



ICAR-IIOR's Smart Seed Coating Technology Strengthens Climate-Resilient Agriculture through Enhanced Seed Quality and Crop Establishment

Smart Seed Technology Delivers Up to 30% Higher Yields in Groundnut and Soybean

Biopolymer-Based Smart Seeds to Strengthen Rainfed Agriculture and Improve Farmers' Incomes

ICAR-IIOR Promotes Partnerships with Public and Private Seed Systems for Large-Scale Adoption

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In a significant step towards strengthening climate-resilient agriculture and improving farm productivity, ICAR–Indian Institute of Oilseeds Research (ICAR-IIOR), Hyderabad, has developed and demonstrated an innovative biopolymer-based Smart Seed Coating Technology designed to enhance seed quality, crop establishment, and resilience against biotic and abiotic stresses across a wide range of agricultural crops.

As agriculture faces increasing challenges from climate change, erratic rainfall, drought, temperature extremes, soil degradation, emerging pests and diseases, and declining resource-use efficiency, ensuring superior seed performance has become more critical than ever. Seed is the primary carrier of agricultural technology and serves as the foundation of crop productivity. Even under optimal management conditions, poor seed establishment can significantly limit yield realization. Strengthening seed performance during the early stages of crop growth therefore offers one of the most cost-effective and scalable approaches to improving agricultural productivity.

The Smart Seed Coating Technology (Indian Patent) developed by ICAR-IIOR utilizes biodegradable biopolymeric materials to create a multifunctional protective layer around seeds. The coating acts as a carrier system for beneficial microorganisms, nutrients, micronutrients, crop protection agents, and plant growth-promoting compounds, delivering them directly at the seed-soil interface. This protective microenvironment promotes rapid germination, vigorous seedling growth, enhanced root development, and improved tolerance to environmental stresses during the critical crop establishment phase.

Field demonstrations conducted under farmer field conditions have shown substantial improvements in crop establishment, plant vigor, and productivity. In Groundnut and Soybean, demonstrations conducted in Telangana recorded yield improvements of nearly 30 percent compared to conventional farmer practices, highlighting the potential of the technology to enhance productivity and profitability. Similar seed

enhancement approaches have demonstrated positive impacts across multiple crops under diverse agro-climatic conditions. Multi-location AICRP-Seed trials across soybean, maize, groundnut, chickpea, cotton, mustard, and pigeon pea demonstrated consistent improvements in seedling vigour, crop establishment, and yield, with productivity gains ranging from **12–37% over untreated controls**, highlighting the potential of biopolymer-based multilayer seed treatments as a scalable Smart Seed technology for diverse cropping systems.

The technology is particularly relevant for rainfed agriculture, which accounts for a major share of India's cultivated area and is highly vulnerable to climatic uncertainties. Delayed monsoons, intermittent droughts, moisture stress, poor soil conditions, and pest and disease pressures frequently affect seedling emergence and crop establishment, ultimately reducing yields. By improving seed performance and protecting emerging seedlings during the most vulnerable stages of growth, smart seed technologies can significantly enhance crop resilience and reduce production risks.

Unlike conventional seed treatments that serve a single purpose, the ICAR-IIOR platform functions as a comprehensive seed enhancement system capable of integrating multiple beneficial inputs into a single application. The technology can be customized for cereals, millets, pulses, oilseeds, fibre crops, fodder crops, vegetables, spices, and horticultural crops, making it a versatile solution for diverse farming systems across the country.

The innovation aligns closely with national priorities on sustainable agriculture, climate resilience, improved seed systems, and enhanced resource-use efficiency. Wider adoption of advanced seed enhancement technologies can contribute significantly to increasing agricultural productivity, reducing input losses, improving nutrient and biological use efficiency, and supporting the country's efforts towards food, nutritional, and economic security.

ICAR-IIOR scientists emphasized that future agricultural growth will increasingly depend on technologies that improve the efficiency and effectiveness of every input used by farmers. Smart Seeds represent an important step in this direction by delivering protection, nutrition, and biological support precisely where they are needed, at the earliest stage of crop growth. Such technologies can help farmers achieve better crop establishment, improved stress tolerance, higher yields, and greater profitability while minimizing environmental impacts.

To maximize the benefits of this innovation, ICAR-IIOR is promoting partnerships with public and private seed systems for large-scale dissemination and adoption. State Seed Development Corporations, National Seed Corporation, Cooperative seed federations, Farmer Producer Organizations (FPOs), seed processing units, seed hubs, custom seed treatment centres, seed entrepreneurs, and private seed companies can play a pivotal role in integrating smart seed technologies into seed production and distribution networks. Such collaborations will help ensure that quality-enhanced seeds reach farmers at scale and contribute to sustainable agricultural growth.

ICAR-IIOR continues to advance research on next-generation seed enhancement technologies involving biopolymers, beneficial microbes, nutrient delivery systems, and environmentally sustainable formulations aimed at transforming conventional seeds into climate-resilient Smart Seeds. The widespread adoption of such technologies can strengthen India's seed systems, improve agricultural productivity, enhance resilience to climate change, and ultimately contribute to improved livelihoods for millions of farmers across the country.

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