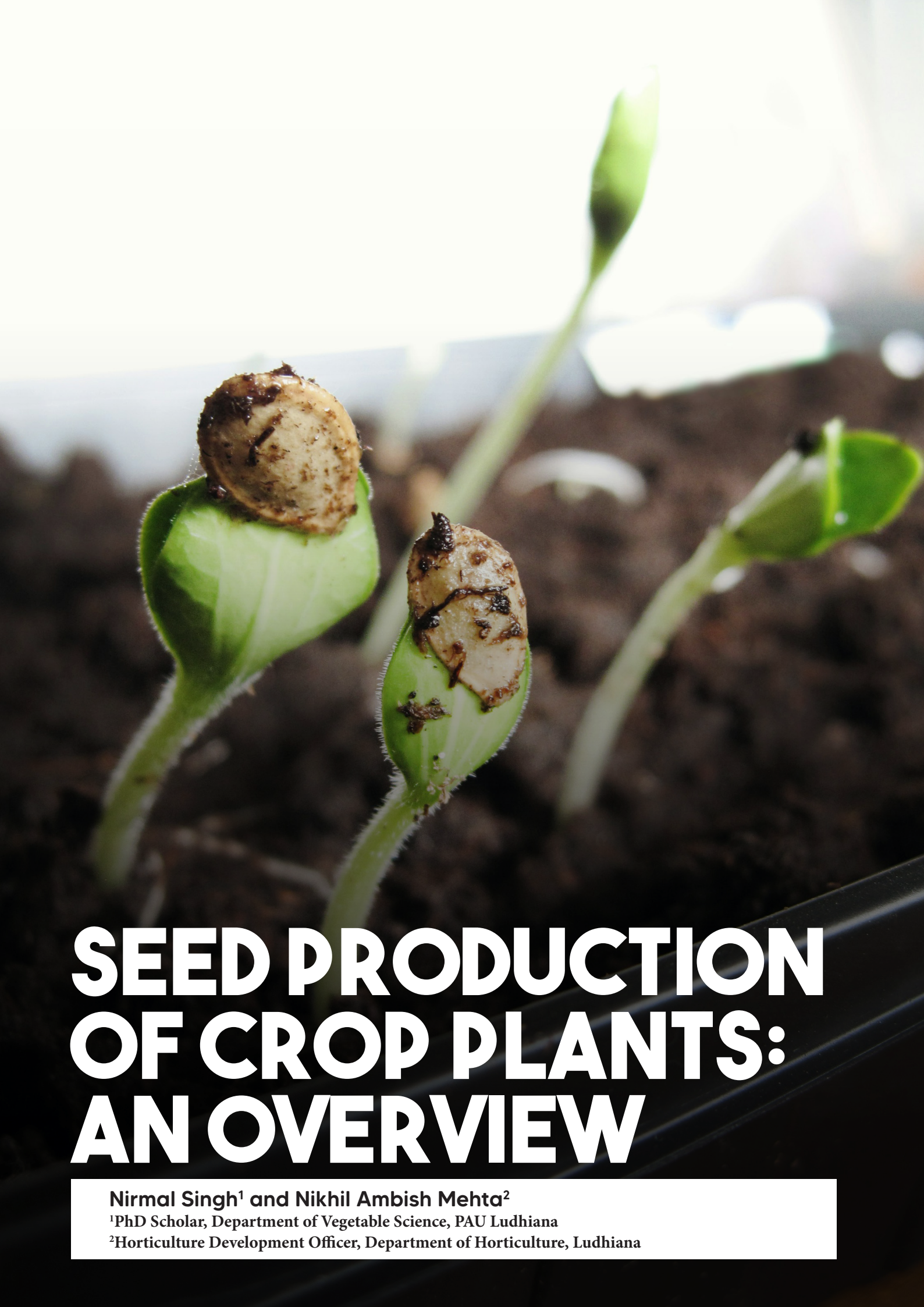

SEED PRODUCTION OF CROP PLANTS: AN OVERVIEW

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SEED:

A seed is any part of a plant used for crop propagation. This includes true seeds, seedlings, cuttings, rhizomes, grafts, and roots. Botanically, a seed is the mature ovule, which consists of an embryo along with a food reserve, all encased in a protective coat.

Parts of a Typical Dicotyledonous Seed

1. Seed Coats: The seed coat is made up of two layers of integument, which may be fused or separate. The outer layer is called the testa, while the inner layer is known as the tegmen. The seed coat features a hilum, marking the attachment point to the stalk, a micropyle—a small pore above the hilum—and a raphe, which is a ridge formed by the funicle or stalk in many seeds.

2. Embryo: The embryo consists of an axis and two cotyledons. The pointed end, known as the radicle, develops into the root, while the feathery end, called the plumule, becomes the shoot.

3. Endosperm: The endosperm is a fleshy tissue that stores food. In some seeds, the endosperm persists until maturity, classifying them as endospermic or albuminous seeds. In others, it is consumed early by the developing cotyledons, resulting in non-endospermic or ex-albuminous seeds.

Parts of a Typical Monocotyledonous Seed

1. Seed Coat: The seed coat is a brownish, membranous layer that adheres to the grain. It is formed by the fusion of the seed coat and the fruit wall.

2. Endosperm: This is the main bulk of the grain and serves as the food storage tissue, primarily composed of starch. In a longitudinal section, it is clearly separated from the embryo by a layer known as the epithelium.

3. Embryo: The embryo is small and located in a groove at one end of the endosperm. It consists of a shield-shaped cotyledon known as the scutellum and a short axis that includes the plumule and radicle. The radicle is protected by a root cap, while the plumule is encased in a protective sheath called the coleoptile. The radicle has its own protective sheath known as the coleorhiza. The scutellum's surface layer, which contacts the endosperm, is called the epithelium, and it functions to digest and absorb the stored food. In cereals like rice, wheat, maize, barley, and oats, the cotyledon (scutellum) supplies the growing embryo with nutrients from the endosperm through the epithelium.

SEED DEVELOPMENT:

Seed Development involves transforming the integument of the ovule into a protective seed coat, forming the endosperm, and developing the embryo—all occurring within the original ovary. Following fertilization, the zygote undergoes mitotic divisions, leading to the formation of the embryo. A cross-section of a nearly mature seed reveals an embryo with two large cotyledons and a small epicotyl located between them, connected to the hypocotyl. Most or all of the endosperm is absorbed by the cotyledons, while the ovule integuments develop into the seed coat. The basal part of the embryo, called the radicle, becomes the root system, while the epicotyl gives rise to the above-ground structures such as the stem, leaves, and flowers. The hypocotyl acts as the transition zone between the root and stem.

Criteria for Quality Seed

1. Genetic Purity: Must meet minimum standards for genetic purity.
2. Germination: Should demonstrate good germination rates.
3. Disease-Free: Must be free from seed-borne diseases and pests.
4. Physical Purity: Should not contain impurities such as other crop seeds or excessive trash.

Seed Quality Characteristics

1. Improved Variety: Should be superior to existing varieties, yielding 20-25% more or possessing desirable traits such as disease or drought resistance.
2. Genetic Purity: Must be true to type, ensuring all desired traits are present; any deterioration directly affects yield.
3. Physical Purity: A seed lot should contain a high percentage of pure seed with minimal inert matter and contaminants.
4. Germination and Vigour: High germination rates and overall seed vigor are essential for effective planting.
5. Freedom from Weeds and Other Crop Seeds: Essential to prevent competition and crop damage from harmful weeds.
6. Seed Health: Must be free from disease organisms and pests to ensure quality.
7. Seed Moisture: Optimal storage moisture of 11-13% is crucial for maintaining viability and preventing pest damage.
8. Seed Size, Weight, and Specific Gravity: These factors correlate positively with

germination and vigor; seeds should be bold and have high specific gravity.

9. Seed Colour: Reflects maturation conditions; high-quality seeds generally exhibit good shine and color.

Seeds with high genetic purity, excellent germination rates, and minimal contaminants are classified as high quality, while those lacking these traits are deemed low quality.

Classes or Types of Seed

1. Nucleus Seed: This is a small quantity of original seed obtained from selected individual plants of a specific variety. It is maintained and purified by the originating breeder. Nucleus seeds are multiplied under the supervision of a qualified plant breeder, forming the foundation for all subsequent seed production. They possess the highest levels of genetic and physical purity.

2. Breeder Seed: This seed is the progeny of nucleus seeds, multiplied over a large area under the supervision of a plant breeder and monitored by a committee. Breeder seeds provide 100% genetic and physical purity for producing foundation seeds. A golden yellow

Seed Standards for Truthfully labelled Seed:

Kind	Minimum limits of germination	Minimum limits of purity
Rice	80	98
Wheat	85	98
Barley	85	98
Oat	85	98
Maize	80	98
Rapeseed and Mustard	85	97
Sesamum	80	97
Groundnut	70	97
Soyabean	70	97
Sunflower	60	98
Blackgram	75	98
Cauliflower	65	98
Cabbage	70	98
Brinjal	70	98
Tomato	70	98
Chilli	60	98

certificate is issued by the producing agency for this category.

3. Foundation Seed: Derived from breeder seeds, foundation seeds can also be traced back to the breeder seeds. The production of foundation seeds is supervised and approved by a Certification Agency, ensuring the maintenance of specific genetic identity and purity. A white certificate is issued for foundation class seeds.

4. Certified Seed: This is the progeny of foundation seeds, produced by registered seed growers under the supervision of a Seed Certification Agency, while adhering to minimum seed certification standards. Certified seeds can also be produced from other certified seeds to ensure adequate supply, as per the discretion of the Certification Agency (Section 14(2) of Seed Rules, 1968). An azure blue certificate (Shade ISI No. 104) is issued for certified seeds.

5. Truthfully Labelled Seed: This category consists of seeds that meet the minimum requirements for germination and purity, and are labeled according to Section 6 of the Seeds Act. Produced by cultivators and private seed companies, truthfully labelled seeds must adhere to field and seed standards as specified by the Seeds Act. Under this legislation, both the seed producer and seller are responsible for the quality of the seeds.

SEED VIABILITY:

Seed viability refers to a seed's ability to germinate over a specific period. The viability of different seeds varies significantly; some lose viability within weeks, while others can remain viable for years.

Lifespan of Seeds:

Based on their longevity, seeds can be classified into three groups:

1. Macrobiotic Seeds: Also known as long-lived seeds, these can last from 15 years to over 100 years. Examples include:

- Lupine seeds found in peat bogs for 10,000 years (Canada)
- Indian lotus seeds over 1,000 years old
- Silk tree seeds (Albizia lebbek) lasting 147 years
- Trifolium seeds lasting several years
- Mesobiotic Seeds: Known as intermediate-lived seeds, their lifespan ranges from 3 to 15 years. Examples include: Barley, Flax, Tall fescue, Carrot seeds
- Microbiotic Seeds: Also referred to as short-lived seeds, these typically do not exceed a lifespan of 3 years. Examples include: Soybean, Onion, River maple, Wild rice

Orthodox and Recalcitrant Seeds:

Seeds can also be divided into two categories based on their viability under different environmental conditions:

- Orthodox Seeds: These seeds maintain viability for longer periods when stored at low moisture levels. Examples include: Rice, Wheat, Maize, Groundnut
- Tomato For long-term storage, orthodox seeds should be dried to low moisture levels (approximately 5% for vegetable seeds and 8% for field crops) and kept in moisture-proof conditions to prevent infection and infestation.
- Recalcitrant Seeds: These seeds retain viability longer at higher moisture levels. Examples include: Lemon, Grapes, Apple, Jackfruit, Litchi

FACTORS AFFECTING SEED LONGEVITY AND VIABILITY

1. Biotic Factors

- Genetic Makeup: The genetic constitution influences longevity; some seeds are naturally short-lived (e.g., onion, soybean) while others are long-lived (e.g., Indian lotus).
- Initial Seed Quality: Seeds with high initial viability are more resistant to unfavorable storage conditions. Mechanically injured seeds lose viability rapidly, while smaller seeds are generally less prone to injury.
- Effect of Provenance: The origin of the seed affects its storability. For instance, red clover seeds from different regions show varying longevity due to differences in climate and soil.
- Seed Moisture Content: Moisture content is crucial for viability. Higher moisture leads to quicker loss of viability due to mold growth, while very low moisture can cause damage. Seeds should be dried to safe moisture levels before storage.
- Microflora, Insects, and Mites: These organisms can damage seeds and reduce viability. Controlling humidity, temperature, and moisture content helps manage their activity. Fungicides and fumigants can extend storage life.

2. Abiotic Factors

- Relative Humidity: This affects seed moisture content and longevity. Seeds reach a characteristic moisture content based on atmospheric humidity, known as equilibrium moisture content. This content tends to increase as temperature decreases.
- Interaction Between Moisture and Temperature: Temperature significantly impacts seed longevity. Higher temperatures can promote insect and mold growth, especially in seeds with high moisture content. Lowering temperature and moisture is an effective way to maintain seed quality during storage.

Harrington's Thumb Rule

Harrington's Thumb Rule provides useful guidelines for evaluating the effects of moisture and temperature on seed storage:

1. Moisture Content: For every 1% decrease in seed moisture content, the lifespan of the seed doubles. This applies within a range of 5% to 14%.
2. Storage Temperature: For every decrease of 5°C in storage temperature, the seed's lifespan also doubles. This rule is applicable between 0°C and 50°C.

Seed Viability Nomograph

Roberts (1972) developed formulas to illustrate the relationship between temperature, seed moisture content, and viability duration. From these relationships, a seed viability nomograph was created, which helps predict seed viability under specific storage conditions and identify optimal temperature and moisture combinations for maintaining seed viability over time.

Gas Atmosphere During Storage

Increased oxygen levels can reduce seed viability, while storage in nitrogen (N_2) and carbon dioxide (CO_2) atmospheres can enhance seed longevity.

SEED DORMANCY:

Seed dormancy is a condition in which viable seeds do not germinate even under favorable conditions.

Causes of Seed Dormancy:

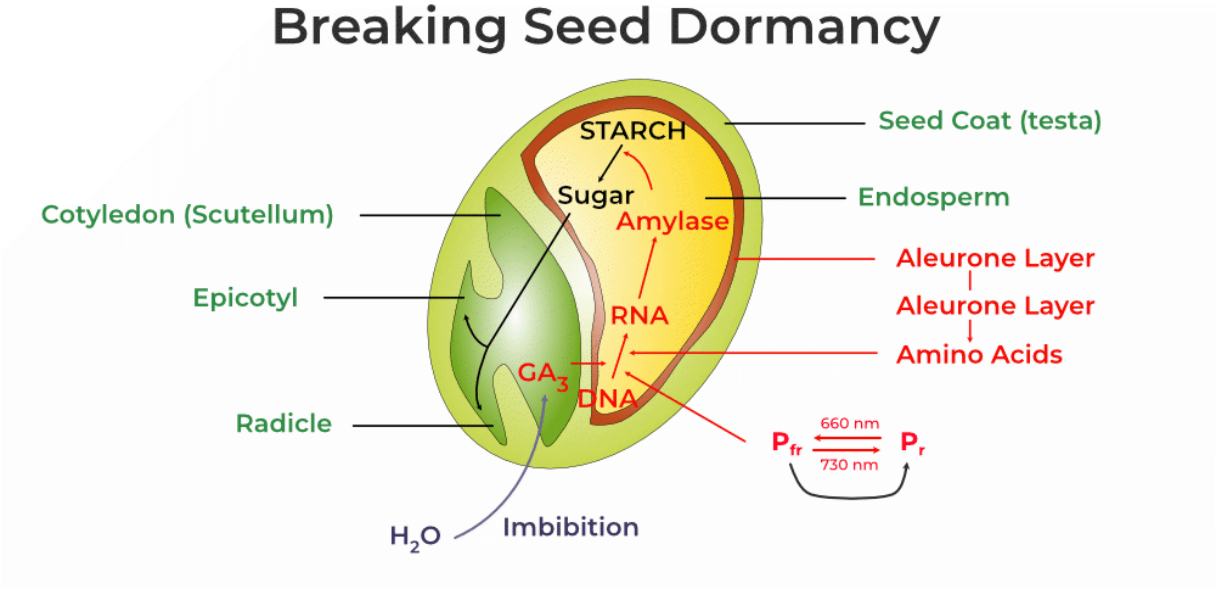
1. Impermeable Seed Coat: Some seeds, particularly from the Fabaceae, Malvaceae, Chenopodiaceae, Convolvulaceae, and Solanaceae families, have hard seed coats that prevent water absorption, keeping them dormant until the coat decays.
2. Oxygen Impermeability: Seeds that cannot allow oxygen in will not germinate, as they cannot respire. This is seen in plants like cocklebur (Xanthium) and certain grasses.
3. Mechanical Resistance: Some seeds, such as pigweed (Amaranthus) and shepherd's purse (Capsella), have tough coats that inhibit embryo growth.
4. Immature Embryo: In plants like orchids and Ginkgo biloba, seeds may contain underdeveloped embryos at harvest, requiring a rest period for proper development before germination.
5. After Ripening: Seeds of crops like barley and wheat, although fully developed, need a period of dry storage for several weeks to months to undergo physiological changes that allow germination.
6. Germination Inhibitors: Dormancy can also stem from inhibitors present in various

seed parts, such as the seed coat, endosperm, or surrounding fruit tissues.
7. Chilling Requirement: Seeds from plants like apple and peach require a cold period to break dormancy, which they receive naturally during winter.
8. Light Sensitivity: Some seeds, such as lettuce and tobacco, require light exposure to trigger germination, known as photoblastic seeds.
9. High CO_2 Concentration: Seeds of subterranean clover require higher CO_2 levels for germination and remain dormant under normal atmospheric conditions.
10. High Osmotic Concentration: Seeds of species like Atriplex require solutes to be washed away by rain to germinate.

Methods to Break Seed Dormancy:

Several techniques are employed by seed scientists to overcome dormancy:
1. Scarification: This method involves weakening the seed coat to promote germination. Techniques include:

- Rubbing seeds on sandpaper (careful not to damage the seed axis).
- Completely breaking hard seed coats for woody seeds (e.g., rubber seeds).
- Soaking hard seed coats in concentrated or diluted sulfuric acid for short periods (e.g., cotton seeds).



2. Temperature Treatments:

- Chilling: Exposing seeds to low temperatures (5-10°C) for a few weeks can break dormancy in species like apple and peach.
- Heat Treatment: Brief exposure to temperatures of 40-50°C for a few hours can prepare some seeds for germination.
- Hot Water Treatment: Soaking seeds in hot water (80°C) for 1-5 minutes can help break hard seed coats.

3. Light Treatments: Exposing photoblastic seeds to red light can initiate germination.
4. Chemical Treatments: Applying growth regulators such as gibberellins, cytokinins, and ethylene can help break dormancy. For example, soaking sorghum seeds in 100 ppm GA3 is effective. Other chemicals like potassium nitrate (0.2%) and thiourea (0.5-3%) can also assist in overcoming dormancy in species like oat and barley.

FACTORS INFLUENCING GERMINATION

1. Moisture: For seed germination, the protoplasm must be fully saturated with water. Air-dried seeds typically contain about 10-15% water, which is insufficient for vital activities. Water is essential to activate the dormant embryo, dissolve salts, hydrolyze stored organic substances in cotyledons or endosperm, facilitate necessary chemical changes, and soften the seed coat to help the embryo emerge.

2. Temperature: A suitable temperature range is crucial for seed germination. Protoplasm functions optimally within specific temperature limits that vary by seed type. Generally, higher temperatures accelerate the germination process.

3. Air: Oxygen is vital for the respiration of germinating seeds, allowing them to liberate energy stored in food reserves. The respiration rate is high, as active protoplasm requires a constant oxygen supply. Seeds sown too deeply in the soil may exhibit little or no germination due to insufficient oxygen.

4. Light: While light is not essential for all seeds, many germinate more effectively in darkness. However, certain seeds, like those of lettuce, require light for germination.

Seed Certification

Seed certification is a system designed to ensure seed quality. Crops intended for certification are cultivated according to the standards set by the seed certification agency, which conducts several inspections to verify seed purity and quality.

Seed Certification Agency

The certification agency operates under Section 8 or is organized under Section 18 of the Seeds Act of 1966. Its primary role is to certify seeds of any notified kinds or varieties.

Steps in Seed Certification

1. Verification of Seed Source: Ensuring the origin of the seeds.
2. Field Inspection: Assessing compliance with prescribed field standards.
3. Supervision During Harvesting:

Overseeing the harvesting process and post-harvest handling.

4. Seed Sampling and Testing: Conducting tests in seed testing laboratories.
5. Tagging and Sealing: Marking certified seeds for identification.

FIELD INSPECTION

Field inspection is a critical step in seed certification, allowing for varietal identification and quality assessment in standing crops. Field standards vary for different crops and are essential for ensuring seed quality.

Crops	Minimum isolation distance(m)		Minimum number of field inspections and stages	Off types% (Max. permitted)	
	Foundation	Certified			
Wheat, Rice, Oat, Barley	3	3	2: from flowering to harvesting	0.05% ear heads	0.20% ear heads
Cotton (varieties)	50	50	2: from flowering to harvesting	0.10%	0.20%
Groundnut	3	3	2: from flowering to harvesting	0.10%	0.20%

Seed Crop Inspection:

The seed crop is evaluated for proper isolation from other crops to prevent the mixing of seeds during harvesting. It is recommended to conduct two to four field inspections throughout the seed production process for various crops.

Seed Sampling:

A seed lot refers to a specific quantity of seed that can be tested for certification. Samples are taken randomly from different areas of the lot and combined into a composite sample. Smaller samples are then extracted from this composite through thorough mixing and subdivision. Sampling can be done manually or with specialized tools like samplers or triers.

Types of samples include:

- Primary Sample: A small portion taken from a single point in the seed lot.
- Composite Sample: Created by mixing all primary samples from the lot.
- Submitted Sample: The sample sent to the testing laboratory, with size specified by Seed Testing Rules.
- Working Sample: A portion taken from the submitted sample for quality testing.

The intensity of sampling depends on the lot size, and only trained personnel should conduct the sampling.

Physical Purity Analysis

Physical purity analysis involves determining the composition of a seed sample, including pure seeds, other crop seeds, weed seeds, and inert matter, expressed as a percentage by weight. Each species of seed and type of inert matter is identified. The weight of the working sample for analysis varies depending on the crop, for example, 700 grams for French beans and 7 grams for tomatoes.

Seed Germination Testing

Germination testing is the most crucial quality assessment for evaluating the planting value of a seed lot. It is performed on the pure seed fraction from the physical purity test under controlled conditions of temperature and humidity. Seedlings, along with any hard, fresh, or dead seeds, are examined after a specified period. Key requirements for seed germination include a suitable substrate, adequate moisture, and favorable temperature and light conditions. Specific media, temperatures, and testing durations are prescribed for different crops.

Germination testing methods include:

- Paper Testing: Seeds can be placed on top of paper, between sheets, or in pleated strips, suitable for small to medium seeds.
- Sand Testing: Seeds are placed on or within sand, generally used for larger seeds.
- Soil Testing: While soil can be used for germination tests, consistent results are often

hard to achieve, making it less recommended as a primary substrate. It may be used to confirm findings from other methods in uncertain cases. All methods must adhere to the guidelines set by the International Seed Testing Association (ISTA).

Rapid Seed Viability Testing

To quickly ascertain seed viability, several rapid methods are employed:

Topographical Tetrazolium Test**: In this method, living cells in viable seeds react with tetrazolium solution, turning red. Developed by German scientist Lakon in 1942, this test uses tetrazolium salt (2, 3, 5-triphenyl tetrazolium chloride). Living seed tissues stain red due to the reduction of tetrazolium by dehydrogenase enzymes, while dead tissues remain colorless. This test helps identify viable, non-viable, and partially stained seeds, with the size and position of necrotic areas indicating viability.

Embryo-Excision Method: In this technique, embryos are removed from soaked seeds and incubated under controlled conditions (typically 20°C) for up to 14 days. Germinating embryos with visible growth or greening are considered viable, while those that remain firm and slightly enlarged are also deemed viable.

Ferric Chloride Test for Mechanical Damage

Mechanical damage in legume seeds can be quickly assessed using the ferric chloride test, which causes affected areas to turn black when immersed in a ferric chloride solution.

Seed Vigour Testing

Seed vigour encompasses the characteristics that influence the activity and performance of seeds during germination and seedling emergence. Even seed lots with similar germination rates may show differences in field emergence and seedling performance. Various vigour tests are available to predict a seed lot's potential in the field. A vigorous seed lot is more likely to thrive under diverse environmental conditions.

It's important to note that vigour tests do not directly measure field emergence or response. They can be categorized as:

- **Direct Tests:** Examples include the brick gravel test (Hiltner Test), paper piercing test, conductivity test, accelerated aging test, and cold test for corn.
- **Indirect Tests:** These involve assessing seedling growth rate, dry weight of seedlings, and speed of germination.

The accelerated aging test, developed in the early 1970s, involves placing seeds in high humidity (near 100%) at temperatures of 40-45°C for varying durations, depending on the seed type. After this period, a germination test is conducted. Initially designed to evaluate seed storage potential, it is now also utilized as a vigour test.

Seed Health Tests

Seeds can carry various microorganisms, including fungi, bacteria, viruses, and nematodes. For example, loose smut in barley and wheat is primarily seed-borne. Thus, detecting and managing seed-borne pathogens is a crucial aspect of seed technology.

Seed health tests can be performed through methods such as:

- Visual examination of dry seeds
- Washing tests
- Seed soak method
- Incubation examinations using blotter, sand, compost, or agar plate methods
- Assessing growing plants
- Disease-specific techniques
- Bioassay tests
- Advanced tests utilizing modern molecular techniques

For specific crop diseases, targeted tests are available. For instance, the sodium hydroxide seed soak method for detecting Karnal bunt in wheat involves soaking 2000 seeds (two replicates of 1000) in a 0.2% sodium hydroxide solution at 20-30°C for 24 hours. Afterward, the seeds are examined visually; infected seeds display a shiny black appearance compared to the pale yellow of healthy seeds. Infection levels are reported as a percentage of the total.

Moisture Tests:

Determining seed moisture content is vital for assessing seed quality. The standard method involves oven drying seeds for either 1-4 hours at 130°C or 17 hours at 103±2°C (the latter for seeds with high volatile oil content). Alternative methods, both destructive and non-destructive, include:

- Drying without heat
- Lyophilization (freeze drying)
- Reversibility method
- Karl Fischer titration, where water is extracted from finely ground seeds using methyl alcohol and moisture content is measured via titration.

In India, the most commonly used moisture meter for seed tests is the Universal-OSAW moisture meter.

Varietal Purity Tests:

Varietal purity can be assessed through various methods:

- Grow-Out Test: This involves planting seeds and observing their morphological traits and the presence of any seed-borne infections. Plants are monitored throughout their growth, with any off-types tagged and counted at maturity to evaluate genetic purity. This method helps eliminate substandard seed lots.
- Biochemical and Molecular Markers: Techniques like DNA fingerprinting can also be utilized if feasible.

Routine Tests:

In seed testing laboratories, routine tests include germination tests, purity tests, and moisture tests. If analysis for diseased seeds or other varieties is required, these should also be included in the routine testing.

Real Value of Seed:

The real value of seed refers to the percentage of a seed sample that will produce seedlings of the certified variety. Also known as utility percentage, it is determined by the purity and germination rates of the seed sample.

Comparison of Seed Lots:

When evaluating two or more seed lots, both purity and germination rates must be considered. This can be efficiently done by determining the real value of the seed lots.

Seed Priming and Pregerminated Seeds

Seed priming is a crucial physiological method that involves controlled hydration to activate the seeds' metabolic processes without allowing radicle emergence. This treatment can be enhanced with plant hormones or beneficial microorganisms, and seeds can be dried for storage or planting. Priming leads to improved germination and seedling establishment, resulting in better crop stands and higher yields, although it may decrease seed storability and requires cool storage temperatures.

Common Methods of Seed Priming:

Osmopriming: Seeds are incubated in aerated solutions with low water potential, achieved by adding osmotica like mannitol or salts like KCl.

Hydropriming: This involves gradually adding a limited amount of water to seeds, often using a drum or humid air. On-farm steeping in warm water is a cost-effective technique.

Matrix Priming: Seeds are incubated in a solid matrix (like vermiculite) with limited water, allowing for slow imbibition.

Pregerminated Seeds: This method allows for radicle emergence before sorting and re-drying, resulting in rapid and uniform seedling development.