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Seed Viability and Vigour Assessment: Principles, Methods and Applications in Seed Quality Evaluation

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Seed quality is a critical determinant of crop establishment, yield stability and overall agricultural productivity. Among quality attributes, seed viability and seed vigour are central to predicting germination capacity and field emergence performance. Viability refers to the ability of a seed to remain alive and capable of germination under favourable conditions, whereas vigour represents the overall physiological potential of seeds to germinate rapidly, uniformly and tolerate adverse environmental conditions. Standard germination tests alone often fail to identify differences among seed lots that may show similar germination under optimal laboratory conditions but perform differently in the field. Therefore, vigour testing complements viability assessment and supports seed industry decisions related to storage, seed processing, marketing and planting recommendations. This article reviews the concept, biochemical basis and major methods used for viability and vigour assessment including standard germination, tetrazolium (TZ) test, accelerated ageing, controlled deterioration, electrical conductivity, radicle emergence test and seedling performance evaluations. The scope, interpretation and practical relevance of these tests are discussed with emphasis on standardization frameworks and seed testing protocols.

Keywords: Seed quality; Germination; Tetrazolium test; Accelerated ageing; Controlled deterioration; Electrical conductivity; Radicle emergence; Field emergence

Introduction

Seed is the most essential and economically valuable input in agriculture. Even with improved varieties and optimized agronomic practices, poor-quality seed can cause weak plant stand, uneven crop establishment and yield reduction. Seed quality is generally evaluated through parameters such as genetic purity, physical purity, seed health and physiological quality, among which physiological quality primarily includes viability and vigour. Seed viability indicates whether the seed is alive and capable of germinating under favourable conditions. However, for field performance prediction, vigour is often a more sensitive indicator than germination percentage because it reflects the seed's ability to withstand stresses such as low temperature, moisture stress and soil crusting (Marcos-Filho, 2015). The International Seed Testing Association (ISTA) has recognized the importance of seed vigour and introduced validated vigour tests in the ISTA Rules, including tests like accelerated ageing and electrical conductivity (ISTA, 2024; ISTA Vigour Committee, n.d.).

Conceptual basis: Viability vs Vigour

Seed viability

Viability means the seed has living embryo tissues capable of producing a normal seedling. Loss of viability is associated with irreversible physiological deterioration and death of embryo cells. Viability is typically assessed through:

• Standard germination test

• Tetrazolium (TZ) test
• Excised embryo test (special cases)

Seed vigour

Seed vigour is a broader and more complex property than viability. It includes:
• Speed and uniformity of germination
• Seedling growth capacity
• Ability to perform under stress conditions
• Storability potential

Thus, vigour explains why two seed lots with same germination % can differ in field emergence and yield (Marcos-Filho, 2015). Vigour tests are primarily aimed at ranking seed lots, not simply passing/failing like viability tests.

Seed deterioration: physiological and biochemical aspects

Seed viability and vigour decline due to ageing and deterioration processes, particularly under high moisture and temperature during storage. Major changes include:
• Membrane degradation → solute leakage
• Oxidative damage (ROS accumulation)
• Enzyme inactivation
• DNA/protein damage
• Reduced respiration and metabolic activity

Membrane integrity is especially important because early deterioration leads to poor membrane repair, causing leaching of electrolytes and metabolites during imbibition—this forms the basis for electrical conductivity tests (Marcos-Filho, 2015).

Methods of seed viability assessment

Standard germination test

The standard germination test remains the most widely used method. It measures the proportion of seeds producing normal seedlings under optimum laboratory conditions.

Advantages:
• Standardized, universally accepted
• Suitable for certification and labeling

Limitations:
• Does not represent field stress conditions
• Cannot distinguish vigour differences among seed lots with similar germination (Marcos-Filho, 2015)

Tetrazolium (TZ) viability test

The TZ test is a biochemical viability test based on the reduction of 2,3,5-triphenyl tetrazolium chloride by dehydrogenase enzymes in living tissues. Viable tissues stain red, while dead tissues remain unstained.

Significance:
• Rapid estimation of viability
• Useful for dormant seeds
• Helpful in quick decision-making (Marcos-Filho, 2015)

However, interpretation requires expertise and may vary among crops.

Methods of seed vigour assessment

Accelerated ageing (AA) test

The accelerated ageing test exposes seeds to high temperature and high relative humidity for a defined period followed by germination test. It simulates rapid ageing and helps in evaluating storability and field performance.

Principle: High-vigour seeds tolerate stress and maintain germination, whereas low-vigour seeds deteriorate rapidly.

Application:
• Storability prediction

• Seed lot ranking (ISTA Vigour Committee, n.d.)

Controlled deterioration (CD) test

In controlled deterioration, seed moisture content is adjusted uniformly before exposing seeds to high temperature stress for a fixed time. It is widely used for Brassica and vegetable seeds and has been included as an ISTA validated vigour test (ISTA Vigour Committee, n.d.). The CD test shows strong association with emergence potential in several crops (Mavi et al., 2007).

Electrical conductivity (EC) test

The electrical conductivity test measures the leakage of electrolytes from seeds during imbibition in water. Higher leakage indicates poor membrane integrity, meaning low vigour.

Merits:

• Rapid and objective

• Strong correlation with emergence for many species (Matthews et al., 2009)

Radicle emergence (RE) test

Radicle emergence is based on recording early radicle protrusion at fixed hours after sowing under controlled conditions. It provides quick discrimination among vigour levels.

Cold test / stress germination tests

Cold test is widely used particularly for maize and other crops to predict performance under low soil temperature conditions. Such stress tests provide field-relevant vigour estimation and are recommended in seed industry vigour handbooks (Baalbaki et al., 2009).

Seedling growth and seedling performance indices:

These methods evaluate seedling length (root + shoot), seedling dry matter and seedling vigour index (SVI).

SVI formulas:

• SVI-I = Germination (%) × Seedling length (cm)

• SVI-II = Germination (%) × Seedling dry weight (g)

Interpretation and practical applications

Importance in seed production and seed industry

Viability and vigour tests guide seed certification decisions, processing and grading, storage management, export/import seed lot evaluation and farmer recommendations on seed rate and sowing time.

Why vigour tests matter beyond germination %

Germination tests are conducted in optimum conditions, but field conditions are rarely optimal. Vigour tests bridge this gap by assessing stress tolerance and physiological robustness (Marcos-Filho, 2015).

Standardization and protocols

ISTA provides global uniformity through International Rules for Seed Testing, including standardized methods for germination and validated vigour tests (ISTA, 2024).

Conclusion

Seed viability and vigour assessment are foundational tools in modern seed science. While viability determines whether seeds are alive, vigour reflects their potential for rapid, uniform germination and successful establishment under variable field environments. Standard germination and tetrazolium tests effectively measure viability, but vigour testing provides stronger prediction of emergence performance and storability. Validated methods such as accelerated ageing, controlled deterioration, electrical conductivity and radicle emergence have improved seed lot ranking and decision-making in seed industry. For PG-level research and seed technology programs, combining multiple tests is recommended to obtain a reliable seed quality profile.

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