SEED SCIENCE: EMERGING TRENDS AND PROMISING TECHNOLOGY

(Cutting-edge technologies employed for seed production)

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ABSTRACT

Seed science employs scientific details and accurate research findings for appropriate technological improvements in modern agribusiness and cultivation strategies. Generally, Seed quality focuses on fundamental parameters such as purity, germination, and resistance to adverse growing conditions. Food security and sustainable agriculture create an ever-increasing demand to improve the seeds of food, flowers, vegetables, crops, and fibres. The emerging seed science trends currently lean towards improving yield varieties and traits, including biotic and abiotic resistance of seeds towards adverse climatic conditions. Genetic enhancement of crop varieties and seed qualities are the key elements behind the global seed industry pushing for better input efficiency and nutritional value. Moreover, advanced molecular tools and imaging techniques can also forge precision farming strategies. This proves that by utilising appropriate modalities and genetic applications, seed enhancement technologies will become integral to forthcoming crop modification initiatives in rural and urban areas.

Keywords: Precision Breeding, Molecular Tools, Hybridization, Heterosis, Molecular Markers

INTRODUCTION

Modern agriculture and cultivation approaches have employed several techniques to boost food security, particularly hybrid varieties for year-round production. Current scenarios created a demand for better research-oriented strategies and goals to meet several requirements of the growing population. Hence, this led to 'Seed science and technology', targeting an adequate rise in crop potential. The main aim is to enhance seed quality for more promising and extensive consumption by people and livestock. Seed science involves several processes: seed production, storage, genetic conservation, sampling, harvest distribution, testing, and conserving agricultural seeds. It is a multi-disciplinary domain that includes plant genetics, biology, breeding, physiology, pathology, entomology, agronomy and agricultural engineering.

This extensive research field connects plant breeding and crop farming for better seed production quality. Seed technology aids in selecting and improving varieties with desirable traits, thus making them resistant to pests, diseases and adverse climatic conditions. Moreover, practical technologies can improve genotypes via selection, hybridisation, seed enhancement, and molecular breeding to withstand biotic and abiotic stress. In upcoming integrations, scientific research, bioinformatics, data science, and AI might provide an advanced angle for technological improvements with tremendous progress.

HYBRID SEED PRODUCTION

From the prior 20^{th} century, hybrid seeds contributed to the most significant advancement in agricultural outcomes. Modern agribusiness, farming, and home gardening approaches utilise hybrid seed production and cultivation techniques. By crossing between two genetically distinct parents, hybrids came into existence. Hybrid crops improve plant characteristics, such as superior uniformity, adequate yield, disease resistance and heterosis. The design of new breeding techniques involves genetic diversity and variety, leading to success in creating desirable agronomic characteristics. For example, the discovery of cytoplasmic male sterility encouraged hybrid breeding in several crop species, such as rice, sorghum, pearl millet, etc.

SEED LONGEVITY

The ability of the seeds to remain in a viable state for a more extended period is called Seed longevity. Based on seed varieties, knowledge about seed storage potential is crucial for farmers and merchants.

Several factors that can influence seed longevity are as follows:

- ***Environment***: Light exposure, oxygen levels, pH levels, air quality and climate conditions. Seeds flourish in dark and low-O_2 conditions that restrict metabolic ageing.
- ***Moisture***: Low moisture causes desiccation, but high levels can create seed deterioration and fungal growth. [Optimal: 5-8% in storage]
- ***Temperature***: Seeds stored in colder conditions [0-10°C] have a long lifespan.

Moreover, specific empirical, biophysical, biological, cytological and molecular parameters have also contributed to model seed desiccation, deterioration and longevity.

SEED DORMANCY

Seed dormancy refers to the natural non-germinating state of the seed, even under favourable growing conditions. Dormancy increases the chances of survival by ensuring that seeds grow during the optimal time. This phenomenon can occur as physiological, physical, morphological, secondary, or thermal dormancy.

Various methodologies such as cold conditions, dry storage, warm stratification, light exposure, or chemical treatments might induce dormancy in seeds. Moreover, several analyses on hormone production (ABA, GA, Auxin, etc.) or upsurge of ROS (Relative Oxygen species) and their manipulating methods also help to control dormancy or trigger germination.

MOLECULAR MARKERS APPLICATION

Modern plant breeding and genetic research groups utilise molecular markers analysis as vital tools to understand the genetic makeup. Molecular markers assist in determining the genetic variety, hybrid purity, fingerprinting, gene mapping, and parent line identification. Numerous or widespread DNA-based molecular markers include microsatellites, Random Amplified Polymorphic DNA (RAPD), Simple Sequence Repeats (SSRs), SNPs, etc.

Among the diverse approaches, a few markers possess the potential to perform different seed quality testing, such as variety determination, hybridity identification, and distinctness testing. Researchers and breeders can create better, robust, high-yielding, resilient crop varieties to ensure agricultural sustainability in rural and urban areas.

SEED ENHANCEMENT TECHNOLOGY

A need exists to improve the planting value of seeds and crop potential for better food security. Hence, various physical, chemical, and biological treatments are necessary to implement seed enhancement technology. In most cases, Seed priming approaches provide rapid, on-demand germination and resistance against biotic and abiotic stress, thus enhancing plant survival in harsh or severe conditions. The consequence of seed enhancement technology via biological means, especially for organic cultivation, safeguards against pests and pathogens during seedling and early vegetative phases.

Moreover, nanotechnological applications have also emerged as supplementary technologies for nutrients, pesticides, and seed enhancement.

SEED VIGOUR

The performance of a seed, either in the soil or storage, can be determined through a vital parameter called Seed vigour. This parameter reveals the seed's integrated characteristics, specifying activity and performance levels during germination and emergence. Moreover, the ISTA congress in 1977 also reflected the significance of seed vigour.

Several factors that influence seed vigour are as follows:

- **a)** Seed weight and size
- **b)** Genetic constitution or makeup
- **c)** Environment and nutrition (mother plant)
- **d)** Maturity at harvest

To obtain optimum plant and crop production, satisfactory seed vigour, moisture, seed health, purity, and germination levels are essential. The ISTA seed vigour committee has provided the following criteria to evaluate the Seed Vigour test of diverse crops:

- **i** *Reproducibility of Vigour Method*
- **ii** *Relationship between Vigour test result and seedling emergence in field soil.*

NON-DESTRUCTIVE TESTING (NDT)

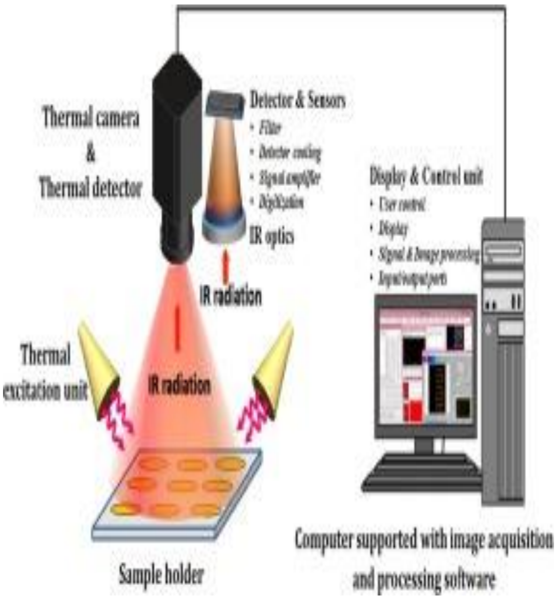
Non-destructive technology refers to the quick, authentic, reliable, and straightforward means of assessing seeds' quality. Technologies that perform non-destructive testing (NDT) include machine vision, spectroscopy, hyperspectral imaging, soft X-ray imaging, electronic nose imaging, and thermal imaging. These tools enable the analysis of variety or trait identification, quality grading classification, damage detection, viability, and forecasting germination ability.

NDT is widespread in detecting insect damage, infestation, and disease in seeds. On the other hand, Hyperspectral imaging detects sprout damage in wheat and barley. Spectroscopy-based methods classify fungus-infected plants such as maize, wheat, rice, and soya beans. This also aids in identifying the green mottle mosaic virus in cucumbers.

ADVANCE IMAGING TECHNOLOGIES

Multispectral imaging performs non-destructive, reliable, and fast analyses of seed quality. This imaging modality is the latest technology deployed to examine seed quality parameters like varietal discrimination and insect damage. Primarily, Multispectral investigates surface structure, size, chemical composition, seed colour and morphology.

Generally, thermal imaging setups are used for non-invasive and non-contact inspection of various food products, i.e. determining the intrinsic quality traits. In seed quality assessment, thermal imaging can examine morphological features, disease factors, insect infestation, germination performance, and continuous seed quality monitoring in storage facilities.



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