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13th INDIAN SEED CONGRESS
NEW DELHI, FEB 23-25, 2025
EMERGING TECHNOLOGIES - PROPELLING SEED REVOLUTION

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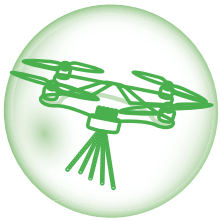

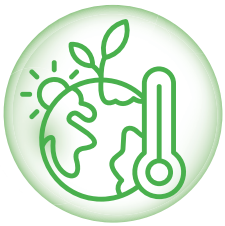


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Preface

Indian seed industry has made a significant contribution in ensuring continued access for farmers to quality seeds and improving food, nutritional and livelihood security for the ever-increasing population. Through innovative breeding techniques, such as marker-assisted and genomic selection, the seed industry has developed crop varieties with improved traits suited to sustainable farming practices. The National Seed Association of India (NSAI) being the apex body representing the Indian seed industry is playing a leadership role in providing an enabling and favourable policy environment for the growth of the seed industry.

The NSAI is organizing the 13th edition of its flagship event, the Indian Seed Congress 2025 on 24th and 25th February, 2025 in New Delhi. In view of the transformative impact of emerging technologies in the agricultural revolution through quality seeds, enabling sustainable agricultural practices to tackle food security challenges, the theme of the ISC 2025 has been appropriately kept as "**Emerging Technologies-Propelling Seed Revolution**". This theme underscores the need for global collaboration in leveraging technological advancements such as modern breeding techniques, genomic innovations, precision agriculture, and biotechnology to unlock the full potential of seeds, ultimately empowering farmers through their access to quality seeds and ensuring a resilient agricultural future.

The ISC 2025 provides a multi-disciplinary and vibrant platform for the Seed and Agri-input industry to interact closely with multiple stakeholders including R&D professionals, seed industry members, global leaders in seed business, farmers, entrepreneurs and policymakers/regulators. The two-day technical sessions would enable comprehensive deliberations and discussions on scientific, technological, regulatory, and business development issues which are going to be the core attraction of ISC. The ISC 2025 has been designed with emerging topics that are in sync with the theme of the event and have a significant impact on the agriculture sector, in general, and the seed industry, in particular. For various technical sessions, the organizing committee has identified the best subject matter experts to present their views in alignment with the challenges and prospects of the Indian seed industry.

The Souvenir brought out on this occasion contains topics on seed and related areas of agriculture contributed by experts, researchers from both private and public sectors and esteemed institutions. The articles in the Souvenir cover a diverse and wide array of topics relevant to the seed sector. We hope the Souvenir will help in focused discussions during different technical sessions and serve as an excellent reference material for the professional engaged in seed science and technology related fields .

I take this opportunity to thank all the esteemed speakers, members of the Technical Committee and the Secretariat involved in bringing out this Souvenir.

Dr. B. B. Pattanaik

General Secretary, NSAI &

Chair, Technical Committee, ISC-2025

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शिवराज सिंह चौहान
SHIVRAJ SINGH CHOUHAN

D.O. No. 62 /AM

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कृषि एवं किसान कल्याण और
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MESSAGE

यह अत्यंत हर्ष का विषय है कि भारतीय राष्ट्रीय बीज संघ (एनएसएआई) 24-25 फरवरी, 2025 को दिल्ली में "उभरती प्रौद्योगिकियां - बीज क्रांति की प्रेरक" विषय पर 13वें भारतीय बीज सम्मेलन 2025 का आयोजन कर रहा है।

हम सभी जानते हैं कि भारतीय कृषि ने पिछले 75 वर्षों में उल्लेखनीय प्रगति की है और भारतीय बीज उद्योग इस विकास में एक प्रमुख भागीदार रहा है। भारत में आयी बीज क्रांति ने हरित क्रांति को प्रेरित किया, जिसने देश को न केवल खाद्य सुरक्षा प्रदान की बल्कि प्रचुर मात्र में खाद्य अधिशेष भी उपलब्ध कराया । इसमें कोई संदेह नहीं कि पादप प्रजनन की नूतन तकनीकों ने देश को ऐसी नई किस्में प्रदान की हैं जो फसल उत्पादकता और बदलते जलवायु के कारण उत्पन्न होने वाले जैविक/अजैविक तनाव की चुनौतियों का सामना करने में सक्षम हैं। हमारे वैज्ञानिक भविष्य की कृषि चुनौतियों का सामना करने के लिए निरंतर नई तकनीकी आधारित समाधान प्रदान कर रहे हैं।

मैं भारतीय बीज संघ को भारतीय बीज सम्मेलन 2025 के लिए "उभरती हुई प्रौद्योगिकियां - बीज क्रांति को प्रोत्साहन" विषय का चयन करने के लिए बधाई देता हूं। मुझे विश्वास है कि इस सम्मेलन के विचार- विमर्श से ऐसी अनुशंसाएं निकलेंगी, जो भारतीय और वैश्विक बीज क्षेत्र की वृद्धि को प्रोत्साहित करने और किसानों को उन्नत किस्मों के गुणवत्तापूर्ण बीज उचित मात्रा में और सस्ती दरों पर उपलब्ध कराने के लिए भविष्य की बीज अनुसंधान रणनीतियों को आकार देने में मदद करेंगी।

मैं भारतीय बीज सम्मेलन 2025 की अपार सफलता की कामना करता हूं।

(शिवराज सिंह चौहान)

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राम नाथ ठाकुर
RAM NATH THAKUR

सत्यमेव जयते

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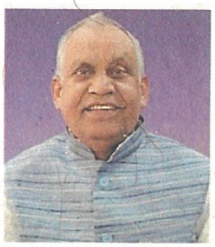

संदेश

मुझे यह जानकर अत्यंत प्रसन्नता हो रही है कि भारतीय बीज उद्योग की शीर्ष संस्था, भारतीय राष्ट्रीय बीज संघ (एनएसएआई), 24 और 25 फरवरी 2025 को दिल्ली में "उभरती प्रौद्योगिकियां-बीज क्रांति की प्रेरक" विषय पर 13वें भारतीय बीज सम्मेलन का आयोजन कर रही है।

बीज उद्योग एक परिवर्तनकारी क्रांति के दौर से गुजर रहा है, जो उभरती हुई नवीनतम प्रौद्योगिकियों से प्रेरित है। ये प्रौद्योगिकियां कृषि को नया आकार दे रही हैं और किसानों को नवीन समाधान प्रदान कर उन्हें सशक्त बना रही हैं। ये प्रगति न केवल बीजों की गुणवत्ता में सुधार कर रही है, बल्कि जलवायु परिवर्तन, खाद्य सुरक्षा और टिकाऊ कृषि जैसी गंभीर चुनौतियों का समाधान भी कर रही हैं।

बीज क्षेत्र में उभरती प्रौद्योगिकियां अधिक उपज देने वाली, रोग प्रतिरोधी और जलवायु अनुकूल फसल किस्मों के विकास को तेजी से बढ़ावा दे रही हैं। साथ ही, जैव प्रौद्योगिकी नवाचारों के माध्यम से फसलें विभिन्न कृषि-जलवायु परिस्थितियों में फल-फूल रही हैं और मिट्टी पोषक तत्वों की कमी जैसी समस्याओं का समाधान प्राप्त कर रही हैं। ये आधुनिक पहल यह सुनिश्चित कर रही हैं कि किसानों को उनकी आवश्यकताओं के अनुसार बीज उपलब्ध हों, जो खाद्य और पोषण सुरक्षा प्रदान करने में सक्षम हों।

मैं भारतीय बीज उद्योग की सराहना करता हूं, जिसने हमेशा देश में कृषि उत्पादकता की चुनौतियों को स्वीकार किया है और इस दिशा में महत्त्वपूर्ण योगदान किया है । मैं एनएसएआई की भी प्रशंसा करता हूं, जो किसानों को उनकी क्षेत्रीय आवश्यकताओं के अनुरूप उच्च गुणवत्ता वाले बीज उपलब्ध कराने में महत्वपूर्ण भूमिका निभा रहा है।

मुझे विश्वास है कि भारतीय बीज सम्मेलन 2025 में किया गया मंथन भारतीय बीज उद्योग के भविष्य के विकास का मार्ग प्रशस्त करेगा और यह तकनीकी नवाचारों से प्रेरित होगा।

मैं भारतीय बीज सम्मेलन 2025 की सफलता की कामना करता हूं।

जय हिंद, जय भारत ।

(राम नाथ ठाकुर)

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GOVERNMENT OF INDIA

संदेश

मुझे यह जानकर खुशी हो रही है कि भारतीय राष्ट्रीय बीज संघ (एनएसएआई) 24–25 फरवरी, 2025 के दौरान दिल्ली में **"उभरती प्रौद्योगिकियां – बीज क्रांति की प्रेरक"** विषय पर 13वें भारतीय बीज सम्मेलन 2025 का आयोजन कर रहा है।

भारतीय कृषि का देश की आर्थिक प्रगति में उल्लेखनीय योगदान है तथा भारत को खाद्यान्न अभावग्रस्त देश की श्रेणी से एक खाद्यान्न अधिशेष देश के रूप में परिवर्तित करने में सफलता पाई है। इस परिवर्तन को एक जीवंत और विकासशील बीज क्षेत्र ने प्रभावी रूप से प्रेरित किया है। आज, भारतीय बीज उद्योग तकनीकी नवाचारों और एक अत्यंत प्रगतिशील कृषि क्षेत्र का व्यवस्थित रूप से उपयोग करते हुए देश की कृषि क्रांति का वाहक बन रहा है। यह तकनीकी – चालित क्रांति भारत को सतत कृषि और खाद्य सुरक्षा में एक वैश्विक नेतृत्व प्रदान करने वाले देश के रूप में स्थापित करती है।

मैं भारतीय राष्ट्रीय बीज संघ को **"उभरती प्रौद्योगिकियां – बीज क्रांति की प्रेरक"** विषय पर भारतीय बीज सम्मेलन 2025 आयोजित करने के लिए बधाई देता हूं, जो अत्यंत उपयुक्त और समयानुकूल है। मुझे आशा है कि इस सम्मलेन के दौरान किए गए विचार–विमर्श भारतीय और वैश्विक बीज क्षेत्र से संबंधित नई तकनीकी चुनौतियों का समाधान करने में सहायक होंगे।

मैं भारतीय बीज सम्मेलन 2025 की भव्य सफलता की कामना करता हूँ।

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AND
INDIAN COUNCIL OF AGRICULTURAL RESEARCH (ICAR)
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Krishi Bhavan, New Delhi 110 001
Tel: 23382629 / 23386711 Fax: 91-11-23384773
E-mail: dg.icar@nic.in

MESSAGE

It is heartening to note that the National Seed Association of India (NSAI) an apex association of Indian seed industry is organising the 13th Indian Seed Congress 2025 during February 24-25, 2025 at New Delhi on the theme "**Emerging Technologies-Propelling Seed Revolution**".

The seed industry has played a prominent role in the agricultural revolution in the country, empowering small-scale and subsistence farmers through access to affordable, high-quality seeds, which can meet the emerging challenges of low productivity, climate change, soil degradation, and pest outbreaks. Leveraging advanced technologies such as genomics, bioinformatics, artificial intelligence, and precision breeding, the industry is now enabling the development of high-yielding, climate-resilient seed varieties. These innovative solutions not only enhance productivity and resilience but also improve rural livelihoods by making agriculture more profitable and sustainable. Digital platforms and block chain are transforming seed production, quality assurance, and distribution, ensuring transparency, traceability, and equitable access to seeds for all farmers. Furthermore, capacity-building initiatives, powered by digital tools like e-learning modules, mobile apps, and data-driven advisory services, are equipping seed producers and farmers with the skills to adapt to evolving agricultural challenges. Today, the Indian Seed industry has greatly evolved itself with a strong R&D set up, massive seed production, processing and logistics infrastructure enabling the nation to meet the new challenges and establishing India as the fifth largest seed economy of the world.

I compliment NSAI for selecting this theme, as it is very relevant in the present context, when agriculture as a whole, and seed sector in particular, is undergoing rapid technological transformation.

I wish the Congress a grand success.

(Himanshu Pathak)

Dated the 30th January, 2025
New Delhi

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डॉ. डी. के. यादव
सहायक महानिदेशक (बीज)
Dr. D. K. Yadava
Assistant Director General (Seed)

No. F. CS.29/2/2021-Seed
Dated: 08.02.2025

MESSAGE

It is heartening to note that the National Seed Association of India (NSAI), an apex association of the Indian Seed industry, is organizing the 13th Indian Seed Congress 2025 on 24th and 25th February, 2025 in New Delhi on the theme "**Emerging Technologies - Propelling Seed Revolution**". As this is going to be a mega event of the seed sector in the country involving various stakeholders from India and abroad, it is hoped that the deliberations would address core issues on seeds like new crop breeding technologies, quality management systems, infrastructure development, global seed business outlook, IPR, etc. bringing out new ideas for the benefit of Indian and Global seed trade.

The critical role of seeds in agricultural development is a well-established fact. Therefore, driving growth in agriculture would require continuous advancements in research and technology development for bringing out high-yielding varieties and hybrids that address emerging environmental and productivity challenges. Equally important are quality seed production, processing, packaging and storage, efficient supply chain management and capacity building for seed producers and farmers. I commend the Indian seed industry for consistently rising to these challenges and establishing India as the fifth-largest seed economy in the world.

I convey my best wishes to the National Seed Association of India for organizing this very important 13th edition of the Indian Seed Congress 2025 on a very relevant and timely theme "**Emerging Technologies-Propelling Seed Revolution**".

I wish the Congress a great success.

(D.K. YADAVA)

Message
FROM THE DESK OF PRESIDENT

The National Seed Association of India (NSAI), is an apex body of the seed industry providing advocacy and technology support to its 450 plus members. It has been relentlessly working towards making available quality seeds to farmers through promotion of cutting-edge technologies in crop breeding, seed production, processing, packaging and supply chain management.

Ever since the launch of green revolution, the seed industry has been instrumental in driving agricultural growth across the country. Technological innovations have made a greater impact in bringing out new varieties/hybrids which are not only high yielding but are also capable of adapting to the changing climate in terms of biotic/abiotic stresses and ensuring nutritional security in the country. Hence, the focus of the seed industry has shifted towards innovations in biotechnology, precision breeding, and advanced seed treatments, improving farmers' access to superior varieties and equipping them with the tools needed to maximize yields. By integrating cutting-edge seed technologies, the industry has revolutionized agricultural practices, offering seeds with enhanced traits such as drought resistance, pest tolerance, and higher yield potential. Ultimately, the synergy between technological progress and the seed industry's commitment to delivering high-quality seeds has been a key driver of the sector's sustained growth and success.

It is therefore, very timely to organize the 13th edition of the Indian Seed Congress 2025 on the theme, "Emerging Technologies- Propelling Seed Revolution". I hope this Seed Congress will provide an excellent opportunity for the delegates to take stock of the developments in the plant breeding and biotechnology industry, new innovations in processing, seed treatments, government policy, etc. for enhancing their capabilities. It will also provide a platform to brainstorm on the industry experiences in adopting innovative technologies and expert views to come out with recommendations for all-round excellence in service to the farmers and the nation.

On behalf of the National Organizing Committee of the event, I welcome all the delegates and participants of ISC-2025 and look forward to productive deliberations which can help in sustainability, unceasing improvement and sustainable growth of Indian seed industry.

Dr. M. Prabhakar Rao

President-NSAI

Message

FROM THE DESK OF EXECUTIVE DIRECTOR

The seed industry has witnessed significant growth, driven by innovation, collaboration, and market adaptability. Advances in crop breeding, biotechnology, and seed treatment technologies have empowered companies to develop superior varieties with higher yields, disease resistance, and environmental resilience. Strong partnerships among researchers, policymakers, regulators and farmers have facilitated the exchange of knowledge, genetic resources, and cutting-edge technologies, accelerating innovations and the adoption of improved seeds. Moreover, the industry's responsiveness to evolving agricultural practices and market needs underscores its vital role in global food production. As the backbone of agriculture, high-quality seeds are crucial for ensuring food security, enhancing productivity, and promoting sustainable farming. The National Seed Association of India (NSAI) which represents over 450 seed companies involving large, medium and SME sector companies is working relentlessly for enabling the seed industry in genetic improvement of crops.

NSAI is organizing the flagship event of Indian seed industry, the 13th Indian Seed Congress 2025 on the theme "**Emerging Technologies-Propelling Seed Revolution**" at Hotel Andaz, Aerocity, New Delhi on 24-25 February, 2025. This Congress is going to serve as a pivotal platform for exploring cutting-edge innovations and emerging technologies that shape the future of the Indian seed industry. By driving sustainability in agriculture and leveraging advancements in genomics, biotechnology, and digital agriculture, the event aims to accelerate progress toward global food and nutritional security by adopting sustainable farming practices.

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PROGRAMME

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Indo-American Hybrid Seeds (India) Pvt Ltd (IAHS) is a **59 year** old pioneer Indian company which takes pride in *contributing quality seeds* to the agri-horticulture business in India and global market. Engaged in extensive **Research & Development (R&D), Bio-Technology, Production and Marketing of hybrid seeds of selected vegetables, field crops, flowers and ornamental plants**, the company is a highly trusted for innovative offerings in the segment.

IAHS R&D strives to offer *superior quality*, *high yielding* and *disease tolerant hybrids of important vegetable and field crops*. The R&D division has won prestigious National Award twice, in 1995 and 2000, for innovative research by the **Council of Scientific and Industrial Research (CSIR), Government of India.**

IAHS Commercial Tissue Culture (TC) laboratory produces disease free TC plants of select *ornamental, fruit and plantation crops*.

The company's **Bio-Technology Laboratory** carries out DNA finger printing, hybrid seed purity analysis using *Electrophoresis (EP) and DNA technology.* It also imparts hands on laboratory training to *graduate and post graduate students of Bio-Technology.*

IAHS seed production division specializes in high quality hybrid seed production in fields and net houses for domestic and export markets. The seed lots are then tested in the **International Seed Testing Association (ISTA)** accredited laboratory.

IAHS seed laboratory is an **ISTA accredited laboratory**, which issues orange and blue ISTA certificates to Indian seed companies for exports. The company has ***won*** **National Awards** for export several times from *APEDA (Agricultural and Processed Food Products Export Development Authority)*. The IAHS brand is synonymous with quality in India and abroad.

INDIAN SEED CONGRESS 2025

EMERGING TECHNOLOGIES - PROPELLING SEED REVOLUTION

(Technical Programme)

Day 1-Monday, 24th February, 2025

Time	Event
9:00 AM-9:45 AM	Registration
9:45 AM-10:00 AM	Inauguration of Exhibition by Chief Guest/Dignitaries
10:00 AM-11:00 AM	Inaugural Session followed by Press Briefing
11:00 AM-11:30 AM	Tea Break

Technical Session I: Innovations & Next Generation Technologies for Crop Improvement
Time: 11:30 AM – 12:50 PM
Chair – **Dr. P. L. Gautam**, Chancellor, Dr Rajendra Prasad Central Agricultural University, Pusa, Bihar
Co- Chair- **Dr. A. K. Singh,** Emeritus Professor, Division of Genetics, IARI, New Delhi
Rapporteur: **Dr Sneha Adhikari**, Scientist, Genetics and Plant Breeding, IARI, Pusa

11:30 AM-11:40 AM		**Opening Remarks by Chair/Co-chair**	
SN	**Duration**	**Topic**	**Speaker**
1.	**11:40 AM-12:00 Noon**	Trends in the Global Seed Market: Role of Technological Innovations as a Key Influencing Factor, Strategies and a Decadal Outlook	**Dr. Bharti Malhotra** Research Manager- Analysis Lead, Crop Science, Agribusiness, S&P Global
2.	**12:00 Noon-12:20 PM**	Precision Breeding through CRISPR-Cas mediated Genome Editing	**Dr. Tanushri Kaul** Group Leader, Nutritional Improvement of Crops, ICGEB
3.	**12:20 PM-12:40 PM**	Speed Breeding: A game changer for global food security	**Dr. Uma Maheshwar Singh** Scientist- Innovative Breeding SARC, IRRI
12:40 PM- 12:50 PM		**Q&A and Closing Remarks by Chair/Co-Chair**	
Sponsor Presentation			
12:50 PM-1:00 PM		Transformative Biological Seed Applied solutions – Driving crop productivity sustainably	**Mr. Chinmay Sardeshpande,** Technical Services Manager for South Asia, Novonesis
Lunch- 1:00 PM- 2:30 PM			

Technical Session II: Digital and Data-Driven Technologies/applications for seed industry
Time: 2:30 PM-3:50 PM
Chair- **Mr. Siraj Hussain**, Former Secretary (Agriculture), MoA&FW, GOI
Co- Chair- **Dr. A K Singh**, Vice Chancellor, CSAU&T, Kanpur
Rapporteur: **Dr Manjeet Kumar**, Scientist, Genetics and Plant Breeding, IARI, Pusa

2:30 PM- 2:40 PM		**Opening Remarks by Chair/Co-chair**	
SN	**Duration**	**Topic**	**Speaker**
1.	**2:40 PM-3:00 PM**	Digital Sequence Information: Technology, Policy & Regulation	**Dr. Sunil Archak** Principal Scientist, NBPGR
2.	**3:00 PM-3:20 PM**	Development of Agri Stack: Building Blocks for a future digital paradigm	**Ms. Ruchika Gupta,** DDG, Ministry of Statistics & Programme Implementation
3.	**3:20 PM-3:40 PM**	AI based Predictive analytics and crop simulation modeling for precision agronomy for realizing Genetic gains	**Mr. Aditya Shah** Global Director – Strategic, Partnerships, CropIn
3:40 PM-3:50 PM		**Q&A and Closing Remarks by Chair/Co-Chair**	
Sponsor Presentation			
3:50 PM-4:00 PM		Technology for Nutritional Enhancement of Seed - "Need of Hour"	**Mr. R K Goyal** Managing Director, Verdesian Life Sciences USA
Tea Break: 4:00 PM- 04:45 PM			

Technical Session III: Strategies and Approaches for harnessing genetic diversity and agronomic innovations for improving profitability of farmers
Time: 4:45 PM-6:05 PM
Chair- **Dr. T. Mohapatra,** Chairperson, PPV&FRA
Co- Chair- **Mr. Ajeet Kumar Sahu**, Joint Secretary (Seeds), DAFW, MoAFW, Government of India
Rapporteur: **Dr. S K Tripathi,** Senior Vice President, Nuziveedu Seeds Ltd

04:45 PM- 04:55 PM		**Opening Remarks by Chair/Co-chair**	
SN	**Duration**	**Topic**	**Speaker**
1.	**4:55 PM-5:15 PM**	Microbiome based approaches for enabling seed, plant and soil health for realization of potential of Plant varieties.	**Dr. K. R. K. Reddy**, President BIPA and MD SRIBIO
2.	**5:15 PM-5:35 PM**	Seed production innovations for a resilient Indian seed industry	**Mr. G. V. Ramana Rao**, CTO, Ganga Kaveri Seeds
3.	**5:35 PM-5:55 PM**	Precision Farming to Improve Input use in Agriculture.	**Dr. Rabi N Sahoo,** Program Leader, Principal Scientist, Division of Agricultural Physics, ICAR-IARI
5:55 PM-6:05 PM		**Q&A and Closing Remarks by Chair/Co-Chair**	

7:20 PM Onward	**Cultural Program & Welcome Dinner**

Day 2- Tuesday, 25th February, 2025

Technical Session IV: Innovations in seed health management and traceability
9:30 AM – 10:50 AM
Chair- **Mr. Ashish Bahuguna,** Former Secretary (Agriculture), MoA&FW, GOI
Co- Chair- **Dr. D. K Yadava,** DDG (Crop Science), ICAR
Rapporteur: **Dr. Sandeep Kumar Lal,** Principal Scientist, Division of Seed Science and Technology, IARI, New Delhi

9:30 AM - 9:40 AM		**Opening Remarks by Chair/Co-chair**	
SN	**Duration**	**Topic**	**Speaker**
1.	**9:40 AM-10:00 AM**	Seed based delivery systems using Biologicals and Nano technologies for improved stress tolerance and crop productivity	**Dr. Gyan Prakash Mishra** Head, Division of SS&T, IARI
2.	**10:00 AM- 10:20 AM**	Innovative approaches towards seed quality certification for promoting exports for a Globally competitive Indian Seed Industry	**Dr. K. Keshavulu,** Director, TSSOCA & President, ISTA
3.	**10:20 AM- 10:40 AM**	Seed Traceability in India: Leveraging the SATHI Portal for Transparency and Quality Assurance	**Dr. Dilip K. Srivastava** DC(QC), Seeds Division, DA&FW
10:40 AM-10:50 AM		**Q&A and Closing Remarks by Chair/Co-Chair**	

Tea Break: 10: 50 AM-11:45 AM

Technical Session V: Shaping the Future: Policy, IP and Emerging Technologies for a Seed Revolution in India
Time: 11:45 AM - 1:05 PM
Chair- **Mr Sanjay Agarwal**, ADG, ICRISAT and Ex. Secretary, DA&FW, Govt of India
Co- Chair- **Dr. S. K. Malhotra**, Vice Chancellor, Maharana Pratap Horticultural University in Karnal, Haryana
Rapporteur: **Mrs. OK Tara**, Head – IPR & Regulatory Affairs, NSL

11:45 AM - 11:55 AM		**Opening Remarks by Chair/Co-chair**	
SN	**Duration**	**Topic**	**Speaker**
1.	**11:55 AM-12:15 PM**	Policy and Systems for IPR Governance relevant to Indian Seed Industry	**Dr. D. K. Agarwal**, RG, PPV&FRA
2.	**12:15 PM-12:35 PM**	Resetting public private partnership in plant genetic resources utilization - an IPR perspective	**Dr. G. P. Singh** Director, NBPGR
3.	**12:35 PM-12:55 PM**	Strengthening In House R&D set up of Seed Companies for DSIR Recognition	**Dr. Deepika Rohatgi** Scientist-E, DSIR
12:55 PM- 1:05 PM		**Q&A and Closing Remarks by Chair/Co-Chair**	
Lunch: 1:05 PM-2:45 PM			

Technical Session VI: PANEL DISCUSSION – Navigating Challenges and Leveraging Opportunities in Seed Technology through Policy Reforms
Time: 2:45 PM-3:45 PM
Chair: **Mr. Devesh Chaturvedi**, Secretary, DA&FW, MoA&FW, GoI*
Coordinator: **Dr. Sanjay Kumar**, Director, ICAR-NISST, Mau
Rapporteur: **Mr R K Trivedi,** Former Executive Director, NSAI

SN	Panelist
1.	**Mrs. Maninder Kaur Dwivedi**, Additional Secretary (NRM, INM, AM & RKVY), MoA&FW and CMD, NSC
2.	**Dr. M. Prabhakar Rao**, Chairman & Managing Director, Nuziveedu Seeds Ltd
3.	**Mr. Ajeet Mulay**, Managing Director, Green Gold Seeds
4.	**Mr. Ajai Rana**, CEO and Managing Director, Savannah Seeds Pvt Ltd
5.	**Dr. Manish Patel**, Executive Director, Incotec India Pvt Ltd
6.	**Mr. Rajvir Rathi,** Director Public Affairs, Science and Sustainability (South Asia) & Lead – Traits Licensing Business, Bayer CropScience
Tea Break: 3:45 PM-4:30 PM	

4:30 PM- 6:00 PM	**Valedictory Session and Award Ceremony**
7:00 PM Onwards	**Cultural Program & Gala Dinner**

*Confirmation Awaited

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Technical Session I

Technical Session I: Innovations & Next Generation Technologies for Crop Improvement **Time: 11:30 AM – 12:50 PM** Chair – **Dr. P. L. Gautam**, Chancellor, Dr Rajendra Prasad Central Agricultural University, Pusa, Bihar Co- Chair- **Dr. A. K. Singh,** Emeritus Professor, Division of Genetics, IARI, New Delhi Rapporteur: **Dr Sneha Adhikari**, Scientist, Genetics and Plant Breeding, IARI, Pusa			
11:30 AM-11:40 AM		**Opening Remarks by Chair/Co-chair**	
SN	**Duration**	**Topic**	**Speaker**
1.	**11:40 AM-12:00 Noon**	Trends in the Global Seed Market: Role of Technological Innovations as a Key Influencing Factor, Strategies and a Decadal Outlook	**Dr. Bharti Malhotra** Research Manager- Analysis Lead, Crop Science, Agribusiness, S&P Global
2.	**12:00 Noon-12:20 PM**	Precision Breeding through CRISPR-Cas mediated Genome Editing	**Dr. Tanushri Kaul** Group Leader, Nutritional Improvement of Crops, ICGEB
3.	**12:20 PM-12:40 PM**	Speed Breeding: A game changer for global food security	**Dr. Uma Maheshwar Singh** Scientist- Innovative Breeding SARC, IRRI
12:40 PM- 12:50 PM		**Q&A and Closing Remarks by Chair/Co-Chair**	
Sponsor Presentation			
12:50 PM-1:00 PM		Transformative Biological Seed Applied solutions – Driving crop productivity sustainably	**Mr. Chinmay Sardeshpande,** Technical Services Manager for South Asia, Novonesis

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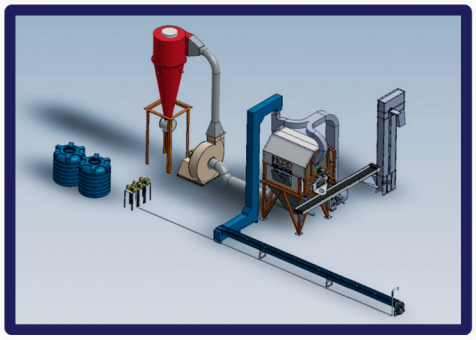

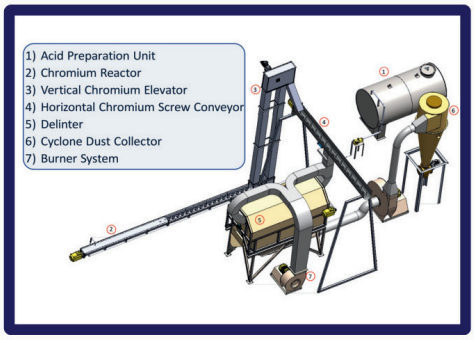

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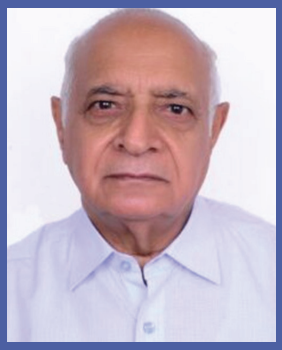


CHAIR

DR. P. L. GAUTUM

Chancellor, Dr. Rajendra Prasad Central Agricultural University, Pusa, Bihar

Dr. P. L. Gautum is Chancellor of Dr. Rajendra Prasad Central Agricultural University, Pusa, Bihar. Dr. Gautam joined his service career as Assistant Professor Plant Breeding at GB Pant University on 16 Sept 1974. He has also served as Associate Professor Plant Breeding, Associate Director CRC, and Joint Director/Associate Dean Hill Campus Ranichauri of this University. He occupied important positions in the country, namely, Chairperson, Protection of Plant Varieties & Framers' Rights Authority New Delhi (Ministry of Agriculture & Farmers' Welfare, Govt. of India) and Chairman, National Biodiversity Authority, Chennai (Ministry of Forests, Environment & Climate Change, Govt. of India) in the rank of Secretary to the Govt of India; Vice Chancellor GB Pant University of Agriculture & Technology, Pantnagar, Uttrakhand; Deputy Director General ICAR-Crop Science; National Director ICAR-NATP Project; Director, ICAR-National Bureau of Plant Genetic Resources; Dean, College of Forestry, YS Parmar University of Horticulture & Forestry, Solan (HP); Managing Director, Uttarakhand Seeds & Tarai Development Corporation Pantnagar Uttrakhand; and Vice Chancellor of Career Point University Hamirpur HP. Presently, he is the Honorary Pro-Chancellor of Career Point University Hamirpur HP, Chairman Advisory Committee Patanjali University Hardwar, Advisor Graphic Era Hill University, Dehradoon, Chairman of Shivshakti School Nihari, Ghumarwin, Bilaspur HP and Chief Patron of Society for community mobilization for sustainable development.

Contributions: He is a distinguished geneticist and plant breeder associated with the development of twelve improved crop varieties of wheat, foxtail millet, soybean, ricebean, amaranth and buckwheat. He has played important role in redefining basmati rice in the light of new breeding tools in protecting national interests .Under his leadership, the first post graduate progrmme in Plant Genetic Resources in India was implemented at NBPGR-IARI He initiated the registration of plant germplasm in India and was associated with the drafting and implementation of Biological Diversity and Protection of Plant Varieties & Farmers Rights Acts of India. He has contributed significantly to the conservation and management of Plant Genetic Resources including *inter alia*, mounting special explorations under the aegis of ICAR-NATP national missions on agro biodiversity management and food & nutritional security.

Member of Delegations: As a member of Indian delegations for negotiations/ meetings of International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGRFA) of FAO and the Convention on Biological Diversity (CBD) of United Nations Organization, he has played important role in reflecting Indian position in the negotiations. He was one of the champions for inclusion of Famers'Rights in the ITPGRFA and the moratorium on the terminator gene in Cartagena Biosafety Protocol. He Co-Chaired, 5th Session of FAO-ITPGRFA and served as a nominated member from the Asian Region to the Executive Board of Global Crop Diversity Trust, Germany, for five years. He has served as Expert consultant of FAO- ITPGRFA Mission on Plant Genetic Resources to Mongolia and the USAID-CISA/STRASA Project of the International Rice Research Institute. He was a member of Board (Indian side) of Joint Indo-US Knowledge Initiative on Agriculture.

Committee Assignments: He has served with distinction as Chair/Member in different committees of ICAR, CSIR, DBT, DST, ASRB, UPSC, FICCI, ICFRE, FSSAI, Ministries, Universities,etc He was Chairman of the committees for restructuring of ICAR- AICRPs, ICFRE, National & State Seed Corporations and strengthening of IARI as a global University. He has also Chaired Research Advisory Committees of many ICAR institutes and served as member of Board of management of seven Universities. Presently, he is member of University Council of SKUAST Jammu & external advisory panel of ICAR-NAHEP and Chairman of Research Advisory Committee (Agriculture) of National Innovation Foundation Ahmadabad.

Recognitions and Awards: In a career spanning over 47 years, he has made outstanding contributions. He has widely travelled in India and over two dozen countries and has left amazing footprints on the positions held in different systems and organizations. During his tenure as Director and Vice Chancellor, NBPGR and GBPUA&T, Pantnagar, respectively, received ICAR's Best Institution Awards. He has been conferred the fellowships of National Academy of Agricultural Sciences (NAAS), Indian Society of Genetics & Plant Breeding (ISGPB), Indian Society of Plant Genetic Resources (ISPGR), National Academy of Biological Sciences and International Society for Noni Science. He has been conferred Honorary Fellowship of Indian Academy of Horticultural Sciences 2022 and Honorary Fellow 2023 of ISPGR .He was President of ISGPB & ISPGR; Vice President of NAAS & Trust for Advancement Agricultural Sciences; and Life Member National Environmental Science Academy. The sterling contributions of Dr Gautam have been verily recognized by conferring Lal Bahadur Shastri Memorial & Punjab University Chandigarh Medals and Life Time Achievement Awards from Agriculture Today and Mobilization Society. He has also received Harbhajan Singh Memorial /Canadian Research Associateship/ Service to Humanity/Indira Gandhi Priyadarshini /Dr.S Radhakrishnan Education Excellence and Eminent Citizen of India awards from different organizations.

He has received *honoris causa* Doctorate of Science degree by ND University of Agriculture and Technology Faizabad (UP) & SKUAST Jammu for his noteworthy contributions as an institution builder, teacher, researcher, guide and research manager and a plaque of Honour by ISGPB for dedicated services and certificate of recognition for contribution in development of landmark wheat variety.

CO-CHAIR

DR. ASHOK KUMAR SINGH

Emeritus Professor, Division of Genetics,
IARI, New Delhi

Dr Ashok Kumar Singh is Emeritus Professor, Division of Genetics and Former Director, IARI, New Delhi, after his superannuation from the position of Director, Indian Agricultural research Institute (IARI), New Delhi.

Dr. Singh has been actively involved in Basmati rice improvement for the last two and half decades. He is associated with development of 13 rice varieties including five MAS derived Basmati varieties.

Dr. Singh has published 120 peer-reviewed research publications in rice genetics, molecular breeding and grain quality. He co-authored a book entitled "**Marker Assisted Plant Breeding: Principles and Practices**" published by Springer.

He has served as an in DBT (Task Forces, STAG), APEDA, RAC (ICAR-NRRI, ICAR-NBPGR, ICAR-IIRR) and SAC (NIPGR, NABI).

He has been awarded with prestigious **ICAR-Rafi Ahmad Kidwai Award** and **ICAR-Bharat Ratna Dr. C. Subramanian Award** during 2013.

He has also been recognized with IARI – Best teacher award (2002), IARI- B.P. Pal Award (2007), ICAR – Special Recognition Certificate (2009), Agriculture Leadership award (2011), Borlaug Award (2012), Dr AS Cheema Award (2012) and Sh Om Prakash Bhasin Award (2017).

Trends in the Global Seed Market: Role of Technological Innovations as a Key Influencing Factor, Strategies and a Decadal Outlook

DR BHARTI MALHOTRA

Research Manager Seed and Traits
S&P Global, Commodity Insights

Dr. Bharti Malhotra, an experienced Research and Analysis Manager in Seeds and Traits at S&P Global, Commodity Insights, holds a Ph.D. in Agriculture Biotechnology and a commendable 16-year career in agriculture. Her journey demonstrates a dedicated effort to explore the possibilities of plant breeding, making a tangible impact on the global agriculture industry.

Career Highlights:

- **Strategic Role at S&P Global:** As Research Manager at S&P Global, Dr. Bharti plays a pivotal role in analyzing and tracking global seed companies' activities, policies, technologies, and trait pipelines. Her leadership in developing seed innovation products, covering over 3000 GMO and 700 new breeding technique products, reflects her commitment to exploring the potential of cutting-edge technologies.
- **Global Contributions:** Dr. Bharti's work extends globally, including projects funded by USAID and the Bill and Melinda Gates Foundation. She worked on developing RNAi potatoes, standardizing next-generation sequencing techniques in tomatoes, and commercializing Bt-brinjal in Bangladesh. She played a vital role in studying 30 South and Southeast Asian seed markets for the Access to Seed Index.

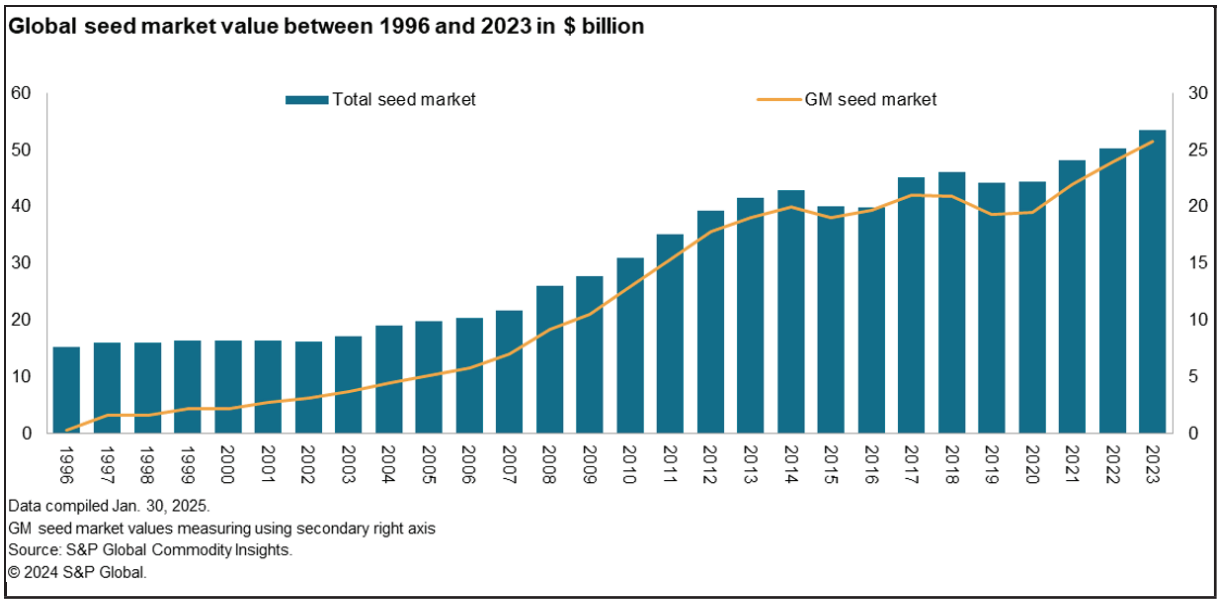
- **Market Research Prowess:** In various roles, including her current position at S&P Global, Dr. Bharti has consistently delivered invaluable insights to major seed companies and financial institutions such as Bayer Crop Science, Syngenta, Vilmorin, and UPL-Advanta, among others. She has been a featured speaker at Barkley's Agriculture Meet for the past four years.

Educational Background:

- **Ph.D. in Agriculture Biotechnology:** Himachal Pradesh University, Shimla, India (2013)
- **M.Sc. in Biotechnology:** Dr. Y.S. Parmar University of Horticulture & Forestry, Solan H.P., India (2007)

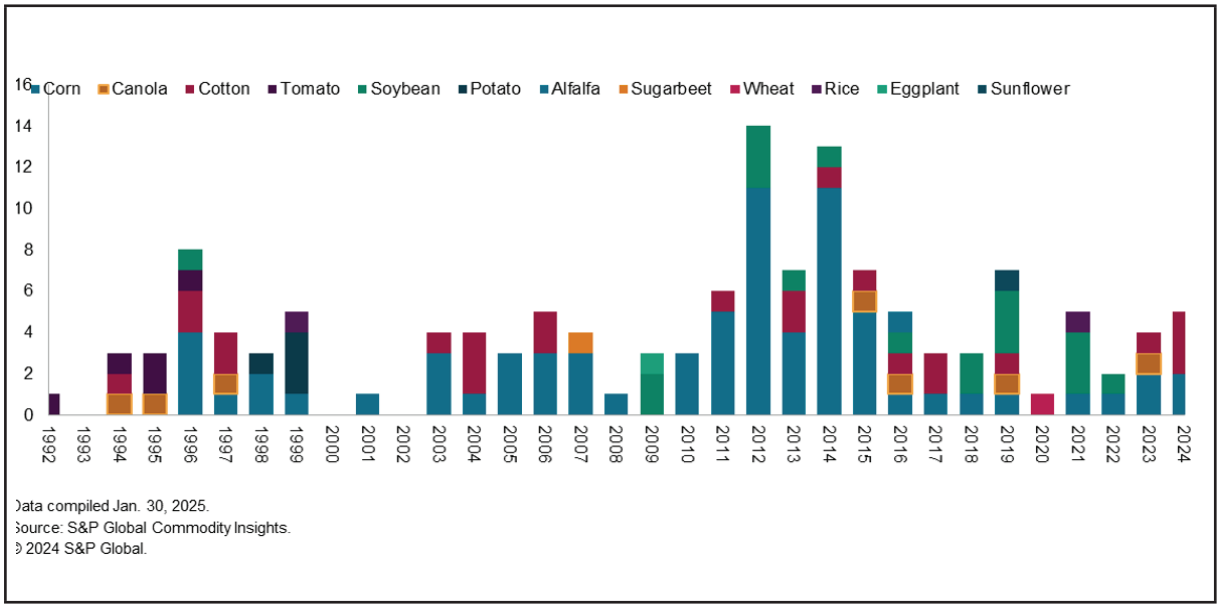
Technological Innovations as a Key Industry Driver

The global seed market has been significantly shaped by technological innovations, which have been crucial in driving industry trends and strategies. The market expanded 3.5 times between 1996 and 2023, with genetically modified (GM) seeds growing from 0% to approximately 50% of the market share, despite only 18% of the global area being under GM seeds. This growth underscores the impact of innovation in enhancing seed performance and addressing agricultural challenges.



The seed industry is heavily research and development (R&D) driven, with around 15% of seed companies sales allocated to R&D. Technological innovations are pivotal in enhancing seed performance and addressing the challenges faced by the agricultural sector. The introduction of GM and new breeding techniques (NBTs) has revolutionized seed development, enabling the creation of crops that are more resilient to pests, diseases, and environmental stresses. These innovations not only improve crop yields but also enhance the sustainability of agricultural practices. The successful launch of new traits and improved seed varieties is a key driver of seed pricing dynamics, as they can significantly impact market demand. A total of 137 GM traits were introduced in 12 crops between 1992 and 2024.

GM Introductions and Market Growth



The introduction of GM crops in the US in 1996 marked a significant shift in seed prices, driving them upward due to increased demand and innovative traits that promised higher yields and pest resistance. From 2005 to 2014, GM seed prices grew at a 7% CAGR. However, a lack of new trait introductions, particularly in cotton, coupled with challenges like herbicide-resistant weeds, led to a 4% decline in GM seed prices in the US between 2014 and 2018. Introduction XtendFlex in cotton and the rising commodity prices have since spurred a recovery, with a 2% CAGR increase in seed prices observed from 2018 to 2022.

The seed prices further grew in 2023 and 2024, impacted from high seed input costs, but also due to adoption of several new traits including RR Intacta Pro and Enlist in soybeans. Some of the new herbicide tolerance traits have given a new lease of life to herbicides which are over 50 years old, namely Dicamba and 2,4-D. Further, increased adoption of new traits like VT4Pro, Vorseed Enlist, SmartStax

Pro in corn, Bollgard 3 XtendFlex in Cotton will push the seed prices upward in the coming years.

Regional Developments and Innovations in Asia

In recent years, the Asia-Pacific region, particularly Mainland China, is at the forefront of GM regulations and developments. China has made considerable strides in the approval of GM corn and soybean varieties. In a strategic shift toward self-reliance, food security and reduction in dependency on imports, the country has approved new soybean and corn varieties for cultivation and provided operation and production licenses to the domestic players in specific provinces. The licenses were provided to Beijing Dabeinong Technology, Denghai Seed, Yuan Longping High-Tech Agriculture and Syngenta-owned business China National Seed, among others. Local Chinese seed companies have been growing fast in recent years, with one (LPHT) now featuring in the top 10 global seed companies and over 10 with sales of over $100 million. India also boasts a strong local seed industry with several large R&D-based domestic companies.

In addition, Bangladesh has begun the commercial planting of GM insect resistant *Bt* cotton in the country since August 2023, making it the second GM crop to be cultivated. The two varieties of GM cotton released are from India-based company JK Agri-Genetics and are resistant to cotton bollworms (Helicoverpa armigera) as well as caterpillars. Pakistan has granted cultivation approvals of two GM sugarcane varieties, one with insect resistance trait (CABB-IRS) and another with herbicide tolerance (CABB-HTS), marking the first GM food crop adoption in the country. However, objections are being raised to reject their commercialization.

In 2022, the government of the Philippines marked *Bt* eggplant as its third genetically engineered crop approved for commercial propagation, followed by *Bt* corn and golden rice. However, in April 2022, the Philippine Court of Appeals ordered the suspension of the commercial release of GM rice and eggplant products. The outcome of this suspension has halted the review/approval of the pending applications for GM crops.

In August 2023, Bayer's Crop Science division launched the genetically modified herbicide tolerant Dekalb DK95R corn (maize) in the Indonesian province of West Nusa Tenggara. The Indonesian government is encouraging the development of new seed varieties through biotechnology. Although no GM soybean events have cultivation approvals in Indonesia, the government has plans to allow GM soybean cultivation in the country. Based on a press release in September 2022 by Indonesia's Ministry of Economic Affairs, the government has plans to encourage farmers to use GM soybean varieties to maintain national food security. The country is preparing

a budget of 400 billion Indonesian rupiah ($26.9 million) to expand the planting of soybeans to 1 million ha in the next few years. The Indonesian government approved Bioceres' drought tolerant HB4 wheat for human consumption in March 2023.

Australia, which has grown GM canola for many years, has approved the commercial release of GM QCAV-4 Cavendish bananas and is conducting field trials for GM wheat and barley. These developments highlight a shift from non-food to food crops in GM approvals, with a focus on the Asia-Pacific region.

New Breeding Techniques (NBTs) and Global Regulatory Landscape

NBTs face regulatory uncertainties due to non-harmonized global regulations. S&P Global's seed innovation platform indicates that 27 out of 45 countries with NBT innovation have established regulatory frameworks. Thailand has made advancement in its regulatory landscape for gene-editing and NBTs in 2024, adopting a product-based approach. During the same year, Australia and New Zealand worked on regulatory frameworks to support NBTs, aiming to foster innovation and market growth.

We have identified 27 countries, wherein NBTs are regulated as conventional, these countries align on the definition of not having any transgene. However, there is still some non-harmonization in the terminology used such as cisgenesis, SDN1, SDN2 etc.

The US leads in NBTs, having introduced the first NBT product, Calyno soybean, in 2019. Although Calyno is no longer on the market, the US continues to dominate with a variety of commercialized NBT products, such as Conscious greens and non-browning lettuce, and a strong pipeline including NBT soybeans and non-browning bananas. Canada follows with Conscious greens and pending commercialization of CLB-1 canola-ODM and waxy corn. Japan has commercialized Sicilian Rouge high GABA tomatoes and approved amylopectin-rich waxy corn.

China in early 2024 expedited the grant of biosafety approvals for corn, wheat, and soybeans, focusing on yield, quality, and resistance traits. In December 2024, MARA approved the issuance of five biosafety certificates for nationwide cultivation of gene-edited soybean, corn, rice and wheat crops, taking the total number of approved gene-edited crop biosafety certificates to ten. It is evident that Mainland China is advancing with biosafety approvals for NBT traits, although it treats NBTs as GMOs, requiring registration and licenses for market entry but the process timeline is reduced as compared to that for GMOs. The US biotechnology sector saw rapid growth after the USDA's 2020 biotechnology rule, but a 2024 judicial ruling vacated

these rules, affecting future deregulations. This has delayed the introduction of new NBT traits. Meanwhile, the EU remains in a regulatory deadlock over new genomic techniques.

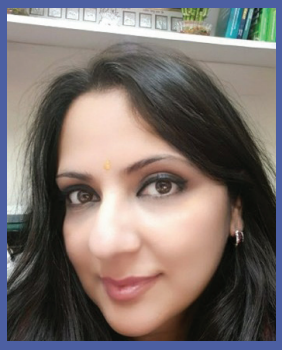
Based on NBT and GM trait data, GM traits are predominantly input traits, while NBTs are more evenly distributed among input, agronomic, and processor/consumer traits. This pattern is expected to continue, with NBTs bringing a diverse variety of crops, including food crops, whereas GM traits focus mainly on industrial crops. The impact of NBTs on seeds is likely to be less than that of GM traits, as their benefits are more marginal and further downstream, making it challenging to compete with established traits and chemistries in corn, soybean, cotton and canola. However, NBTs could be helpful to drive innovation in fruits and vegetable category, food crops like rice and wheat where GM technology faced several rejections.

Future Outlook and Market Growth

In this decade, the seed market will be primarily driven by GM traits and hybrids, with technologies like direct-seeded rice and hybrid wheat poised to enhance market growth. The impact of NBTs is not anticipated within this timeframe. The global regulatory framework for NBTs is still underdeveloped and requires harmonization for successful adoption, delaying their significant influence on the market.

For 2025, the global seed market is projected to face challenges due to depressed farm fundamentals and record production levels in South America, which may strain global commodity prices. While input costs are expected to decrease, the overall impact on farmers' income will depend on the interaction with persistent commodity price pressures. Global crop areas are expected to remain flat, with slight increases in corn, rapeseed, rice, and sorghum, but declines in soybeans, cotton, wheat, sunflowers, and sugar beet. In the US, corn acreage is forecasted to increase, while soybean acreage is expected to decrease. Trade tensions, particularly with China, could further impact US soybean areas, as China may prefer Brazilian soybeans due to competitive pricing. The outlook remains fluid, with S&P's agricultural teams monitoring acreage forecasts in response to changing conditions, including weather patterns and global biofuel policies.

Precision Breeding through CRISPR-Cas mediated Genome Editing



TANUSHRI KAUL

Group Leader, Nutritional Improvement of Crops, International Centre for Genetic Engineering and Biotechnology (ICGEB), New Delhi

Dr. Tanushri Kaul is an internationally acclaimed and eminent scientist, serving as Group Leader at the International Centre for Genetic Engineering and Biotechnology (ICGEB), New Delhi, India. Dr. Kaul has emerged as a trailblazer and a leading authority, catapulting to the forefront of plant molecular biology, genome engineering, plant nutrition, and stress biology, earning recognition as a visionary scientist and a pioneer in her field.

Her educational background includes a Ph.D. in Botany from Delhi University (2002), M.Phil. in Botany from Delhi University (1996), (link unavailable) in Botany from Delhi University (1994), B.Ed. from Delhi University's Central Institute of Education (1995), and DIM from IGNOU, School of Management Studies (2000).

As an international expert in nutritional cum stress biology, Dr. Kaul leverages state-of-the-art genome- editing technology for crop improvement. Her expertise spans genome editing, plant molecular biology, biofortification, nutrient enhancement, and plant stress responses. Dr. Kaul's groundbreaking research and leadership have significantly advanced crop biotechnology and sustainable agricultural solutions. Dr. Kaul has had an illustrious career, serving as Group Leader, Nutritional Improvement of Crops at ICGEB since 2016. Prior to this, she was a Research Scientist in the Plant Molecular Biology Group at ICGEB (2012-2016).

Her research focuses on biofortification and genome engineering of crops to combat global micronutrient malnutrition, as well as understanding plant stress

responses and developing stress-tolerant crops. She has designed phytase-rich tomatoes and phytate-free cereals and legumes, developed wheat grains with enhanced micronutrient remobilization, cisgenic cereal plants with enhanced tolerance to non-selective herbicides and employed genome editing strategies and tools for instance CRISPR-Cas9, -Nickase, -Cpf1 and RNP approach for precise crop modification in maize, rice, pigeon pea, soybean and cotton; particularly targeting EPSPS and ALS genes to confer herbicide resistance- a technology that can be applied to other crops facing weed-related challenges. Furthermore, Dr. Kaul has been working on improving the photosynthetic efficiency and overall yield of rice by introducing a minimal C4 pathway from millets like Pennisetum glaucum. Another area of her research focuses on understanding the regulatory mechanisms of DNA replication and homologous recombination, processes crucial for genome stability, chromosome condensation, and accurate segregation during meiosis. Her research contributes significantly to advancing crop biotechnology and developing sustainable agricultural solutions.

Notably, Dr. Kaul works at the confluence of crop improvement and human health, developing innovative solutions to address micronutrient deficiencies. Her flagship project involves genome-edited high iron and zinc rice, aimed at alleviating anaemia and stunting in schoolers, pregnant women, teenage girls, and other vulnerable populations. This groundbreaking work has the potential to positively impact millions of lives worldwide.

Throughout her career, Dr. Kaul has received several prestigious awards and fellowships, including the BioCare Award and Fellowship (2012), Rapid Grant for Young Investigator Award (RGYI, 2011), Research Associateship (2010-2011), Research Scientist positions in the Centre for Excellence Project (2008-2010) and Indo-Belarus DST Project (2003-2004), Post-Doctoral-Indo-Israel DST Fellowship (2006-2008), and DBT-IISC-Post Doctoral Fellowship (2004-2006). In recognition of her outstanding contributions to crop improvement, Dr. Kaul has been nominated for the prestigious VIWA Award for Distinguished Scientist-2025 in Crop Improvement.

Cumulatively, Dr. Kaul's pioneering work in crop improvement and genome editing has paved the way for innovative solutions to global food security challenges, inspiring future generations of scientists and researchers.

Introduction

Crops provide Food, Feed, Fuel and other consumable resources, thereby contributing to the progress of human race and society. The world population is predicted to hit

9.6 billion by 2050, and globally the demand for crops will increase by 100-110% in the next 30 years. Hence, to feed and nourish this burgeoning population in the face of climate change, reduced arable land and water shortages, there is a pressing need for innovation in crop breeding technologies to enhance agricultural-productivity and accelerate sustainable agricultural-development. Nature has been editing, altering and re-writing genomes from time immemorable, with natural selection enabling organisms both plants and animals with genomic variants to survive. Moreover, humans have been employing artificial selection to domesticate crops for more than 10,000 years. The quantum of crops that we presently consume have been domesticated from their wild progenitors within the last 12,000 years. For instance, modern corn was produced by this process from its wild ancestor teosinte. Cross breeding, mutation breeding and transgenic breeding are. Currently the main methodologies for crop improvement in modern agriculture also referred to as first, second and third generation technologies. Amongst these techniques Cross & Mutation Breeding are time and labour intensive that have led to generic erosion or reduction in genetic diversity. Currently 4th generation breeding technology is emerging as precision design agriculture via the integration of deep exploration on crop functional genomics, popular precision editing technologies, big data mining and AI/AGI that have been synergized into breeding strategies.

We are on the cusp of a new era in the history of life on Earth-an age wherein humans exercise an unprecedented level of control over the genetic composition of the species that co-inhibit our plant. CRISPR has already changed the face of research and novel ideas showed that what has been achieved so far can just be the tip of the iceberg, when it comes to CRISPR's potential and CRISPR revolution is far from over. We at ICGEB have leveraged this state of the art technology for crop improvement via underscoring its immense potential in generating de novo genetic diversity in beneficial genes or alleles.

Re-designing Rice Crop for Improved Grain Micronutrients Using CRISPR-Cas9 Based Genome Editing

Malnutrition, particularly iron (Fe) and zinc (Zn) deficiencies, is a widespread issue affecting billions globally, with rice being a primary staple food in many developing countries. We targeted key negative regulator genes responsible for Fe and Zn accumulation, as well as genes involved in cadmium (Cd) transport, using CRISPR/Cas9-based genome editing. The successful knockout of these genes resulted in increased Fe (15-120 ppm) and Zn (28-150 ppm) levels in rice grains, while Cd accumulation was significantly reduced (<0.01 ppm). These advancements not only improve nutritional security but also offer a safe, cost-effective solution to combat malnutrition and toxic metal contamination, with the potential to positively impact vulnerable populations and contribute to global health.

Combatting Aggressive Weeds in Pigeon-pea (Cajanus cajan L.) through CRISPR-Based Genome Editing

Weed infestation severely limits pigeon-pea (arhar) productivity. To address this, the *CcEPSPS* and *CcALS* genes were precisely edited using CRISPR-Cas9-mediated HDR, reducing glyphosate binding affinity. Sequencing of T_0 plants revealed successful mutations in *CcEPSPS*, including four substitutions, while two crucial edits, were identified in *CcALS*. The edited plants exhibited stable inheritance, enhanced glyphosate resistance, and maintained superior photosynthetic efficiency and agronomic performance post-herbicide application, offering a sustainable and efficient weed management solution.

CRISPR/Cas9-Mediated Base Editing for Herbicide Resistance in Maize (Zea mays L.)

Weed infestation poses a global threat to crop yield. To address this, CRISPR/Cas9-mediated HDR was used to knock out a conserved region of the native *ZmEPSPS* gene and knock in a modified fragment with triple amino acid substitutions (GATIPS). The edited maize lines exhibited superior glyphosate resistance, transgene-free inheritance, and enhanced aromatic amino acid content, with agronomic performance comparable to wild-type plants, offering a sustainable solution for improved crop resilience.

CRISPR/Cas9-Mediated Genome Editing for Enhanced Fibre Quality and Agronomic Traits in Cotton

Cotton production faces challenges in simultaneously improving fibre quality and yield due to its complex genome. Through CRISPR/Cas9-based genome editing, a key negative regulator of fibre development was precisely knocked out, achieving a 100% mutation efficiency. Molecular analysis validated the successful edits. The edited plants demonstrated a significant twofold increase in fibre length, a 25-30% yield enhancement, and improved plant morphology. Early flowering was also observed, contributing to shorter cultivation periods. These advancements provide a promising approach for developing early-maturing, high-yielding, and high-quality Upland cotton cultivars, supporting sustainable cotton production and improved market competitiveness.

Combatting Aggressive Weeds: Advancing Herbicide Resistance in Soybean (Glycine max L.) through CRISPR/Cas9 Genome Editing

Weed infestation poses a significant challenge to soybean production, leading to

severe yield losses. To tackle this issue, CRISPR/Cas9 genome editing technology was used to develop herbicide-resistant soybean lines by targeting key genes involved in herbicide sensitivity, *GmEPSPS* and *GmALS*. Sequencing of T_0 plants revealed successful mutations in *GmEPSPS*, including four substitutions, while two crucial edits, were identified in *GmALS*. Cas9 integration and mutation-specific primer analysis validated the incorporation of these edits, with sequencing confirming site-specific modifications. These promising lines will undergo further screening and agronomic evaluation to establish robust, herbicide-resistant soybean varieties capable of sustaining productivity under aggressive weed pressures.

Enhancing GABA, Vitamin D, and Lycopene Levels in Tomatoes (Solanum lycopersicon L.) Using CRISPR-Cas9/RNP Genome Editing

CRISPR/Cas9 technology was employed to enhance the nutritional profile of *Solanum lycopersicon* by targeting key regulatory factors involved in metabolite accumulation. The knockout of a critical regulator boosted glutamate decarboxylase activity, leading to increased GABA levels, which are beneficial for human health. Another modification prevented the breakdown of a precursor to pro-vitamin D, resulting in its increased accumulation. Additionally, the disruption of a factor responsible for lycopene degradation allowed for higher lycopene retention. These successful genome edits led to tomatoes enriched with GABA, pro-vitamin D, and lycopene, offering enhanced nutritional benefits for consumers.

CRISPR/Cas9-Mediated Development of Hypoallergenic Tomato (Solanum lycopersicum L.) for Enhanced Nutritional Security

Tomato's allergenic properties affect 12–14% of consumers, posing health risks and impacting food security. To address this issue, CRISPR/Cas9 genome editing was employed to precisely knock out a key allergen-regulating factor, achieving a 100% mutation rate and complete gene disruption. The edited lines exhibited significantly reduced allergenicity and improved nutritional safety. Enhanced stress adaptation was also observed in these modified plants. This breakthrough promotes healthier tomato consumption, reduces health risks for sensitive consumers, and contributes to sustainable agriculture. The innovation aligns with efforts to tackle food security challenges and improve consumer health.

These innovations demonstrate the vast potential of gene editing technologies in improving crop nutrition and sustainability. As we move forward, it's essential to continue exploring these technologies and collaborating with stakeholders to ensure that these advancements benefit humanity.

Speed Breeding: A Game Changer for Global Food Security

DR. UMA MAHESHWAR SINGH

Scientist- Innovative Breeding
IRRI- South Asia Regional Centre, Varanasi

Dr. Uma Maheshwar Singh is a Scientist at the IRRI South Asia Regional Centre, Varanasi, leading the breeding program at IRRI Varanasi. His expertise lies in pre-breeding, trait mapping, and sequencing-based trait discovery. He has been instrumental in developing multiple stress-tolerant rice varieties, direct-seeded rice (DSR)-suitable varieties, and advancing research in speed breeding.

Dr. Singh earned his PhD from GB Pant University of Agriculture and Technology, Pantnagar, where he worked on deciphering the molecular basis of grain calcium accumulation in finger millet. And from last 10 year he is working with IRRI with different capacities. His research was recognized with the prestigious Governor's Award for Best Research. He has contributed to nearly 50 research and review articles and has played a key role in developing several important germplasm resources.

Technical Session II

Technical Session II: Digital and Data-Driven Technologies/applications for seed industry **Time: 2:30 PM-3:50 PM** Chair- **Mr. Siraj Hussain**, Former Secretary (Agriculture), MoA&FW, GOI Co- Chair- **Dr. A K Singh**, Vice Chancellor, CSAU&T, Kanpur Rapporteur: **Dr Manjeet Kumar**, Scientist, Genetics and Plant Breeding, IARI, Pusa			
2:30 PM- 2:40 PM		**Opening Remarks by Chair/Co-chair**	
SN	**Duration**	**Topic**	**Speaker**
1.	**2:40 PM-3:00 PM**	Digital Sequence Information: Technology, Policy & Regulation	**Dr. Sunil Archak** Principal Scientist, NBPGR
2.	**3:00 PM-3:20 PM**	Development of Agri Stack: Building Blocks for a future digital paradigm	**Ms. Ruchika Gupta,** DDG, Ministry of Statistics & Programme Implementation
3.	**3:20 PM-3:40 PM**	AI based Predictive analytics and crop simulation modeling for precision agronomy for realizing Genetic gains	**Mr. Aditya Shah** Global Director – Strategic, Partnerships, CropIn
3:40 PM-3:50 PM		**Q&A and Closing Remarks by Chair/Co-Chair**	
Sponsor Presentation			
3:50 PM-4:00 PM		Technology for Nutritional Enhancement of Seed - "Need of Hour"	**Mr. R K Goyal** Managing Director, Verdesian Life Sciences USA

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CHAIR

MR. SIRAJ HUSSAIN

Former Secretary, Agriculture,
Ministary of Agriculture and Farmers Welfare,
Government of India

Mr. Siraj Hussain is a distinguished former Secretary of Agriculture, Government of India, with extensive experience in agricultural policy, food security, and rural development. A retired Indian Administrative Service (IAS) officer of the 1979 batch (Uttar Pradesh cadre), he has played a pivotal role in shaping India's agricultural landscape.

During his tenure as **Secretary, Ministry of Agriculture and Farmers' Welfare (2014–2016)**, he was instrumental in policy formulation on agricultural marketing, foodgrain management, and crop insurance. His leadership was crucial in implementing reforms in the National Food Security Act (NFSA) and strengthening institutions like the Food Corporation of India (FCI) and the National Agricultural Cooperative Marketing Federation of India (NAFED).

Post-retirement, Mr. Hussain has remained active in agricultural policy discourse as a scholar, columnist, and advisor to various think tanks and institutions. He regularly contributes to policy discussions on food security, minimum support prices (MSP), agri-marketing reforms, and rural economy.

Presently, Mr. Siraj Hussain is acting as Chairman, National Electronic Repository Limited, which providing the system and platform for Electronic Negotiable Warehouse Receipts.

CO-CHAIR

DR. ANAND KUMAR SINGH

Vice Chancellor, C.S.Azad University of Agriculture and Technology, Kanpur, UP, India

Dr. Anand Kumar Singh is currently Vice Chancellor of Chandra Shekhar Azad University of Agriculture & Technology, Kanpur, UP, India.

Dr. Singh has completed his graduation from Banaras Hindu University, Post graduation and Ph.D. from Indian Agricultural Research Institute, New Delhi. He joined the Saga National University, Japan as a Post-Doctoral Fellow in 1989 and completed his degree in 1991. Later he also obtained his Post-Doctoral Fellow from University of California, USA during 2007-2008.

With over 22 years of experience in agricultural sciences, he served as Deputy Director General (Horticulture) ICAR for more than 6 years. In addition to that he also served additional charge for Deputy Director General (Crop Science) for 3 years, MD, National Horticulture Board for more than 2 years, Chairman, Coconut Development Board (CDB), Additional Charge as Executive Director in National Oilseeds and Vegetable Oils Development (*NOVOD*) and Head, Division of Fruits & Horticulture Tech, IARI, ICAR for more than 8 years. He is the first Indian who served as Board of Directors for World Vegetable Center, Taiwan.

Dr. Singh has a great penchant in research and has developed 6 mango varieties with special export specific traits. In addition to that as chairman of Central Variety Release Committee has released and notified 750 crop varieties. He has been entrusted with many other responsibilities, initiated Bio-fortification research programme and developed more than 17 technologies with respect to improved crop production.

Dr. Singh has published 161 Research papers/review papers/other articles and authored/edited 11 Books including 2 from Elsevier and 1 from Springer.

He is the recipient of several awards including “Mombusho” Award from Japanese Government, Bronze Award for Indian Exhibition at World Expo, Turkey, AIPH, UK. AS MD, NHB. He also received Gold Medal from National Academy of Hort, Sciences & Delhi Agri-Horti Soc. New Delhi.

Dr. Singh has been leader of 3 International delegation from India provided leadership to 49 ICAR Institutes as Deputy Director General (Crops) and Hort. Sciences.

Digital Sequence Information: Technology, Policy & Regulation

DR. SUNIL ARCHAK

Principal Scientist and Officer in Charge of the Germplasm Exchange and Policy Unit, ICAR-NBPGR , New Delhi

Dr. Sunil Archak is currently working as a Principal Scientist and the Officer in Charge of the Germplasm Exchange and Policy Unit, ICAR-NBPGR.

He has 27 years of experience working with various aspects of Plant Genetic Resources. He was ICAR-National Fellow (*A Professorial Chair*) at the National Bureau of Plant Genetic Resources (ICAR-NBPGR), New Delhi from 2014-2024. He was instrumental in establishing National Genomic Resources Repository (2010) and a PGR Informatics Facility (2011) at NBPGR. He has developed many web-based applications including PGR Portal, National Rice Resource Database, E-Herbarium, G2G, and mobile apps (*http://pgrinformatics.nbpgr.ernet.in/*).

Dr. Archak holds a dual faculty membership at IARI in the disciplines of *Plant Genetic Resources* and *Bioinformatics* and has guided many PhD students. He has published a number of papers in the areas of PGR, bioinformatics and PGR policy (https://scholar.google.co.in/citations?hl=en&user=u2zNBBUAAAAJ&view_op=list_works&sortby=pubdate).

He has organized trainings on DNA fingerprinting, genomic data analysis, conservation of genomic resources, climate analogue tools, etc. He was a member of teams that organized National Symposium on Plant Genetic Resources: Advances and Challenges (2001), Global Consultation on Use and Management of Agrobiodiversity for Sustainable Food Security (2013), International Agrobiodiversity Congress (2016), Strategies for implementation of Delhi Declaration (2017), 9th

Meeting of the FAO-ITPGRFA governing body (2022), etc.

Dr. Archak represented India in FAO-ITPGRFA Governing Body meetings at Kigali (2017), Rome (2019; 2023) and Delhi (2022). He is currently the Co-Chair of the Treaty Working Group to enhance the functioning of the Multi-Lateral System of the Plant Treaty and a member of the Scientific Advisory Committee on the Global Information System. He also represents India in FAO-CGRFA and CBD meetings.

What is 'digital sequence information'?

In spite of garnering global attention, there is still no internationally agreed definition of digital sequence information (DSI). A general definition could be "DSI on genetic resources refer to the genetic sequence data (GSD) that describe the order of nucleotides in DNA or RNA in genetic material. There are proposals to include DNA, RNA, proteins and metabolites in the scope of DSI.

Why is DSI relevant to seed industry?

Today, due to the rapid adoption of genome editing technology and its variants, several genome-edited crop products have been commercialized globally, including high-GABA tomato, high-oleic acid soybean, high-amylopectin corn and pungency-free mustard greens, with many more genome-edited crops with improved traits are in the pipeline. It is important for researchers from private and public sector engaged in genome editing to appreciate that countries are currently engaged in highly intense negotiations to develop new rules for sharing benefits derived from the use of DSI. Just as CRISPER could have an IP protection or a variety could be registered in the name of a company, DSI derived from genetic resources developed by farmers and communities, could demand sharing of benefits.

Why DSI as technology attracts policy makers and regulators?

There are multiple issues that are making the potential benefit sharing from the use of DSI a hot and sticky issue.

(i) Most of the world's crop-biodiversity (almost freely accessed) has evolved in the global south.

(ii) By and large, developing countries have a common concern that developed countries had an unfair and unequal technological advantage to exploit this genetic diversity for their economic development and profit.

(iii) Stakeholders believe that the international access and benefit-sharing (ABS) agreements (CBD, 1993; Nagoya Protocol, 2010; Plant Treaty, 2004)

failed to address inequity by redirecting monetary benefits derived from the use of genetic diversity to developing countries.

(iv) Genome sequencing getting faster and cheaper resulting in explosion of open access sequence data in the public domain. Add to that the availability of unprecedented ways of using DSI in basic research as well as breeding by means of genome editing. There is a pervasive apprehension that DSI will contribute to further widening of the technology gap between north and south, and the ability of countries to exploit PGRFA (material) through DSI.

(v) Existing regulatory oversight apparatus globally (CBD, Nagoya and ITPGRFA) were concluded during the pre-genomics era of 1990s and early 2000s. Their purpose was to facilitate and regulate access to material (e.g. seeds) and ensure sharing of monetary benefits when accessed 'genetic material' is 'incorporated' in new, commercialized products. On the other hand, DSI from the same genetic material are accessible free of cost and research leads and commercial products arising out of DSI use do not trigger benefit sharing obligations.

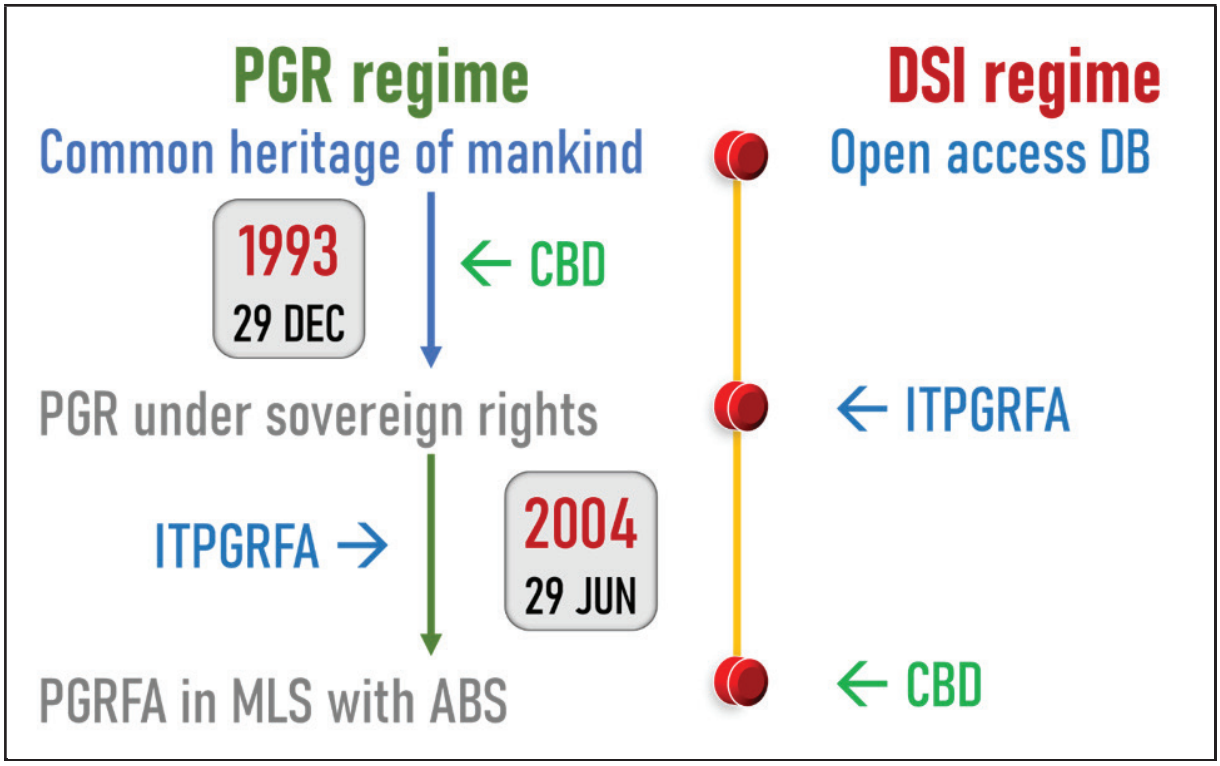
Database issues

The International Nucleotide Sequence Database (INSDC; https://www.insdc.org/), by Nov 2024, contains as much as 32 million next generation sequence runs and 4.76 billion assembled sequences (non-human). INSDC declares that it is committed to open science and data sharing. DSI sans metadata (annotation or contextual data) is barely useful. The strength of a comprehensive DSI database is that users can learn about the source and function of their experimental sequences by comparing with the archive sequences. However, if the a DSI record does not contain adequate metadata, its utility decreases. By the end of 2024, all new submissions to INSDC archives require spatiotemporal information (geolocation and collection date) to be included with the sample description to enhance the utility of the sequences.

As ICT has become omnipresent in our society and researchers become increasingly dependent on digital data and their repositories that provide access to and enable the use of such resources, it is time these DSI repositories earn the trust of the communities they intend to serve and demonstrate that they are reliable and capable of appropriately managing the data they hold. There are discussions and negotiations on how data repositories can balance the principles of TRUST (Transparency, Responsibility, User focus, Sustainability and Technology), CARE (Collective Benefit, Authenticity, Responsibility, and Equity) and FAIR (Findable, Accessible, Interoperable, and Reusable). Post-COP16-CBD (Cali, 2024), Parties shall explore decentralized database setup and additional tools to facilitate ABS.

DSI policy issues

1. As multiple UN fora develop parallel rules for sharing benefits from the commercial use of DSI, better coordination will be critical. International policymakers need to come together on harmonizing new benefit-sharing rules to ensure open access to data, database interoperability, and better benefit sharing outcomes. DSI regime today is similar to pre-CBD PGR regime – open access to all without ABS obligations. Interestingly, the proposed DSI regulatory system in CBD is multilateral akin to PGR-ABS in Plant Treaty. And conversely, ITPGRFA is negotiating to bring DSI together with PGR under sovereign rights (please see figure).



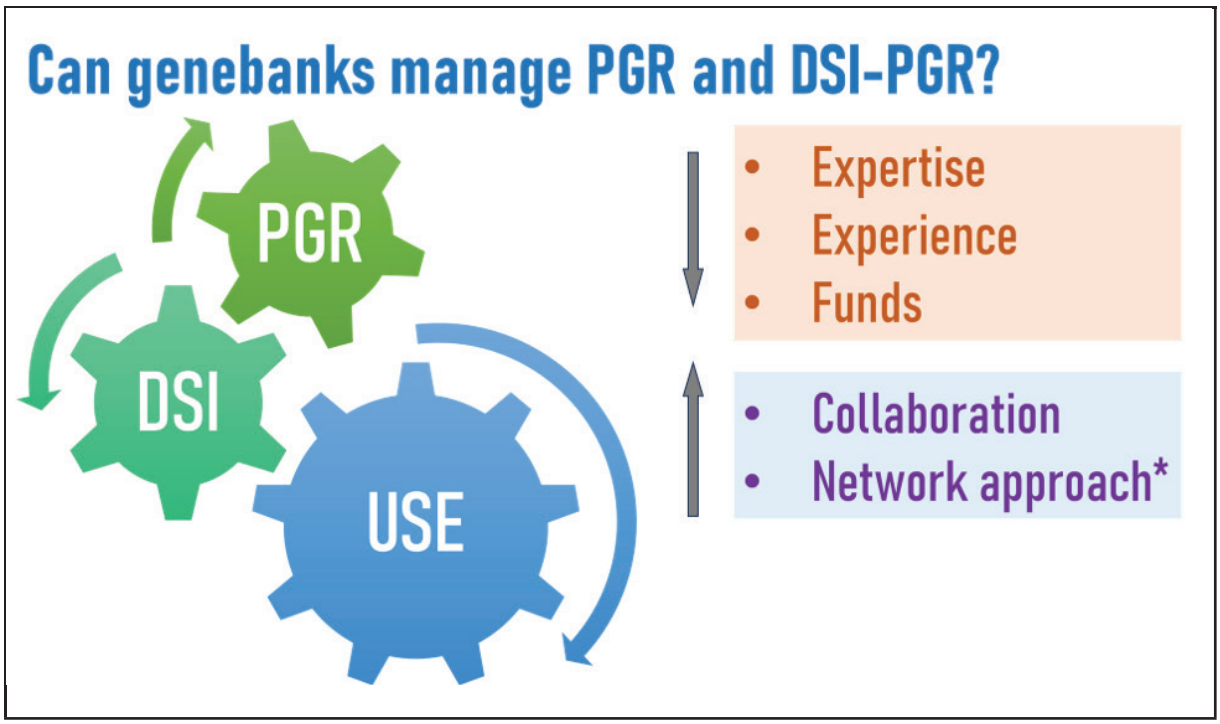
2. In CBD-COP16, modalities for brining into effect the multilateral benefit-sharing mechanism from the use of DSI-PGRFA were adopted, and the Cali Fund was established. However, the achievements are only the beginning of a long-drawn process to finalize the mechanism, rates, fund use, etc. In ITPGRFA, efforts are on to develop a package of measures including DSI, expansion of MLS and an upfront payment system.

Conclusion

- Countries are interdependent for PGRFA that led to the creation of the Plant Treaty's multilateral system of access and benefit-sharing. On the contrary

to the general notion, onset of DSI based technologies increases countries' interdependence in agricultural R&D. Because it increases collective ability to compare information about genetic resources (comparative genomics) by employing sequencing, phenotyping, genotyping, bioinformatics and finally gene editing and achieving enhanced breeding efficiency.

- DSI as a collective common resource for use in R&D, for sustainable agriculture and development, is becoming increasingly important. The outcome of all negotiations will affect, constructively or otherwise, how researchers will generate, access, use and share DSI, and how benefits associated with that work will be distributed.



- Genebanks as repositories of PGRFA may need to re-invent the role vis-à-vis DSI. We can only maximize benefits by establishing international cooperation, public-private partnerships and enhancing stakeholder awareness (see figure).

- It is unequivocally clear that open access digital infrastructures are essential for exploiting the power of DSI. Therefore, on one hand it is critical that proposed benefit sharing systems don't undermine open access. On the other, private industry needs to remain responsible for their actions and aim to comply with ABS obligations.

Agri Stack DPI: Building Blocks for a Future Digital Paradigm

MS. RUCHIKA GUPTA

Deputy Director General (DDG) Social Statistics Division, Ministry of Statistics & Programme Implementation, New Delhi

Ms. Ruchika Gupta is currently serving as Deputy Director General (DDG) in the Social Statistics Division, Ministry of Statistics & Programme Implementation, New Delhi. She holds a Bachelor of Science (Honours) degree in Statistics and a Master of Science degree in Statistics. She has over 20 years of extensive experience in Executive Leadership, Strategic Planning, and Management in the field of Statistics within the Government Sector. Previously, she worked for more than four years as an Advisor in the Economics, Statistics & Evaluation Division, Ministry of Agriculture & Farmers Welfare, Government of India, New Delhi. A keen strategist, she possesses expertise in managing fieldwork for data collection and implementing IT tools for statistical compilation. She has a proven track record of consistently achieving targets and excels in analytical, communication, organizational, and troubleshooting skills. Her ability to analyze data, compile statistical documents and reports, and provide insightful recommendations is well established. Additionally, she has strong interpersonal, leadership, and team management abilities, fostering effective relationships with stakeholders and ensuring seamless collaboration across various projects and initiatives.

Organizational Details:

Nov 2001 – Nov 2003	Under probationary training
Nov 2003 – Jan 2007	National Sample Survey Organisation, Zonal Office, Lucknow
Jan 2007 – Feb 2015	Ministry of Human Resource Development, New Delhi

Feb 2015 – Sept 2016	Ministry of Civil Aviation, New Delhi
Sept 2016 – Jun 2020	Union Public Service Commission, New Delhi
Jun 2020 – Jan 2025	Ministry of Agriculture, New Delhi
Jan 2025 – Till date	Ministry of Statistics & Programme Implementation, New Delhi

Key Areas handled

- Overseeing field work of data collection and performing the duties of Head of Office.
- Collection, Compilation and Analysis of data in Agriculture, Education, Aviation. Writing reports.
- Implementation of latest tools in data collection and compilation.

Special Achievement

- Launching of All India Survey of Higher Education using latest IT technology.
- Key member in preparing Indian National Standard Classification on Education
- Initiated release of city pair wise domestic traffic data and international traffic data
- Played a crucial Role in Recruitment of Joint Secretary on contract basis in different Ministries/ Departments. This exercise was undertaken for the first time.
- Played leadership role and lead **Digital Crop Survey** which is a transformational project mentioned in budget.
- Key member in development of **UPAg portal** related to agriculture statistics.
- Leading the work of **Krishi Mapper** portal.

Introduction

The introduction of Digital Public Infrastructure (DPI) for agriculture i.e. Agri Stack, under the Digital Agricultural Mission, marks a paradigm shift India's agriculture sector. Agri Stack through a comprehensive digital ecosystem approach offers scalable, interoperable, and inclusive solutions for farmers while fostering private innovation.

Agri Stack DPI is designed to enhance entire agricultural value chain by improving governance, service delivery, and inclusivity. By leveraging technology, it aims to build a transparent, efficient and sustainable digital agricultural ecosystem.

Key Components of Agri Stack as DPI

Agri Stack is built on the core principles of interoperability, scalability, reusability, and private innovation across the agriculture sector-

1. **Digital Identity Systems**: The core of Agri Stack includes the Farmer Registry, Geo Reference Village Maps, and Crop sown Registry. The digital identity i.e. Farmer ID (11 digit unique number) is a key to farmers' demographic data, their land holdings and the seasonal crop data.

    - **Support Registries**: A suite of 30+ Support Registries, including the Crop Registry, Seed Registry, Pesticide Registry, etc. are being put in place to standardize agricultural data nationwide.

2. **Consent Manager:** The Consent Manager ensures secure, consented data sharing while giving farmers granular control over sharing and revocation of consent, in line with the Digital Personal Data Protection Act, 2023.

3. **Unified Farmer Service Interface:** UFSI acts as a gateway for seamless information exchange across heterogenous systems similar to how UPI facilitates transactions between banks where each CBS may have different architecture and systems. Built on a Federated Architecture, UFSI ensures secure and privacy compliant data sharing while empowering States and farmers to retain control over their data.

Agri Stack compliance to Principles of DPI

Agri Stack's design adheres to the principles of DPI:

1. **Usability Across Stakeholders**: Components such as the Farmers Registry and Crop Sown Registry support multiple schemes, including credit, insurance, advisory services etc.

2. **Interoperability by Design**: Standardized data and APIs specifications shall enable seamless data sharing across government, Agri-Techs and research organizations.

3. **Scalability for National Impact**: Designed to support millions of farmers across diverse regions, Agri Stack is scalable and shall facilitate initiatives such as precision farming and improved market access.

4. **Inclusion at Its Core**: Equitable access is ensured for smallholder farmers, agricultural labourers and women through features like consent and farmer centricity.

Beyond IT: Agri Stack as a Catalyst for Transformation

Agri Stack goes beyond a traditional IT project by catalysing systemic change in agriculture. Historically, the process of land record updation was fraught with challenges and was not an administrative urgency of the Revenue Department, resulting in outdated and inaccurate records that hindered economic development.

The formation of the Farmer Registry necessitates that all agricultural land parcels owned by farmers are updated and linked to their profile because benefits associated with farmland such as crop insurance, seeds, fertilizers, and irrigation—will be tied to the Farmer Registry. Hence there is a direct and urgent demand for updating land records. This shall nudge both the farmers and the Revenue Department for land record management. Accurate and up-to-date land records shall reduce disputes, streamline service delivery, enhance supply chain efficiency, improve market access and contribute to GDP growth.

The Road Ahead

Agri Stack's vision extends beyond land owning farmers to include animal husbandry, fisheries, tenant farmers, and forest land rights holders in the next phase of the Farmer Registry rollout.

Conclusion and Way Forward

The digital transformation of agriculture through Agri Stack harnesses emerging technologies to empower citizens, promote sustainability and create equitable access to opportunities. With its inclusive approach and emphasis on scalability, Agri Stack can revolutionize agriculture, enhance livelihood and drive national growth.

AI based Predictive analytics and crop simulation modeling for precision agronomy for realizing Genetic gains

MR. ADITYA SHAH

Senior Director - APAC Business and Global Partnerships, Cropin

Mr. Aditya Shah serves as the Senior Director - APAC Business and Global Partnerships at Cropin, where he plays a transformative role in driving technological innovation in agriculture. With over 15 years of experience, including co-founding a startup, Aditya brings a deep passion for revolutionizing the agricultural landscape through cutting-edge solutions that empower farmers and farming enterprises.

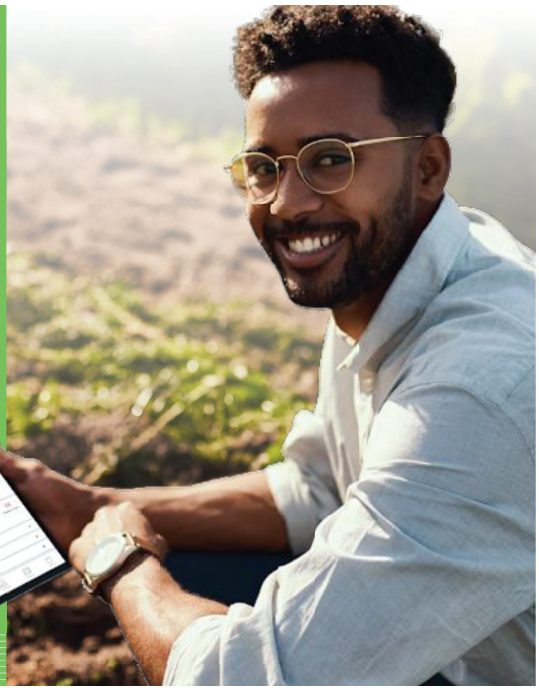
With Cropin, Aditya focuses on advancing the adoption of smart agri-tech solutions, enabling stakeholders across the agricultural value chain to enhance productivity, sustainability, and profitability. He has been instrumental in spearheading initiatives that promote Climate Smart Agriculture and sustainable practices, addressing critical challenges such as climate change, resource optimization, and food security. His efforts have left a lasting impact on agricultural ecosystems in countries like India, Sri Lanka, Bangladesh, Indonesia, Mexico, and beyond.

By leveraging technology, Aditya and Cropin are reshaping how agriculture is practiced, introducing innovations like data-driven insights, precision farming, and digital platforms that enable real-time decision-making. His work contributes to empowering farmers, enterprises and governments with tools to improve yield quality, manage resources efficiently, and build resilience against climate uncertainties, fostering a brighter and more sustainable future for agriculture worldwide.

Cropin™

Securing the future of food with the world's first intelligent agriculture cloud

CORPORATE PRESENTATION



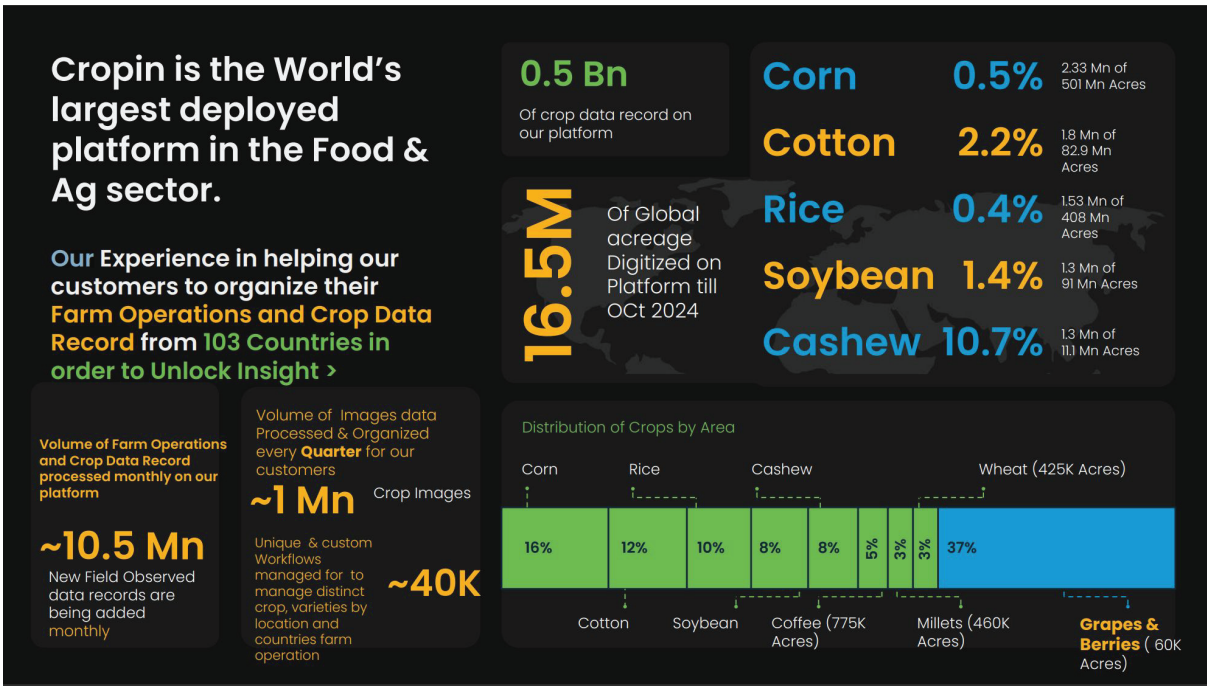
Power your seed value chain from research to market

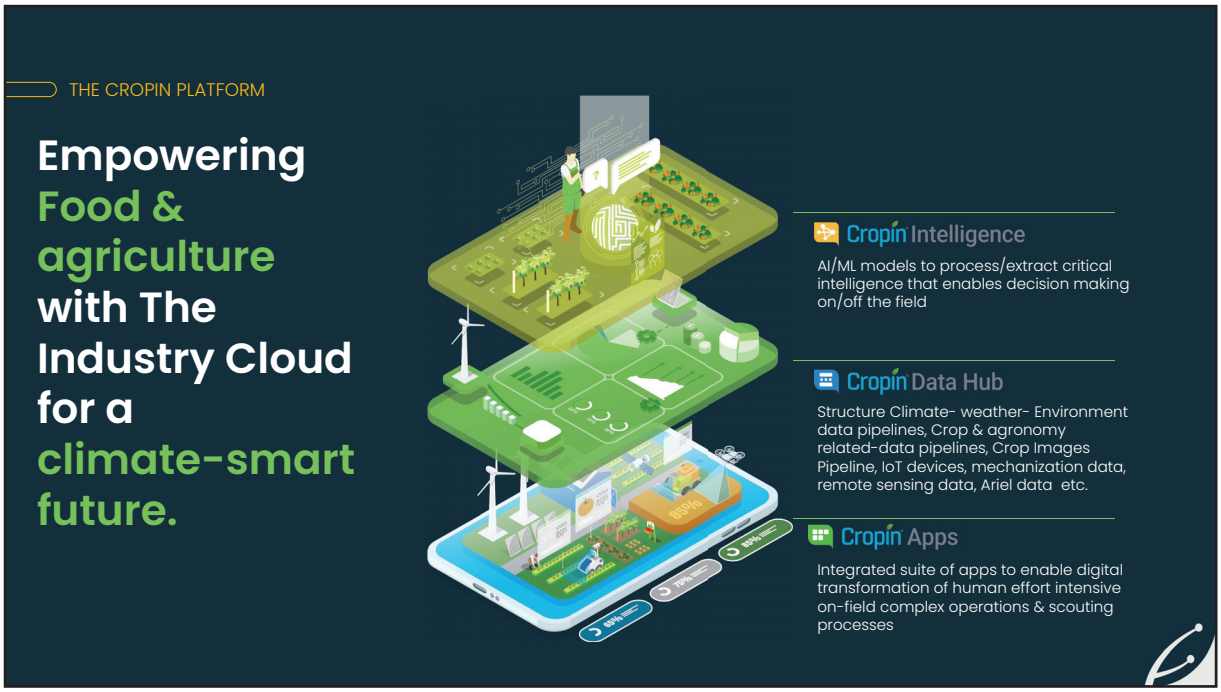
We understand the complex challenges, seed companies, navigate through day-to-day. From seed research, variety grading, seed traceability, to demand forecasting - challenges like these hinder productivity & growth, impacting your bottom-line.

Moreover, the increased global focus on compliance regulations & sustainability objectives are certainly adding more strain to the problem.

Innovation in digital transformation is the need-of-the-hour. It could address these seed production challenges while ensuring that you grow sustainably & responsibly.

Read on to know how our digital transformation suite - Cropin Cloud can help with seed use cases.


Cropin is the World's largest deployed platform in the Food & Ag sector.
Our Experience in helping our customers to organize their Farm Operations and Crop Data Record from 103 Countries in order to Unlock Insight >
0.5 Bn
Of crop data record on our platform
16.5M
Of Global acreage Digitized on Platform till OCt 2024
Corn 0.5% 2.33 Mn of 501 Mn Acres
Cotton 2.2% 1.8 Mn of 82.9 Mn Acres
Rice 0.4% 1.53 Mn of 408 Mn Acres
Soybean 1.4% 1.3 Mn of 91 Mn Acres
Cashew 10.7% 1.3 Mn of 11.1 Mn Acres
Volume of Farm Operations and Crop Data Record processed monthly on our platform
~10.5 Mn
New Field Observed data records are being added monthly
Volume of Images data Processed & Organized every Quarter for our customers
~1 Mn
Crop Images
Unique & custom Workflows managed for to manage distinct crop, varieties by location and countries farm operation
~40K
Distribution of Crops by Area
Corn
Rice
Cashew
Wheat (425K Acres)
16%
12%
10%
8%
8%
5%
3%
3%
37%
Cotton
Soybean
Coffee (775K Acres)
Millets (460K Acres)
Grapes & Berries (60K Acres)


THE CROPIN PLATFORM
Empowering Food & agriculture with The Industry Cloud for a climate-smart future.
Cropin Intelligence
AI/ML models to process/extract critical intelligence that enables decision making on/off the field
Cropin Data Hub
Structure Climate- weather- Environment data pipelines, Crop & agronomy related-data pipelines, Crop Images Pipeline, IoT devices, mechanization data, remote sensing data, Ariel data etc.
Cropin Apps
Integrated suite of apps to enable digital transformation of human effort intensive on-field complex operations & scouting processes

IMPROVING VALUE PER ACRE

Challenges we solve for our customers Globally

Platform to break data silos & bring standardization in global operation.

2,000 global companies, found that digital solutions can generate revenue increases upto to 25% and cost savings of up to 28% compared with the pertinent baseline.

Sourcing: Yield & Quality & Predictability

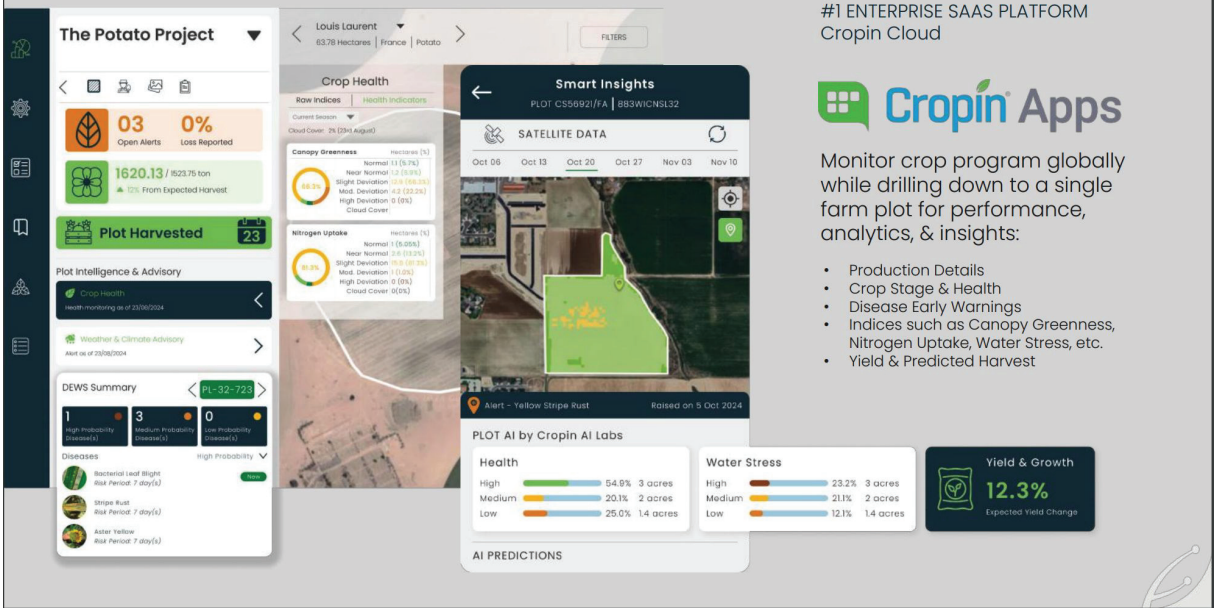
Globally 30-50% Production forecast Error impact the Top Line negatively

Model Climate change to solve for Production losses

Ag-Enterprises - Reported Losses accounting upto 2% to 8% of the revenue in last 5-10 years

Solve compliance like EUDR, Food Security & Sustainability

EUDR Penalty: 4% of revenue if non-compliant. New study which estimated that current deforestation is costing the world $2-5 trillion per year.

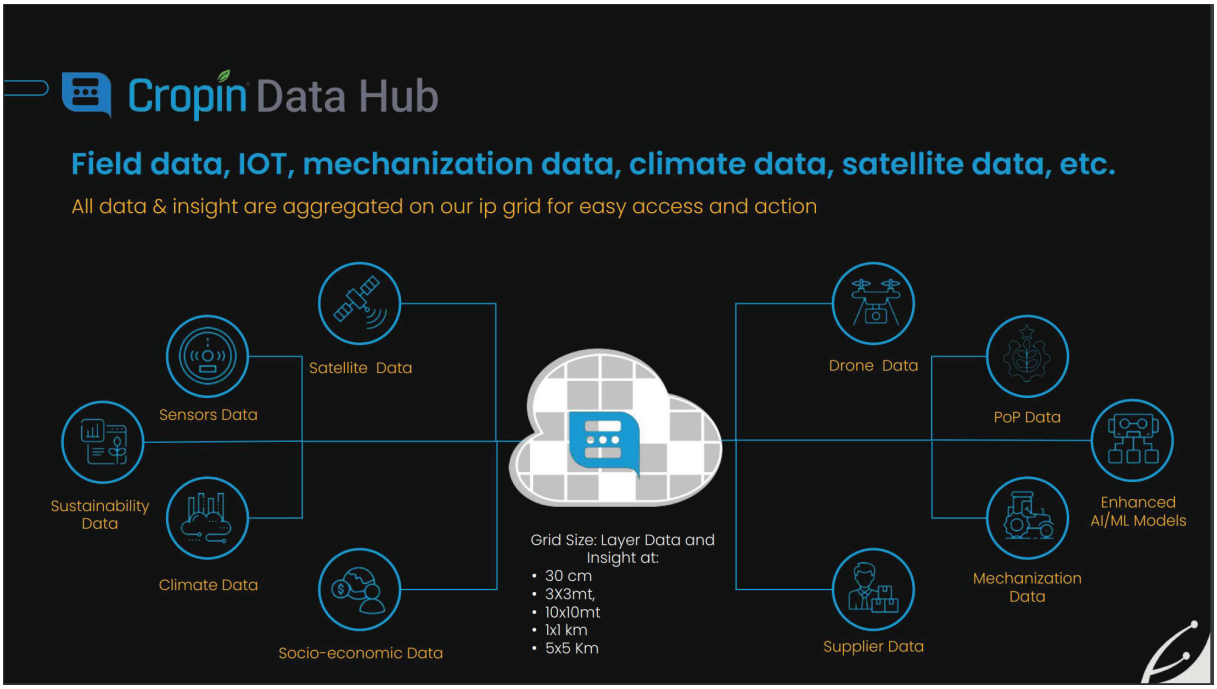


#1 ENTERPRISE SAAS PLATFORM
Cropin Cloud

Cropin Apps

Monitor crop program globally while drilling down to a single farm plot for performance, analytics, & insights:

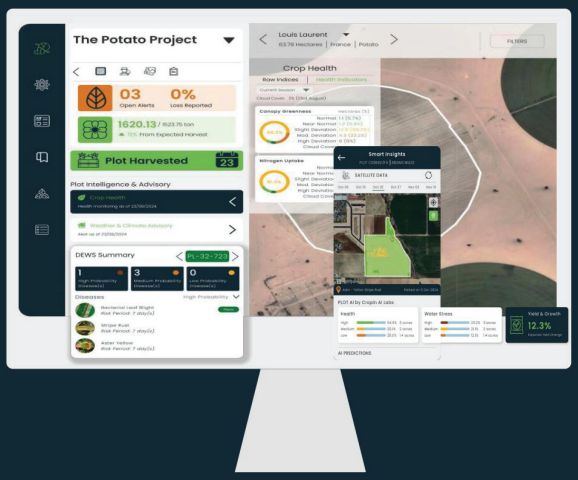
- Production Details
- Crop Stage & Health
- Disease Early Warnings
- Indices such as Canopy Greenness, Nitrogen Uptake, Water Stress, etc.
- Yield & Predicted Harvest


Cropin Data Hub
Field data, IOT, mechanization data, climate data, satellite data, etc.
All data & insight are aggregated on our ip grid for easy access and action
Satellite Data
Sensors Data
Sustainability Data
Climate Data
Socio-economic Data
Grid Size: Layer Data and Insight at:
• 30 cm
• 3X3mt,
• 10x10mt
• 1x1 km
• 5x5 Km
Drone Data
PoP Data
Enhanced AI/ML Models
Mechanization Data
Supplier Data


CROPIN INTELLIGENCE
Pre-Trained AI Models for Prediction & Data Intelligence
We are continuously investing & improvising domain specific foundation models.
Crop Detection Models
Detect crop area & production estimate at country, county, &/or plot-level
Nitrogen Uptake Models
Nitrogen uptake monitoring
Water Stress Models
Monitor water stress & advise irrigation by location & growth stage
Disease Models
Early disease warnings
Crop Progress Models
Monitor crop stage progress
Yield Forecast Models
Estimate yield & maturity dates
Deforestation Models
Detect land use changes
Carbon Models
Detect biomass & estimate net carbon
Forest Fire Models
Detect forest fires or stubble burning

CROPIN INTELLIGENCE

In-Season Crop Monitoring & Intelligence with Actionable Insights at farm or supply chain



Models O/P & insight in real world

Yield Prediction , Disease Prediction and Crop Progression Prediction, Harvest window for better quality, Climate Smart insight and its impact etc

Regenerative Ag Model

- Tillage,
- Cover crop
- Deforestation detection & monitoring
- Carbon Stock/Biomass

Cultivate exceptional outcomes for seed production

With Cropin Cloud as your agtech partner, digitize seed production using prescriptive & predictive intelligence, & drive optimal yield output, sustainably.

And all this, in compliance with regulations & SDG goals like EUDR, Food Security, etc

USE CASES

For Breeding & Trialing

01

Reduce time-to-commercialization of new varieties

Optimize breeding programs by predicting traits likely to succeed under various environmental conditions using Cropin's crop knowledge graph. Accelerate identification of new & promising seed varieties with Cropin Cloud's **AI-powered granular insights**. Optimize trial management, track dynamic performance metrics in real-time, and automate data collection. Thereby, reduce the breeding cycle and speed up commercialization.

02

Optimize cost of seed trialing with efficient resource management

Leverage Cropin Cloud's **weather, water usage, satellite data and insights** to monitor trial plots remotely & minimize manual intervention. Trialing insights reduce labor & resource use, optimizing costs across multiple trial locations.

03

Ensure process compliance

Cropin Cloud digitizes trial processes, ensuring adherence to regulatory standards. With **task tracking, audit trails, and digital records**, compliance becomes easier to adhere and monitor.

04

Ensure climate resilient seed suitability map

Shift the decision-making from reactive (based on past performance) to proactive (based on future resilience) with Cropin's advanced AI analytics. The predictive map powered by Cropin Sage forecasts the best regions for a seed variety considering future climate risks like heat tolerance, drought resilience, etc., enabling you to focus on varieties with the highest potential.

For Seed Multiplication

01
Estimate yield accurately

AI-powered predictive models analyze historical and real-time data to provide accurate variety & location-wise yield forecasts, helping you align seed production with sales strategies.

02
Bolster revenue & reduce costs

Cropin Cloud lifts critical processes of seed production & avoids overstocking or understocking scenarios by factoring in **future climate, varietal, & farm performance variable**s. It suggests optimal resource use, reduces input costs, & boosts yields & profitability.

03
Farmer advisory for personalized seed recommendation

Cropin Sage leverages data-driven insights, to deliver hyper-personalized farmer-focused seed variety recommendations based on soil type, weather, and pest risk. This approach drives higher seed adoption while reducing input costs for farmers. It improves farmer's trust by aligning seed solutions with specific farmer needs, ultimately improving customer satisfaction and driving sales.

04
Ensure PoP adherence and quality assurance

Ensure adherence to best practices by providing **real-time alerts, reminders & checklists** to better support seed quality & compliance, through the platform. Deploy Cropin Cloud to **track crop health and growth stages via remote monitoring** and ensure quality standards are met throughout the production process.

05
Plan production efficiently

Forecast demand, avoid overstock or stockouts, & enable precise production scheduling with the platform's **predictive analytics capabilities**.

06
Mitigate in-season production risks

Cropin Cloud's **risk assessment tools** analyze weather patterns, disease outbreaks, & other risks, arming you with proactive recommendations to minimize production disruptions.

07
Digitize farm-to-factory processes

Streamline end-to-end supply chain operations by integrating farm-level data with factory process management systems, enabling **seamless data flow and real-time visibility**.

08
Expand & diversify confidently

Cropin Cloud's **regional performance insights and trend analysis** can help you identify new regions for expansion or crop diversification based on futuristic assessments of a considered region of operation.

For Seed Sales & Marketing

01
Manage demo farms

Set up **digitally managed demo farms** to showcase seed performance comparatives to stakeholders with remote sensing & provide real-time data to inform sales and marketing decisions.

02
Seamlessly connect to all stakeholders

Connect with growers, distributors, and retailers through a **unified ecosystem** in the platform. Improve product visibility & facilitate stronger demand generation across the value chain.

03
Optimize product placement

Get **granular insights into regional performance** to optimize seed placement in markets where they are likely to perform better. Thus, the platform will help you reduce product waste & maximize sales.

For All Departments

01
Adopt an intuitive solution easily

Cropin Cloud's **easy-to-use interface** can be customized in local languages to enable easy global adoption while accounting for regional nuances & practices.

02
Combat climate change

Embrace **climate-smart agriculture** by adapting farming practices to weather vagaries. Reduce climate-change impacts & maximize farmer livelihoods, yield outputs, & other outcomes.

03
Trace seed generations

The platform's **multi-generation traceability** capabilities ensure transparency across the supply chain. Track products across generations, enhance operational efficiency & profitability.

04
Reduce carbon footprint

Cropin Cloud supports **carbon sequestration tracking**, helping you to manage carbon credits while promoting low-carbon agricultural practices.

05
Grow sustainably

Monitor sustainable practices like minimum tillage, use of cover crops, & deforestation prevention through **satellite imagery & AI analytics**.

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Still wondering if Cropin Cloud is the right fit for your seed business?

See what East West Seed (EWS) has to say about our partnership

EAST WEST SEED

East West Seed (EWS) adopted Cropin Cloud to achieve 100% production visibility - from sowing to harvest.

The platform's remote monitoring & data collection capabilities provided EWS with visibility to seed varieties & field ops. It enabled production accuracy with inputs traceability & output predictability through historical data, satellite & weather data, AI/ML, & big data. The multilingual secure support system further helped in farmer engagement & improved collaboration.

> We were looking for a real-time monitoring & a mobile tool that we could use to monitor the activity of our seed production farms.
>
> There was no software that did this. So we worked with Cropin to do it.
>
> Michel Devarrewaere
> VP Production & Projects, EWS

21.6K+	14.2K+	35+	400+
Hectares audited	Farmers registered	Crops covered	Varieties covered

FEATURED SEED PARTNERS

Get Solution Guide

East West Seed | Mahindra HZPC | Suba Seeds Co.
Bejo Seeds | Savannah | C.P. Group | BASF | Syngenta
Sayaji Seeds | Bioseed | Hytech | ITC | KWS

Why Cropin?

Unlock every acre's full potential with the world's leading Food & Ag-Tech SaaS

Food & Ag-Tech Experts

Be assured that your needs will be understood with our decade-long industry experience and extensive knowledge of geographies and the agri-supply chain. We enable our clients to manage 500 crops, 10K Varieties in 103 countries and successfully helped them to deploy digital transformation unlocking value and ROI.

Robust AIML Technology

Tap into a full-stack tech ecosystem with proprietary algorithms designed to provide accurate and relevant predictive insights. Our Crop models are contextualized for Crop, Variety & location.

Versatile Solution Suite

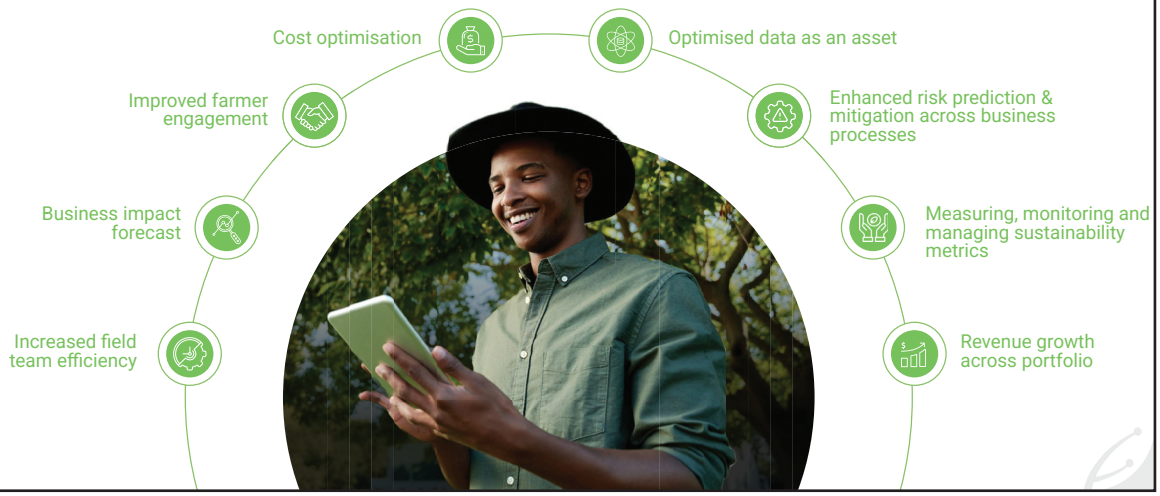
Configure our solutions to meet your organisation's needs, regardless of your location, existing infrastructure and/or data requirements

Global Ag Knowledge Graph

Region and crop agnostic solutions able to generate intelligent insights for an extensive range of crop & farm types

Partnerships:

Start unlocking value within your business and across the global agriculture ecosystem with Cropin



Coffee Sourcing Intel

From Cropin Lens

COFFEE Sourcing and Procurement Solution

LOCATION:
Brazil, Uganda, Burundi, Rwanda, Ethiopia, Tanzania, Kenya, Indonesia, Papua New Guinea, Vietnam

OBJECTIVES:
"From Bean To Cup" Enabling seamless procurement from the farmers and assisting on monitoring sustainable procurement along the coffee value chain.

CROP: Coffee

SOLUTIONS IMPLEMENTED:

Cropin Grow

Case Study

Digital Transformation: Ensuring a sustainable coffee value chain for one of the world's leading coffee trading houses

THE PROJECT(S):

Farmer trainings digitization

- Planned, documented and evidence based farmer trainings.
- Verification by time stamped photos of participants taken, GPS coordinates of event location, etc.
- Enabling a farmer associate to attend an event on farmer's behalf.

Monitoring of field activities for intensive quality control

- Monitoring the adherence of all the certifications for plots and farmers.
- Ensuring compliance with international market regulations and standards.

Post harvest supply chain management & traceability

- Daily, weekly and monthly status reports on how much coffee processed per coffee washing station, as well as reports on individual processes.
- Enabling post processing of coffee from cherry to drying of parchment.

OUR IMPACT:

Digitizing close to **3,00,000** Farmers

Monitoring **3,32,000+ farm plots**

1 Million individual coffee purchase transactions

LOCATION:
Campo Belo, Brazil

OBJECTIVES:
Coffee Acreage , **Yield, Production, Water stress & climate Impact (Short term and long term)**

CROP: Coffee

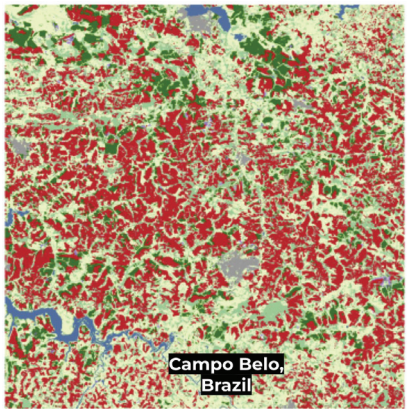
SOLUTIONS IMPLEMENTED:

Cropin Intelligence

Case Study

Sustainable Coffee Sourcing & Procurement - Acreage and Yield estimation

THE PROJECT(S):



Coffee

Overall Accuracy
Coffee Farm detection
85-90 %
Kappa Stats: **0.89**

LOCATION:
Minas Gerais, Brazil

OBJECTIVES:
Water stress & climate Impact (Short term and long term)

CROP: Coffee

SOLUTIONS IMPLEMENTED:

Cropin Intelligence

Case Study

Water Stress Map of Coffee Growing farm in Minas Gerais, Brazil

Cropin Capabilities

Coffee disease early warning base models

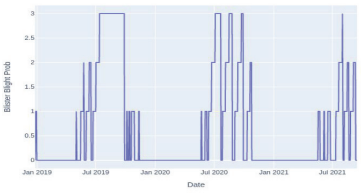
Coffee Leaf Rust

Blister Blight

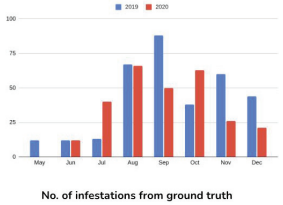
Coffee Berry Disease

and more ...

Example : Blister Blight Prediction and ground Truth results



Model risk score output



No. of infestations from ground truth

Risk Score:
3 - High, 2 - Moderate, 1 - Low, 0 - No Occurrence

LOCATION:
Brazil, Uganda, Burundi, Rwanda, Ethiopia, Tanzania, Kenya, Indonesia, Papua New Guinea, Vietnam

CROP:
Coffee

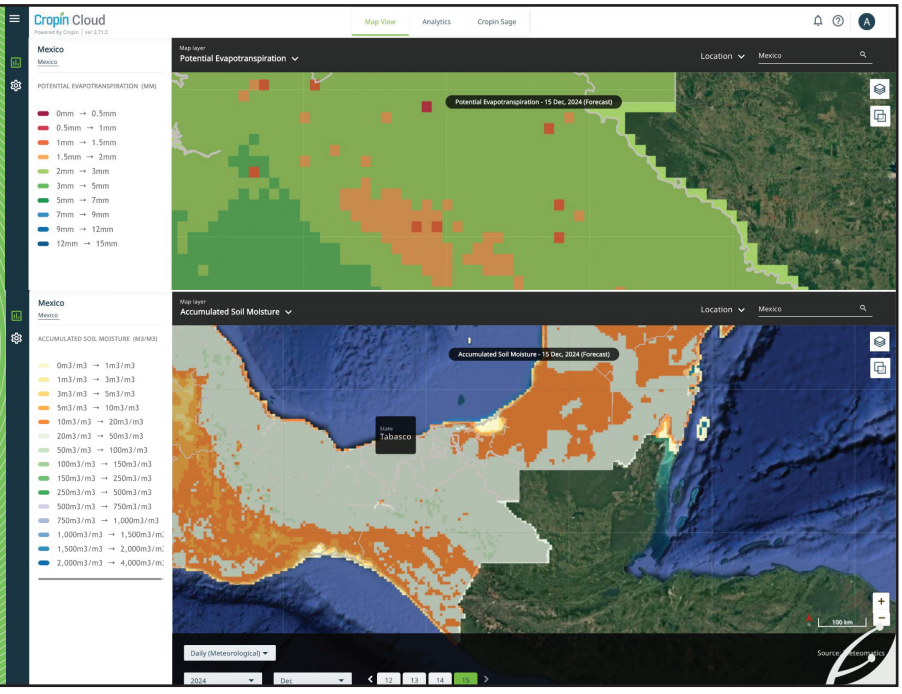
IMPACT:
80% predictive accuracy

APPLICATION:
DEWS **predictive model** built for Coffee to predict following disease on coffee farms 15 days in advance.

Automated workflows to trigger predictive and prescriptive intelligence for farmers, extension agents and the organization.

Early warnings and advisory **delivered digitally and seamlessly** through a digital platform that supports IVR, SMS PDF and video formats.

Climate Impact: Dec 2024
Coffee growing grids in **Chiapas** and **Tabasco** in **Mexico** that indicate areas that might have up to 50% impact on yield if the trends continue!



Technical Session III

Technical Session III: Strategies and Approaches for harnessing genetic diversity and agronomic innovations for improving profitability of farmers
Time: 4:45 PM-6:05 PM
Chair- **Dr. T. Mohapatra,** Chairperson, PPV&FRA
Co- Chair- **Mr. Ajeet Kumar Sahu**, Joint Secretary (Seeds), DAFW, MoAFW, Government of India
Rapporteur: **Dr. S K Tripathi,** Senior Vice President, Nuziveedu Seeds Ltd

04:45 PM- 04:55 PM		**Opening Remarks by Chair/Co-chair**	
SN	**Duration**	**Topic**	**Speaker**
1.	**4:55 PM-5:15 PM**	Microbiome based approaches for enabling seed, plant and soil health for realization of potential of Plant varieties.	**Dr. K. R. K. Reddy**, President BIPA and MD SRIBIO
2.	**5:15 PM-5:35 PM**	Seed production innovations for a resilient Indian seed industry	**Mr. G. V. Ramana Rao**, CTO, Ganga Kaveri Seeds
3.	**5:35 PM-5:55 PM**	Precision Farming to Improve Input use in Agriculture.	**Dr. Rabi N Sahoo,** Program Leader, Principal Scientist, Division of Agricultural Physics, ICAR-IARI
5:55 PM-6:05 PM		**Q&A and Closing Remarks by Chair/Co-Chair**	

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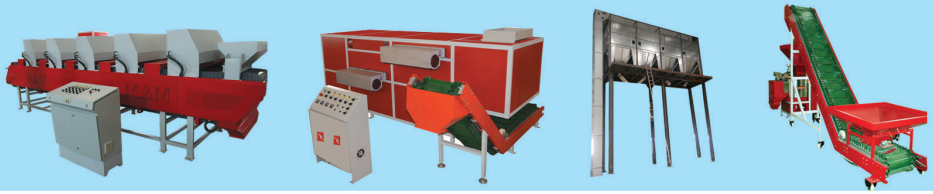

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- RAS - 6060-6TPH Weighmetric
- RAS - 3560-4TPH Voluemetric / Weighmetric
- RAS - 1560-2TPH Voluemetric
- RAS - 1060-1TPH & RAS - 560-0.5 TPH Manual

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CHAIR

DR. TRILOCHAN MOHAPATRA

Chairperson, Protection of Plant Varieties and Farmers' Rights Authority (PPVFRA), Ministry of Agriculture, Govt. of India, New Delhi

Dr. Trilochan Mohapatra is currently working as the Chairperson, Protection of Plant Varieties and Farmers' Rights Authority (PPVFRA), Ministry of Agriculture, Govt. of India, New Delhi. Prior to this, he worked for more than six years (2016-2022) as Secretary, Department of Agricultural Research and Education (DARE), Ministry of Agriculture, Government of India as well as the Director General of the Indian Council of Agricultural Research (ICAR). He worked for twenty years as a researcher and teacher at the National Institute of Plant Biotechnology (formerly National Research Centre on Plant Biotechnology), New Delhi. In the year 2012, he moved to the National Rice Research Institute (formerly CRRI), Cuttack, Odisha as Director, and then to Indian Agricultural Research Institute (IARI), New Delhi as the Director and Vice Chancellor in the year 2015.

As DG, ICAR, Dr. Mohapatra successfully implemented new programmes on gene editing, precision/digital agriculture, cloning of productive cows and buffalo bulls, large-scale *in situ* management of rice straw etc. His focus on biofortification led to development and release of more than 80 biofortified crop varieties, which occupied more than four million hectares area in the country. During his tenure, the production of pulses and sugar touched new heights with additional ten million tons each.

Dr. Mohapatra has over 200 research papers in national and international journals of repute. He initiated and developed Molecular Breeding research and strengthened this area through intensive capacity building. His research contributions include decoding of rice and tomato genomes through international partnership, and development of more than 15 crop varieties through effective collaborations. He has rich experience of serving national and international agricultural research and development organizations and professional societies as president/chair/vice-chair/member and helped development of programmes and policies. He has the distinction of receiving several honours and awards in recognition of his excellent academic and research contributions, which include DBT Bio-science Award, NASI-Reliance Industries Platinum Jubilee Award, NAAS-Tata Award and Shri Om Prakash Bhasin Award. Dr. Mohapatra is an esteemed Fellow of leading science academies of the country. He has been conferred doctoral degree (honoris causa) by twelve different universities.

CO-CHAIR

MR. AJEET KUMAR SAHU

Joint Secretary (Seeds),
DAFW, MoA&FW, GOI

Mr. Ajeet Kumar Sahu is a distinguished Indian Administrative Service (IAS) officer of the 2003 batch from the AGMUT cadre. Currently, he is appointed as the Joint Secretary (Seeds), Department of Agriculture & Farmers Welfare, Ministry of Agriculture & Farmers Welfare, Government of India.

In July 2023, he was appointed as Joint Secretary in the Department of Agriculture & Farmers Welfare, Government of India, where he handled sectors including Institutional Credit, Oilseeds, and Oil Palm.

Mr. Sahu has held various significant positions throughout his career. Notably, he served as the Chief Executive Officer of the Mata Vaishno Devi Shrine Board in Jammu from May 2015 to September 2017. He also held the role of Commissioner & Secretary in the Public Works Department in Leh & Ladakh from August 2020 to July 2023.

Mr. Sahu's tenure in Ladakh was marked by significant achievements, particularly in implementing the Jal Jeevan Mission, which provided safe and adequate drinking water through individual household tap connections to all households in the region.

In his current role, he continues to contribute to the agricultural sector, focusing on enhancing productivity and sustainability in oilseed cultivation and improving farmers' access to institutional credit.

Microbiome-Based Approaches for Enabling Seed, Plant, and Soil Health for Realization of Potential of Plant Varieties

DR. KRK REDDY

President BIPA and MD SRIBIO

Dr. KRK Reddy – A Pioneer in Agricultural Biotechnology and Sustainable Crop Solutions

Dr. KRK Reddy is a distinguished scientist and entrepreneur in the field of Plant Sciences and Agricultural Biotechnology. He obtained his **M.Sc. and Ph.D. in Plant Sciences** from **Kakatiya University, Warangal, India** and later pursued **post-doctoral research in Plant Biotechnology** at the **Central University of Hyderabad, India**, and the **University of Bayreuth, Germany**. His research has significantly contributed to the advancement of plant biotechnology, particularly in sustainable agriculture and biological alternatives to agrochemicals.

Founder of Sri Biotech Laboratories & Leader in Agricultural Biotechnology

In **1994**, Dr. Reddy founded **Sri Biotech Laboratories India Pvt. Ltd.** in **Hyderabad, Telangana, India**, with a vision to develop **safe and eco-friendly alternatives** for **crop nutrition and protection**. Under his leadership, the company's in-house **R&D division** gained national and international recognition, pioneering innovative **biological solutions** that seamlessly integrate with traditional farming practices.

Dr. Reddy's research primarily focused on developing **novel delivery systems** to enhance the efficacy of biofertilizers and biopesticides, ensuring their compatibility with conventional agricultural methods. His commitment to sustainable agriculture led to multiple **collaborative research projects under public-private partnerships**,

securing prestigious **national and international grants** for advancing **Agricultural Biotechnology**.

Contributions to Research, Policy, and Industry

With a passion for academic excellence, Dr. Reddy has mentored **numerous postgraduate and doctoral students** and has filed **several patents** in the field of agricultural biotechnology. He has actively contributed to **policy-making and research initiatives**, serving as a **Task Force Member** for the **Department of Biotechnology, Government of India**, particularly in the areas of **Biofertilizers and Biopesticides**.

Dr. Reddy is an esteemed member of **multiple national and international scientific societies, university boards, and biotech committees**. He has played a key role in shaping the future of agricultural biotechnology in India through his involvement with **industry associations**, including:

- **President, Bio-agri Input Producers Association (BIPA)**
- **Member, FICCI Telangana State Sub-Committee on Agriculture and Food Processing**
- **Member, CII Telangana State Task Force on Agriculture**

Awards & Recognitions

Dr. Reddy's pioneering contributions to research, innovation, and sustainable agriculture have been recognized at **state, national, and international levels**. He has received **multiple prestigious awards**, including:

- **Best R&D, Best MSME, Best Innovation, and Best Industry Awards**, presented by **Honorable Presidents of India**
- **Recognitions from former Presidents Honorable Dr. APJ Abdul Kalam and Honorable Smt. Pratibha Patil** for his groundbreaking work in **bio-intensive integrated crop management**

Current Leadership – Advancing Crop Microbiome Research

Currently, Dr. Reddy is the **Founder and Head of Sri BioAesthetics Pvt. Ltd.**, based in **Hyderabad, Telangana, India**. The company is at the forefront of **Crop Microbiome and Nano Research and Product Development**, addressing critical agricultural challenges and promoting **sustainable crop productivity**.

Through his **scientific vision, innovative approach, and entrepreneurial leadership**, Dr. Reddy continues to drive impactful advancements in **biological agriculture**, ensuring a **greener, more sustainable future** for global farming communities.

Abstract

The microbiome, comprising diverse microbial communities associated with plants and soil, plays a crucial role in enhancing agricultural productivity and sustainability. Harnessing microbiome-based approaches can significantly improve seed vigor, plant health, and soil fertility, thereby unlocking the full potential of plant varieties. These approaches leverage beneficial microbes to promote growth, enhance stress tolerance, and suppress pathogens, ultimately leading to improved crop yields and resilience.

Recent times, microbiomes gained importance in agriculture with special reference to seed health management through microbial seed coatings for better germination, and disease resistance, plant growth promotion through application of beneficial microbes for enhanced nutrient uptake and for overall soil health improvement.

The various strategies adopted to use microbiomes in agriculture include direct application of microbial inoculants, microbiome engineering to develop synthetic communities tailored to specific crops for enhanced productivity, soil microbiome restoration in degraded and contaminated soils, disease suppression to combat soil borne pathogens and imparting systemic resistance. These strategies and applications ensure yield enhancement and reduce dependency on chemical inputs leads to sustainable and resilient agriculture.

Besides the potential and prospects, the microbiome-based approaches offer several challenges such as microbial stability, field efficacy, and regulatory frameworks that need to be addressed. Advancements in metagenomics, AI-driven microbial selection, and precision agriculture will drive the future of microbiome applications in sustainable farming. Integrating microbiome-based strategies into modern agriculture is key to unlocking the genetic potential of plant varieties. By enhancing seed, plant, and soil health, these approaches contribute to resilient and sustainable food production systems. Continued research and technological innovations will further optimize microbiome applications, ensuring long-term agricultural sustainability and food security.

Seed Production Innovations for a Resilient Indian Seed industry

MR. G V RAMANA RAO

Chief Technology Officer,
Ganga Kaveri Seeds, Hyderabad

Mr. G V Ramana Rao is having about 4 decades of versatile experience in Indian Seed Industry.

He worked in different functions of Indian Seed Industry with exposure to various Agro-Climatic zones, Crops and Industry trends. This is instrumental for his deep understanding about Indian Agriculture in general and Indian seed industry in particular.

He served millions of farmers by supplying Quality Seeds during his service in various capacities- Indian and MNCs namely **EID Parry, Proagro, Spic, ITC, Advanta, Bayer BioSciences, Spriha and Ganga Kaveri Seeds.**

He started his career as Field Supervisor and became President and COO of a Seed Company through his Learning Skills, dedication, hard work and integrity.

He is a co-founder of Spriha BioSciences Private Limited.

He is also co-founder of two startup companies, now managed by his elder son.

He also served as a Member, Board of Studies in few premier educational institutions including Department of Botany (PG Courses in Botany, Agriculture Biotechnology & Horticulture & Landscaping) for 9 years as an external member.

He has delivered several guest lectures at National and International institutes, including ISTA-Hyderabad, CIMMYT-Nepal, Several SAUs and reputed Universities.

Before starting his professional career in Indian seed sector, Ramana Rao completed

two practical training Programs on Crop improvement in premium agricultural research institutes like **ICRISAT** and **AICRIP** (Presently Indian Institute of Rice Research **(IIRR)**).

He has started his new role as an **Organic Farmer** few years ago and has first-hand information about problems of Indian Agriculture and Farmers.

He has completed his **Master Degree in Plant Sciences** with Radiation Genetics and Cytochemistry as specializations from Andhra University, Visakhapatnam.

Introduction

High-quality seeds are one of the key components for the Green Revolution in India. High Yielding Varieties have significantly increased agricultural productivity and contributed to food security.

Seed Production is a complex process and involving various sequential activities. Of late, Seed Production is facing many challenges and requires careful management, innovations and new technologies to overcome these challenges. Some of the main challenges are as follows:

1. Soil Health
2. Nutrient & Water Management
3. Increasing Pest Incidence
4. Labour Availability
5. Climate changes
6. Seed Production Technology
7. Post Harvest Care

1). SOIL HEALTH

Soil health is the ability of soil to support plant, animal, and human life. Healthy soil is productive and it can recycle nutrients.

Soil is a complex mixture of minerals, organic matter, water, and air. Though, the composition of soil varies from area to area, it's made up of 45% mineral, 20-30% water, 20-30% air and 5% organic matter typically.

Soil degradation is happening rapidly and resulting in declining soil quality, which is caused by natural calamities and or man-made errors. This is leading to a loss of nutrients and organic matter, and a decline in the soil's ability to support plants.

Adapting different Soil Health Management Systems can lead to increased organic matter, more diverse soil organisms, reduced soil compaction and improved nutrient storage and cycling.

2).NUTRIENT MANAGEMENT & FERTIGATION

Nutrient management is the practice of applying various nutrients to grow crops efficiently while protecting the environment. Soil health can be maintained by using different nutrient sources and following different practices.

Organic manure, organic & biological amendments as well as mineral fertilizers add a range of nutrients along with organic matter.

They are a mixture of high-quality compost, Oil(Press) Cakes, Bio-stimulants, Beneficial microbes that provide lower doses of nutrients in a phased manner so as to make it effective over a longer period of time.

It also provides Organic Carbon that is crucial for improving carbon to nitrogen to phosphorus *(C:N:P)* ratio and nutrients availability. It also improves soil structure and soil health in the Rhizosphere of the crop.

It will also help in development of good plant microbes. As a result, it will prevent the loss of nutrients from chemical fertilizers applied by farmers.

Fertigation:

Due to Green Revolution, the fertilizer consumption in agriculture is increasing significantly. The traditional methods of application are resulting in wastage and have negative consequences for the local ecosystem.

One of the many practices of precision agriculture, fertilization is a highly adaptable and scalable practice that combines fertilizer and irrigation into a waste-averse system.

It has been a popular practice amongst farmers and agricultural professionals for several decades in many countries and regions. It is increasing efficiency and efficacy as it becomes incorporated with modern technologies that continue to streamline and automate the process. We need to propagate and implement these technologies in Seed Production areas as well to improve the crop growth in general and helps in nicking management.

Foliar Spray:

Foliar fertilizer is applied directly to leaves, while soil fertilizer is applied to the soil. Foliar fertilizer can be more efficient than soil fertilizer.

This method allows for the fertilizer to be quickly absorbed by the plant, which can quickly correct nutrient deficiencies and reach the plant's leaves directly. Foliar application can also be used to target specific parts of the plant, such as the fruit or flowers, which can be beneficial for certain crops. However, foliar application is typically more expensive and requires more precise application, hence this can be an option in case of nutrient deficiencies observed during seed production and a speedy way to improve the crop condition.

Farmers can choose the most cost-effective methods of foliar spray including Drone Spray for their crops and achieve optimal growth and yields.

3). SMART PEST CONTROL

Smart Technologies

Though, Seed Production growers are following various pest control operations including IPM methods, spraying pesticides is a common method of pest control. AI-powered systems streamline early pest detection and monitoring by using cameras and sensors to capture data such as heat, movement, and sound. Machine learning algorithms then analyse this data to identify pests and recommend targeted treatments accordingly.

Sensors deployed in fields collect data on environmental conditions, crop health, and pest activity. For example, temperature and humidity sensors can provide insights into favourable conditions for pest breeding, while plant health sensors can detect signs of stress caused by pest infestations.

Drones and Biocontrol

Drones equipped with high-resolution cameras and multispectral sensors offer another valuable tool for smart pest control. These drones can survey large agricultural areas rapidly, capturing detailed images of crops and identifying areas of pest infestation or crop damage. AI-powered image recognition algorithms analyse these images to distinguish between healthy plants and pest-affected ones, enabling targeted treatment strategies.

One innovative approach to smart pest control is the use of biocontrol agents, such as beneficial insects or microbial pesticides, in combination with precision targeting technologies. For example, drones equipped with micro-sprayers can deliver biopesticides directly to pest-infested areas, minimizing off-target effects

and reducing the overall quantity of pesticides used.

Integrated Pest Management

Furthermore, the concept of integrated pest management (IPM) lies at the heart of smart pest control strategies. IPM combines multiple pest control tactics, including cultural practices, biological control, and chemical interventions, to maintain pest populations below economically damaging levels while minimizing risks to human health and the environment. Technology serves as a powerful enabler of IPM by providing farmers with the data and tools needed to implement integrated pest management practices effectively.

4). LABOUR AVAILABILITY

Though, labour availability is high in Rural India , there is a significant gap in availability during peak Sowing, Detasseling, pollination and Harvest periods. Migration of workers from rural areas to cities and other areas for higher wages is happening in some areas.

Apart from this, the quality and skill level of the agricultural workforce in certain Seed Production areas is a matter of concern and needs to be address seriously.

We need to develop and adopt suitable machinery for small seed farms, optimize planting and harvesting schedules to manage the situation effectively. Based on affordability, we should also consider smart farming technologies like precision agriculture, AI based digital tools, drone technologies in certain crops.

5). CLIMATE CHANGE

Climate Change is Real and must be Acknowledged.

The Ministry of Earth Sciences (MoES) published the 'Assessment of Climate Change over the Indian Region,' in 2020, providing a comprehensive analysis of climate change's impact on the Indian subcontinent. The key findings from the report are as follows:

1. Between 1901 and 2018, India's average temperature increased by approximately 0.7 degrees Celsius.
2. The frequency of daily extreme precipitation events (rainfall intensities exceeding 150 mm per day) rose by about 75% from 1950 to 2015.
3. The occurrence and spatial extent of droughts in India significantly increased during the period from 1951 to 2015.
4. Over the last 25 years (1993-2017), the sea level in the North Indian Ocean rose at

a rate of 3.3 mm per year.

5. The Arabian Sea experienced a rise in the frequency of Severe Cyclonic Storms during the post-monsoon seasons from 1998 to 2018

The Indian government has been actively involved in efforts to tackle the effects of climate change and promote sustainability. One of the key initiatives, which is relevant to our Seed Production is Climate-Resilient Agriculture.

6). SEED PRODUCTION TECHNOLOGY

The following are some of the Climate-Resilient Seed production technologies that have been developed recently or are in the process of development.

- To develop and use Inbreds/Parents/Cultivars that thrive in advent climate
- Selection of Suitable Parents for Hybrid Seed Production
    - Photo-insensitive
    - Flag Leaf Angle
    - Zero Staggering
- New Breeding & Seed technologies for sustainable Seed Production
    - Gynoecious Cucurbits, TGMS in Rice, CMS in Corn et al
    - Alternative pollination strategies are required in the advent of Climate Change

The Indian seed industry should consider working together for effective development and implementation of these technologies.

Pollination is very critical in hybrid seed production due to transfer of pollen from one line to another that is essential for producing the desired combination between different genetic lines to produce a hybrid seed.

Alternative pollination strategies are required in the advent of Climate Change

7). POST HARVEST CARE

Post-harvest care in hybrid seed production is crucial as it directly impacts the quality and viability of the seeds, ensuring genetic purity, high germination rates. It also prevents contamination, mechanical damage, and losses during handling, drying, cleaning and storage, ultimately maximizing the value of the seed produced.

Harvesting at an appropriate time by considering seed maturity and development

is very critical for seed quality and longevity.

The following are the various steps and careful post-harvest management is at each and every stage to ensure good seed quality.

- Physiological : Maturity & Seed Moisture
- Biotic : Seed Borne Diseases & Pests
- Abiotic : Temperature & Relative Humidity
- Mechanical : Harvesting & Drying
- Transportation : Proper packing material & Time

CONCLUSION

We need to achieve The Sustainable Development Goals**(SDG)** by 2030. Industry and individual seed companies should work together to test, validate and implement new innovative technologies effectively in a phased manner.

The combination of established, time-tested agricultural practices with innovative technologies and methods is essential for resilient seed production. This balance ensures stability while allowing for adaptability to changing environmental conditions, pest resistance, and improved crop yields.

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Precision Farming to Improve Input use in Agriculture.

DR. RABI N. SAHOO

Principal Scientist, Division of Agricultural Physics, Indian Agricultural Research Institute (IARI), New Delhi

Dr. Rabi N. Sahoo, is working as Principal Scientist in the Division of Agricultural Physics, Indian Agricultural Research Institute (IARI), Indian Council of Agricultural Research (ICAR), New Delhi-110012, India and has more than 25 years of experience in research, teaching and capacity building in Remote Sensing & GIS and its applications in Agriculture.

His major research interest is Hyperspectral Remote Sensing and its applications in Agriculture, drone remote sensing, precision farming, plant phenomics and Digital Agriculture using sensors at ground, air and satellite platforms and was leading many national and international programs total funding more than Rs 175 Crores.

Currently, as ***Program Leader***, he is leading ICAR - ***Network Program on Precision Agriculture (NePPA) i***nvolving multidisciplinary team from 16 ICAR Institutes. Dr. Sahoo was also co-leading National ***Network Program on Imaging Spectroscopy and Applications***, (NISA) of DST having 37 research institutes covering different thematic areas of applications. He has guided 2 M.Sc. and 10 Ph.D. students and more than 30 students as Chair and Cochair of their advisory committee respectively.

Dr. Sahoo Developed state of art laboratories on hyperspectral remote sensing, Drone remote sensing, Big Data Analytics and National Facility on Plant Phenomics and recently experiential learning centre on Drone Robotics and Machine learning and 5G use Lab.

He has published more than 240 publications having 130 research papers in refereed national and international journals and mostly on remote sensing applications in agriculture. He has been expert member to various committees of NITI Aayog, Ministry of Agriculture & Farmers' Welfare, Department of Biotechnology and Department of Science & Technology (DST) and Indian Space Research Organization and ICAR research Institutes. **Dr Sahoo has been expert member of Working Group on Spectroscopy of DST and now a member of Working Group of Indian Council of Agricultural Research, New Delhi**

He was visiting faculty to University of Nebraska, USA, University of Saskatchewan and Dalhousie University, Canada and has been deputed to United Kingdom, Japan, China and Luxemburg, USA, Thailand, Canada, Kenya for participation and deliberation on cutting edge technologies for Smart & Precision Farming.

Technical Session IV

Technical Session IV: Innovations in seed health management and traceability
9:30 AM – 10:50 AM
Chair- **Mr. Ashish Bahuguna,** Former Secretary (Agriculture), MoA&FW, GOI
Co- Chair- **Dr. D. K Yadava,** DDG (Crop Science), ICAR
Rapporteur: **Dr. Sandeep Kumar Lal,** Principal Scientist, Division of Seed Science and Technology, IARI, New Delhi

9:30 AM - 9:40 AM		**Opening Remarks by Chair/Co-chair**	
SN	**Duration**	**Topic**	**Speaker**
1.	**9:40 AM-10:00 AM**	Seed based delivery systems using Biologicals and Nano technologies for improved stress tolerance and crop productivity	**Dr. Gyan Prakash Mishra** Head, Division of SS&T, IARI
2.	**10:00 AM- 10:20 AM**	Innovative approaches towards seed quality certification for promoting exports for a Globally competitive Indian Seed Industry	**Dr. K. Keshavulu,** Director, TSSOCA & President, ISTA
3.	**10:20 AM- 10:40 AM**	Seed Traceability in India: Leveraging the SATHI Portal for Transparency and Quality Assurance	**Dr. Dilip K. Srivastava** DC(QC), Seeds Division, DA&FW
10:40 AM-10:50 AM		**Q&A and Closing Remarks by Chair/Co-Chair**	

CHAIR

MR. ASHISH BAHUGUNA

Former Secretary (Agriculture),
Ministry of Agriculture and Farmers' Welfare,
Government of India

Mr. Ashish Bahuguna was appointed to the Indian Administrative Service in July, 1978 and retired in February, 2015 on superannuation. He has worked in the State Governments of West Bengal and Rajasthan, as well as in the Government of India, in various capacities in the fields of agriculture, rural development, education, textiles, tourism and financial management. He has about 20 years of experience of working in the food and agriculture sector in, both, the Central Government and the State Government and has held the posts of Joint Secretary, Additional Secretary, Special Secretary and Secretary in the Ministry of Agriculture in the Government of India. As a Joint Secretary in the Ministry of Agriculture he headed the Seeds Division of the Department of Agriculture & Cooperation.

Post retirement, Mr. Bahuguna was appointed for a period of three years as Chairman, Food Safety and Standards Authority of India till July, 2018. Currently, he is a Public Interest Director on the Board of National Commodity and Derivatives Exchange Ltd and also a member of the Board of Consumer Voice, an NGO dedicated to protecting the rights of consumers. He is also a Trustee of the Mobius Foundation, an NGO dedicated to promoting education for sustainable development. He has been intimately involved in the development and implementation of policies, programmes and schemes in all the sectors He has worked in with the active collaboration of other stakeholders viz industry, NGOs and other departments of the Government. He also had the opportunity of working with several international multilateral organisations such as FAO, UNDP, WTO, ESCAP and IJO and has served on the Board of ICRISAT, an international agricultural research institute. He also has experience in negotiating bilateral and multilateral trade and other pacts on behalf of the Indian Government.

CO-CHAIR

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Dr. Devendra Kumar Yadava, DDG (Crop Science), Indian Council of Agricultural Research, New Delhi was born on 10 April 1966 at Village Chandawas, District Rewari (Haryana). He did his B.Sc. Hons. (Ag.), M.Sc. (Plant Breeding) and Ph.D. from CCS Haryana Agricultural University, Hisar. He started his professional career in 1993 from CCS Haryana Agricultural University, Hisar. He served as Assistant Professor (Plant Breeding & Genetics) at Rajasthan Agricultural University, Zonal Research Station, Sriganganagar during 1996-2003, Senior Scientist and Principal Scientist (Plant Breeding) at Division of Genetics, ICAR Indian Agricultural Research Institute, New Delhi during 2003-2021; Head, Division of Seed Science and Technology, IARI, New Delhi during 2014-2021; simultaneously as Assistant Director General (Seed) Acting charge (2017-2021), Assistant Director General (NASF), Additional Charge (2021-2023) and Assistant Director General (Seed) from 2021-12 Feb, 2025.

Dr. Devendra Kumar Yadava has revolutionized brassica breeding and seed system in India. Dr. Yadava has significantly contributed in development of total 24 varieties including 21 of mustard and 3 of pulses, which include very early *juncea* varieties viz. Pusa Mustard-25, PM-27 and PM-28 to replace low yielding toria for September planting; timely sown varieties viz., RGN-48, RGN-13, Pusa Aditya, RGN-73, RGN-145, Pusa Vijay and PM-26 with heat tolerance, and seven low erucic acid (Pusa Mustard-21, PM-22, PM-24, PM-29, PM-30, PM-32, PM-34) and four Canola quality (Pusa Double Zero Mustard (PDZM) 31, 33, 35 and 36) varieties. PDZM 31 is country's FIRST Canola quality variety, branded as "INDOLA". As per the breeder seed indents, these varieties are occupying ~40% of mustard growing area in the country. He has guided three M.Sc. and eight Ph.D. students and published 103 research papers in peer-reviewed journals.

He contributed significantly in development of state seed rolling plans including new varieties and brought down varietal mismatches in breeder seed production from

34.7% in 2015-16 to 13.3% during 2022-23.He is contributing towards various policy issues viz., Guidelines for Genome Editing in crops, revision of Biological Diversity Act 2002, New Seed Bill, Revision of Seed Policy 1988 and Seed Control (Order) 1983, Online Seed Portal "Seed Authentication, Traceability, Holistic Inventory" and upscaling of biofortified varieties.

Dr. Yadava is recipient of Dr. Rafi Ahmad Kidwai Award and Dr. Rajendra Prasad Puruskar of ICAR; Dr. A.B. Joshi Memorial and Dr. B.P. Pal Memorial Awards of IARI, New Delhi; National Academy of Agricultural Sciences Recognition Award-2018 and Dr. K. Ramiah Memorial Award 2021-22 and Life Time Achievement Award and Dr. P.R. Kumar Brassica Outstanding Scientist Award 2017, SRMR, Bharatpur. He is Fellow of the National Academy of Agricultural Sciences (NAAS), New Delhi; Fellow, National Academy of Sciences India (NASI), Prayagraj and five other crop based societies. He has guided three M.Sc. and eight Ph.D. students and published more than 100 research papers in high impact factor journals.

Seed-Based Delivery Systems Using Biologicals and Nanotechnologies for Improved Stress Tolerance and Crop Productivity

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Dr. Gyan Prakash Mishra was born on March 3, 1978, in Varanasi, Uttar Pradesh. He earned his BSc (Ag) from Banaras Hindu University, Varanasi, and his MSc and PhD in Genetics from Indian Agricultural Research Institute (IARI), New Delhi. He pursued post-doctoral research at University of California, Riverside, and Purdue University, USA during 2010–2011. Dr. Mishra began his career at the DRDO-Defence Institute of High Altitude Research (Leh) as Scientist 'C' in 2007 and transitioned to the Indian Council of Agricultural Research (ICAR) in 2012. Since then, he has served ICAR in various capacities and is currently Head, Division of Seed Science and Technology at IARI, New Delhi.

Dr. Mishra has made significant contributions to the improvement of various crops through a combination of conventional and molecular breeding approaches. Of 12 varieties to his credit, four are in lentil, one in mungbean, six in okra (including one hybrid), and one in French bean. He has also developed five transgenics for tackling various biotic and abiotic stresses in groundnut and potato; and registered eight unique germplasms in lentil, mungbean, and garden pea. Furthermore, he licensed eight okra genotypes to seed companies and established a National Permafrost-Based Germplasm Storage Facility at Chang-La, Ladakh (17,586 feet AMSL) for the conservation of important germplasms as safety duplicates. Dr. Mishra also developed and commercialized an antioxidant-rich microgreen kit, "*TinyFields*."

He identified a *5-methylcytosine DNA glycosylase/lyase* in rice that demethylates the retrotransposon *Tos17*, promoting its transposition. His work includes mapping genes and QTLs for economically important traits like fertility restorer in rice; earliness, multi-flowering and seed size in lentil; YMV resistance in mungbean; resistance to stem rot, rust, and leaf spot diseases in groundnut, facilitating marker-assisted breeding.

Dr. Mishra has published over 150 research papers, reviews, and technical articles in reputed national and international journals. He has authored one book, edited three books, and contributed 44 book chapters, 11 bulletins, and 9 training manuals. He is the Fellow of National Academy of Agricultural Sciences (NAAS), Indian Society of Genetics and Plant Breeding (ISGPB), and Indian Society of Vegetable Sciences (ISVS). He has received numerous prestigious awards and honours, including DST-BOYSCAST Fellowship (2010), NAAS-Associate (2018), ICAR-Rajendra Prasad Award (2020), ISCA-Pran Vohra Award (2012), NAAS Recognition Award (2023-2024), IARI-Best student of the Year Award (2001), IARI-Ram Nath Singh Award (2019-21), ISGPB-8th Harbhajan Singh Memorial Award (2022), Member-NASI (2018), ISVS-Dr. Harbhajan Singh Memorial Award (2018), 5th Dr. P.N. Bahl Award (2020-21), Limca Book of Records (2007), ICARDA-Certificate of Recognition (2018), DRDO-National Science Day Award (2009), and CSIR Award for S&T Innovations for Rural Development (2010), among others. Dr. Mishra is a member of the International Seed Testing Association, Switzerland (2023), and the Central Seed Certification Board, Government of India (2024).

Abstract

Seeds are the carriers of technologies and significantly impact crop productivity. Seed-based delivery systems leveraging biologicals and nanotechnologies represent an advanced approach for enhancing stress tolerance and improving crop productivity. Of the several seed-based delivery systems, biologicals and nano technologies are the latest, with highly encouraging results. These systems integrate innovations in biotechnology, materials science, and agronomy, providing sustainable and efficient methods to boost agricultural output under stress-prone conditions. Seed-based delivery systems help mitigate various stress-related impacts, thereby enhancing crop productivity.

Introduction

As agriculture is facing mounting challenges from climate change, soil degradation, and resource scarcity, innovative solutions are required to sustain crop productivity and resilience. Seed-based delivery systems represent a cutting-edge approach to address these challenges by incorporating advancements in biology and nanotechnology. These systems enable the precise delivery of essential agricultural inputs directly to seeds, ensuring targeted action during the critical growth phases.

By leveraging beneficial microorganisms, bioactive compounds, and nanoscale carriers, these delivery systems not only enhance seed germination and seedling establishment but also improve plant tolerance to biotic and abiotic stresses (Mittal et al., 2020). Furthermore, this approach reduces reliance on synthetic agrochemicals, minimising environmental impacts while fostering sustainable farming practices. The integration of biological and nanotechnologies into seed treatments offers an unparalleled opportunity to revolutionise modern agriculture, providing farmers with tools to achieve higher yields and greater resilience in an increasingly unpredictable environment (Maswada et al., 2022).

1. Biologicals in Seed-Based Delivery Systems

Biologicals refer to products derived from natural sources such as microorganisms, plant extracts, or naturally occurring compounds. Biologicals, including beneficial microorganisms, (PGPRs, mycorrhizal fungi), biostimulants, and biofertilizers, play pivotal roles in improving seed performance and crop resilience under adverse environmental conditions. Biological seed priming is an advanced agricultural technique that improves the stress tolerance of plants by treating seeds with beneficial biological agents before sowing. Biological seed priming is an eco-friendly approach that reduces the need for chemical treatments, promoting sustainable farming practices. It is a cost-effective method to enhance crop resilience without significant additional inputs and a sustainable solution to ensure crop resilience in the face of climate challenges (Kumar et al., 2020a).

The bioagents trigger several physiological and biochemical changes, such as enhanced enzyme activity, accumulation of osmoprotectants, and activation of stress-related pathways. This results in improved seed germination, increased uniformity, and stronger root systems, which help in efficient water and nutrient uptake. Stress-related oxidative damage is reduced by the production of several antioxidants, which mitigates cellular damage. Further bio-seed priming induces epigenetic changes that activate stress-responsive genes, enhancing the plant's ability to cope with abiotic stresses. These changes result in better growth and yield of the plants, even under abiotic stresses (Raj et al., 2004). When applied through seed treatment, these biologicals offer targeted benefits:

(i) Beneficial Microorganisms: Rhizobia, mycorrhizal fungi, and **endophytic bacteria** enhance nitrogen fixation, nutrient uptake, and stress resilience (Kour et al., 2021; Rai et al., 2020). **Plant growth-promoting rhizobacteria (PGPRs) i**mprove plant hormone levels (e.g., auxins, cytokinins) and boost tolerance to abiotic stresses such as salinity, drought, and heavy metals (Lugtenberg & Kamilova, 2009). **Biocontrol agents p**rotect seeds from pathogens through competitive exclusion and induced systemic resistance (Keswani et al., 2016).

(ii) Biostimulants: Compounds such as **humic substances, seaweed extracts,** and

amino acids enhance germination rates, root growth, and stress tolerance (Colla et al., 2015). Application of biostimulants induces stress-responsive gene expression, leading to robust early growth and improved adaptation to environmental challenges (Rouphael & Colla, 2020).

(iii) Metabolite-Based Enhancements: Secondary metabolites such as phenolics and flavonoids derived from plant extracts activate antioxidant pathways, enhancing seedling resilience and mitigating oxidative stress (Balmer et al., 2015). Microbial metabolites like siderophores aid in iron acquisition, which is crucial for early plant development (Rajkumar et al., 2010).

Seed coatings with biologicals have shown significant promise in the following areas:

(i) Stress Tolerance: Microbial inoculants such as *Rhizobium*, *Azospirillum*, and *Trichoderma* are introduced to seeds to help plants withstand abiotic stresses, such as drought, salinity, and extreme temperatures. Biopriming with drought-tolerant microbes enhances root growth, water uptake, and the production of osmoprotectants like proline. While with halotolerant bacteria it reduces sodium uptake, improve the potassium-to-sodium ratio and ensure better ionic balance. Microbial biopriming minimizes the incidence of diseases by producing antimicrobial compounds and competing with pathogens for nutrients and space (Kumar et al., 2019). *Rhizobium* forms a symbiotic relationship with legume roots, converting atmospheric nitrogen into ammonia, a form that plants can readily absorb, thereby addressing soil nitrogen deficiencies (Chandrasekaran et al., 2021). *Azospirillum* promotes robust root system development and increases water absorption capacity by producing phytohormones, such as indole-3-acetic acid (IAA), which is especially advantageous under arid or nutrient-poor conditions (Bashan et al., 2014). *Trichoderma* contributes to the synthesis of antifungal compounds, enzymes, and secondary metabolites that suppress harmful pathogens, such as *Fusarium* and *Pythium*, while simultaneously activating the plant's innate defense systems to enhance resilience (Mukherjee et al., 2020). These microorganisms colonise the rhizosphere, producing growth-promoting substances, such as phytohormones (e.g. indole-3-acetic acid), and improving nutrient availability by solubilising phosphorus or chelating iron (Kumar et al., 2017).

(ii) Nutrient Efficiency: Biofertilizers play a crucial role in enhancing the availability and uptake of essential nutrients by plants. When integrated into seed coatings, these biological agents significantly improve nutrient use efficiency, enabling plants to thrive, even in nutrient-deficient soils. For instance, phosphate-solubilising bacteria (PSB) produce organic acids such as citric and lactic acid, which dissolve insoluble phosphate compounds in the soil and convert them into plant-accessible forms (Kumar et al., 2020b). Similarly, mycorrhizal fungi form symbiotic associations with

plant roots, extending the effective root surface area through the hyphal networks. This enhanced reach allows plants to access phosphorus and vital micronutrients that would otherwise remain unavailable in low-fertility soils. Remarkably, this symbiotic relationship can increase phosphorus uptake by up to 30%, providing a substantial boost to early seedling growth and overall plant development (Zaidi et al., 2017).

(iii) Disease Suppression: Biocontrol agents such as *Bacillus subtilis* and *Pseudomonas fluorescens* are effectively used as seed coatings to protect plants from soil-borne pathogens. They also help sequester heavy metals, reducing their toxicity to plants. *Pseudomonas fluorescens* is particularly notable for its ability to produce siderophores, which are molecules that tightly bind iron in the soil, making it unavailable to pathogens that rely on iron for growth and proliferation (Choudhary et al., 2007). This mechanism starves harmful pathogens of essential nutrients and effectively reduces their impact. On the other hand, *Bacillus subtilis* is renowned for synthesizing a diverse array of antifungal metabolites, including lipopeptides and antibiotics, which actively suppress diseases such as root rot and damping-off. Together, these biocontrol agents not only mitigate pathogen-related damage, but also enhance seedling vigour and overall plant health (Ongena et al., 2008).

(iv) Plant Growth Promotion: Biostimulants such as seaweed extracts and amino acids play a pivotal role in activating key metabolic pathways within seeds. These compounds promote the synthesis of enzymes, hormones, and other bioactive molecules, which are essential for early plant development (Shukla et al., 2018). Seaweed extracts, rich in natural growth regulators such as cytokinins, auxins, and gibberellins, stimulate robust root growth and enhance nutrient absorption. Amino acids serve as building blocks for proteins and signalling molecules, improving the efficiency of photosynthesis and stress response mechanisms. Together, these biostimulants strengthen root systems, increase chlorophyll production, and boost the resilience of plants to abiotic stresses, such as drought, salinity, and extreme temperatures. This cumulative effect not only improves plant health but also significantly enhances the overall yield potential (Bulgari et al., 2019). Thus, bio-primed seeds produce healthier plants with increased biomass, flowering, and fruiting, leading to higher crop yields.

Challenges in Biologicals based Seed-Based Delivery Systems: There are certain challenges in this technology like

(i) ensuring the long-term survival and activity of microbial inoculants under field conditions,

(ii) compatibility between seeds, microbial strains, and environmental conditions needs optimization,

(iii) standardized guidelines for the production and application of biopriming agents are essential for large-scale adoption and

(iv) scalability for large agricultural systems (Bashan et al., 2014).

In spite of these challenges, biopriming has immense potential for the sustainable development of agriculture by enhancing stress tolerance and crop productivity to meet the world's needs in a more eco-friendly way.

2. Nanotechnologies in Seed-Based Delivery Systems

Nanotechnology presents a transformative approach to improving seed-based delivery systems by enabling controlled and precise administration of agricultural inputs. Seed nanopriming is an emerging agricultural technology that integrates nanotechnology with seed priming methods to enhance plant stress tolerance and crop productivity. This innovative approach involves treating seeds with nanomaterials in controlled amounts to activate physiological and molecular mechanisms that improve plant performance under abiotic and biotic stress conditions. Seed nanopriming operates at the cellular level, where nanoparticles interact with seed tissues and influence various physiological processes (Mahakham et al., 2017). It enables the precise delivery of nutrients, agrochemicals, or biological agents at the nanoscale, improving their efficiency and reducing environmental impact (Nair et al., 2010).

(i) Nanoparticles (NPs): Nanofertilizers gives slow-release and targeted delivery of essential nutrients (e.g., zinc, iron) enhance seedling vigor by ensuring nutrient availability during critical growth stages (Prasad et al., 2014). Nanoformulated pesticides and herbicides provide protection against early-stage pests and weeds with reduced chemical load and minimal off-target effects (Kah et al., 2018). Stress-protective NPs are engineered nanoparticles (e.g., silica, titanium dioxide) enhance antioxidant enzyme activity, reduce oxidative damage, and improve water use efficiency under stress conditions (Lateef et al., 2016a).

(ii) Nanocarriers for Biologicals: Nanocarriers, such as chitosan, liposomes, and polymer-based particles, deliver bioactive compounds or microorganisms directly to the seed, ensuring controlled release and enhanced stability (Chen et al., 2020). Encapsulation of biologicals using nanotechnology protects them from environmental degradation during storage and enhances their viability during application (Rai et al., 2020).

(iii) Sensors and Coatings: Nanosensors embedded in seed coatings monitor soil conditions such as moisture, temperature, and nutrient levels, providing real-time feedback for stress management (Parisi et al., 2015). Smart coatings with temperature- or pH-responsive properties enable the release of agro-inputs under specific environmental conditions, optimizing seedling support (Liu & Lal, 2015).

Nanoparticle based protective seed encapsulation and its application in agriculture:

Through the use of nanoscale carriers, such as nanoparticles and nanostructured materials, active ingredients, such as nutrients, pesticides, or biostimulants, are encapsulated or bound to ensure their stability and gradual release. This protective encapsulation prevents the degradation of active compounds due to environmental factors, such as UV radiation, moisture, or microbial activity (Fincheira et al., 2023). Moreover, these nanoscale carriers facilitate targeted delivery, ensuring that the active ingredients reach the seed or the immediate soil environment with minimal waste. This precision not only enhances the efficiency of nutrient uptake and protection but also reduces the environmental footprint by minimising runoff and over-application of agrochemicals (An et al., 2022).

(i) Nano-Fertilizers: Nano-sized formulations of essential nutrients, including nitrogen, phosphorus, and zinc, offer a highly efficient approach to nutrient delivery in agricultural systems. These nanoscale formulations are designed to release nutrients in a controlled and sustained manner, aligning with the crop-specific growth requirements (Yadav et al., 2023). By slowing down the release rate, these formulations minimise nutrient losses that typically occur through leaching into groundwater or volatilisation into the atmosphere. For instance, nano-P particles remain available in the soil for extended periods, providing a consistent supply to plant roots. Similarly, nano-zinc formulations improve micronutrient uptake efficiency, which is critical for enzymatic function and overall plant health. This precision in nutrient availability ensures optimal support during critical growth stages, such as germination, flowering, and fruiting, ultimately enhancing crop productivity while reducing the environmental impact of traditional fertilisation practices (Yadav et al., 2023).

(ii) Nano-Pesticides: The encapsulation of pesticides within nanoparticles facilitates precise and targeted delivery to specific pests, which significantly reduces the quantity of active ingredients needed for effective control. This approach not only enhances the efficiency of pest management, but also minimises the potential for environmental contamination and non-target effects (Ali et al., 2024). Nano-pesticides are particularly advantageous for managing seed-borne and soil-borne pests, offering a more sustainable and efficient alternative to conventional pesticide applications.

(iii) Abiotic Stress Mitigation: Nanoparticles such as silica, titanium dioxide, and carbon nanotubes have demonstrated the ability to significantly enhance seed germination and bolster plant resilience to abiotic stresses including drought and salinity. These nanoparticles exert their beneficial effects by influencing key physiological and biochemical processes within plants. For instance, they improve

the water uptake efficiency, optimise the photosynthetic process for better energy capture and utilisation, and stimulate the activity of antioxidant enzymes. This combined action helps plants mitigate oxidative stress, maintain cellular integrity, and adapt more effectively to challenging environmental conditions, ultimately supporting healthy growth and development (El-Saadony et al., 2022).

Priming with zinc, iron, or silicon nanoparticles facilitates the efficient delivery of essential nutrients directly to seeds. This promotes better germination and early seedling vigour. Nanoparticles interact with seed cells to stimulate stress-responsive pathways. Nano priming with silicon nanoparticles enhances the expression of genes related to drought and salinity tolerance. Nano priming with silica nanoparticles also mitigates the toxic effects of high salt concentrations by improving ion homeostasis and reducing sodium uptake. The carbon-based nanostructures improve water uptake and retention, making plants more resilient to drought stress. Seeds primed with silicon or carbon-based nanoparticles exhibit enhanced water uptake, more profound root growth, and reduced water loss, enabling plants to survive under water-scarce conditions (Sharma et al., 2021). Furthermore, several nanoparticles induce the production of antioxidants, which help neutralize reactive oxygen species generated under stress conditions. This protects cellular components like membranes, proteins, and DNA from oxidative damage. Metallic nanoparticles like zinc oxide help seeds cope with heat stress by stabilizing proteins and enhancing antioxidant activity. Also, nano priming improves seed resilience against pathogens by activating systemic acquired resistance and stimulating the production of antimicrobial compounds (Lateef et al., 2016b).

The seeds treated with nanoparticles germinate faster and more uniformly, providing a strong start for crop growth. Nanoprimed seeds result in healthier plants with increased biomass, fruiting, and grain yield under normal and stressed conditions. By delivering nutrients and growth stimulators directly to seeds, nanopriming reduces the need for fertilizers and pesticides, making farming more sustainable and cost-effective. It also minimizes environmental impact compared to conventional chemical treatments. Thus, this technique aligns with global goals for sustainable agriculture by improving resource use efficiency and reducing agrochemical dependency (Khan et al., 2021). Controlled-release systems, which utilise advanced nanocarriers, such as liposomes, dendrimers, and polymeric nanoparticles, offer a highly effective method for delivering bioactive compounds. These nanocarriers are designed to release their contents gradually over an extended period, ensuring sustained and consistent delivery of the active ingredients. This controlled release mechanism not only prolongs the protective effects of the compounds but also enhances their efficacy by maintaining optimal concentrations at the target site. Additionally, this approach minimises the frequency of application, reduces

potential waste, and lowers the risk of environmental contamination, making it a more sustainable and efficient solution for agricultural and industrial applications (Lee et al., 2022).

Challenges in Nanotechnologies based Seed-Based Delivery Systems: There are specific challenges in using nanotechnologies through seed-based delivery systems. The foremost challenge is the potential toxicity of nanomaterials to the environment and human health, which needs to be ascertained. There is a need for clear guidelines and standards for the extensive use of nanomaterials in agriculture, particularly for large-scale adoption. Finally, developing cost-effective methods for large-scale seed nanopriming remains a challenge. Despite these challenges, seed nanopriming can revolutionize agriculture by enhancing stress tolerance and crop productivity. Ongoing research and technological advancements will likely address current limitations and pave the way for the widespread adoption of this innovative technique (Servin et al., 2015).

3. Synergistic Approaches: Combining Biologicals and Nanotechnology

The integration of biological agents with nanotechnology represents a ground-breaking approach in the development of advanced seed-based delivery systems. This synergistic combination leverages the strengths of both fields to maximise efficiency and effectiveness (Arora et al., 2024). For instance, nanoparticles can be employed to encapsulate beneficial microorganisms, significantly extending their shelf life by protecting them from desiccation, ultraviolet (UV) radiation, and other adverse environmental factors. Furthermore, nanomaterials serve as highly efficient carriers for biological agents, improving their adhesion to seed surfaces and enhancing their uniform distribution in soil (Zhang et al., 2024). This ensures that beneficial microorganisms are strategically delivered to the rhizosphere, promoting better colonisation and sustained activity, ultimately leading to improved plant health and productivity.

(i) Microbial-Nano Hybrids: Integrating microorganisms with nanoparticles amplifies their efficiency. For example, bioinoculants combined with silica NPs improve seed germination and stress tolerance under adverse conditions such as drought or salinity (Nair et al., 2010).

(ii) Seed Priming: Nano-priming with biologically active nanoparticles, such as biochar-loaded NPs or nanoclay composites, enhances seed resilience to stress by preconditioning seeds to withstand environmental challenges (Khodakovskaya et al., 2012).

(iii) Multi-functional Coatings: Seed coatings infused with both biologicals and nanomaterials provide sustained protection and growth stimulation, delivering

multiple benefits such as nutrient supply, pathogen resistance, and abiotic stress mitigation (do Espirito Santo Pereira et al., 2021).

4. Advantages of Seed-Based Delivery Systems

(i) Precision and Sustainability: Reduces input waste and environmental contamination by ensuring localized and efficient delivery of agro-inputs. Minimizes the application of synthetic agrochemicals, promoting eco-friendly farming practices (Sustainable Agriculture Reviews, 2020).

(ii) Enhanced Stress Tolerance: Promotes seedling survival and growth under abiotic stresses such as drought, salinity, and extreme temperatures. Induces stress-related gene expression and activates antioxidant pathways to protect seedlings from oxidative damage (Hasanuzzaman et al., 2020).

(iii) Improved Crop Productivity: Boosts germination rates, seedling uniformity, and early-stage vigor, which are critical for high crop yields. Enhances nutrient use efficiency, photosynthetic performance, and overall plant health, resulting in improved productivity under both normal and stress conditions (Chen et al., 2018).

5. Challenges and Future Directions

The compatibility of biologicals with nanoparticles and seed coatings requires careful optimization to prevent adverse interactions that could compromise their effectiveness. Additionally, regulatory challenges and public perception of nanotechnology in agriculture pose significant barriers to its widespread adoption. Ensuring the long-term stability and efficacy of nanoformulations and biologicals during storage and application is crucial to maximize their potential and establish their viability for sustainable agricultural practices (do Espirito Santo Pereira et al., 2021).

The development of multi-functional coatings tailored to specific crops and environmental conditions offers significant potential to maximize the benefits of seed-based delivery systems. Integrating these systems with precision agriculture tools, such as IoT and AI, can further optimize resource use and enhance stress management strategies. Exploration of biodegradable and renewable nanomaterials presents eco-friendly solutions that align with sustainable agricultural practices (Jampílek & Králíková, 2017). Additionally, advancements in genetic engineering can pave the way for biologicals with enhanced traits, such as improved resilience to environmental fluctuations and compatibility with nanocarriers, ensuring their effectiveness under diverse conditions.

Conclusions

The integration of biological agents and nanotechnologies into seed-based delivery systems represents a revolutionary advancement of modern agriculture. These

innovative systems not only enhance crop productivity, but also improve plant resilience to various stresses, aligning perfectly with the objectives of sustainable farming practices and global food security. By enabling precise, efficient, and environment-friendly solutions, they offer a pathway toward addressing critical challenges in agriculture, such as climate change and resource limitations. However, realising the full potential of these transformative technologies requires ongoing innovation, interdisciplinary research, and strong collaboration among scientists, policymakers, industry stakeholders, and farmers. Such collective efforts will be instrumental in scaling these solutions for widespread adoption, paving the way for a sustainable and secure agricultural future.

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Global Seed Certification Systems: An Overview

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Dr. K. Keshavulu is the President, ISTA, Switzerland, and Director, Telangana Seed & Organic Certification Authority, Hyderabad, India

He has worked in various capacities in the Government of Telangana, the State Agriculture University, the ISTA and associated with the several other international seed organizations and made significant contributions in the fields of agriculture in general and the seed industry in particular.

Dr. Keshavulu has more than 26 years of work and management experience in seed sector development, seed systems, quality assurance, policy support and regulations, plant genetic resources, building capacities and capabilities in the seed sector.

He has provided strategic vision and leadership to the Telangana Seed Organizations, resulted in exemplary growth in seed production certification, global networking and supplying for more than 10 states of India and also exporting to other countries.

Dr. Keshavulu is instrumental in initiating the International OECD Seed Certification for the first time in India and facilitated the seed exports to different countries from India, which is a landmark in the history of Indian Seed Industry for OECD seed certification.

He also contributed in bringing several seed policy reforms at national and state level and as a President of ISTA, he has been leading seed quality assurance and setting seed testing standards to meet the seed industry requirements at global level.

He has been recognised as a global seed leader and received several awards, including the M.S. Swaminathan Award and others, in recognition of his outstanding contributions. It is a matter of honour and pride that Dr. Keshavulu is the first ever person from Asia to become the President of ISTA. At the global level, he is striving to accomplish the mission of ISTA and knowledge of ISTA across the world in general and the Asia region in particular as well as supporting Indian seed sector globally.

Introduction

Ensuring global food and nutritional security remains one of the most pressing challenges of the 21st century. With the world population projected to reach 9.7 billion by 2050, agricultural productivity must increase significantly to meet rising food demands (FAO, 2021). Access to high-quality seeds plays a fundamental role in enhancing crop yields, ensuring resilience to climate change, pests and diseases, and improving overall agricultural sustainability. The seed market has transformed into a globalized industry, with international seed trade exceeding USD 15 billion in 2020 (International Seed Federation, 2021). The liberalization of economies and advancements in plant breeding technologies have significantly contributed to the growth of commercial seed markets. However, with increased cross-border seed movement, concerns regarding seed quality, regulatory compliance, and biosecurity risks have intensified (Tripp, 2001). In this context, seed certification has emerged as a key mechanism to ensure the genetic purity, physical quality, and genuinity of seeds, directly influencing crop performance and farm profitability. The globalization of seed markets, driven by technological advancements, commercialization, and trade liberalization, has further emphasized the importance of robust seed certification systems to regulate quality and facilitate international seed trade (OECD, 2020).

Seed certification is a systematic, legally sanctioned process that ensures the varietal identity, purity, and genuinity of seeds during seed production and multiplication. Effective seed certification programs safeguard farmers from counterfeit or substandard seeds, contributing to food security and economic stability (AOSCA, 2019). Several international and regional certification systems, such as the OECD Seed Schemes, the European Union (EU) seed certification framework, and the Association of Official Seed Certifying Agencies (AOSCA), regulate and facilitate the global seed trade. While these systems have improved seed quality worldwide, variations in certification protocols across regions pose challenges to harmonization.

Seed certification systems play a crucial role in maintaining the quality of seeds

in agricultural food production globally. These systems ensure that seeds are of high quality, disease-free, and genetically pure, contributing significantly to crop productivity and food security. Globally, seed certification systems are broadly classified into three major frameworks: (i) the OECD Seed Schemes, (ii) the AOSCA system, and (iii) the European Union (EU) certification system, with each serving a distinct purpose based on its geographic scope and regulatory characteristics. These systems collectively facilitate the international trade of seeds, ensuring consistent quality standards while addressing regional and local agricultural needs.

The OECD Seed Schemes:

The Organisation for Economic Co-operation and Development (OECD) Seed Schemes provides the international framework for the varietal certification of agricultural seeds moving in the international trade through International Seed Certification. The OECD Seed Schemes facilitates the international seed trade through globally recognized labels and certificates, which act as passport for seeds. Improves the seed quality regulatory system in the participating countries and thereby promotes quality seed production. These are most prominent international frameworks for seed certification, encompassing 64 member countries including India.

This system is mandatory and provides a benchmark for international seed trade. It encourages the use of high-quality seeds in participating countries and facilitates the movement of certified seeds across borders through authorized labels and certificates. The OECD Seed Schemes cover eight broad categories of seeds, comprising the rules and regulations applicable to eight groups of species constituting the eight Schemes, such as, Grasses and Legumes, Crucifers, and other Oil or Fibre Species, Cereals, Maize, Sorghum and Pearl Millet, Sugar and Fodder Beet, Subterranean Clover and Similar Species, and Vegetables. These rules and regulations define the technical standards developed by seed certification specialists in participating countries in close co-operation with other international seed-related organisations, such as the FAO, ISF, ISTA and UPOV. Many regional seed organisations also participate in the development of technical standards (https://www.oecd.org/). The schemes are designed to harmonize certification standards across countries, improving the regulatory framework for seed quality and thereby boosting international seed trade (OECD, 2020).

In the 2019-2020 period, approximately 1.2 million tonnes of seed were certified under the OECD framework. The largest seed producers within the OECD system were Serbia, France, and Egypt, contributing 143,000, 142,000, and 132,000 tonnes of certified seed, respectively. Europe is the dominant continent in seed certification production, followed by Africa, North and South America, while Asia remains the

least producer in this global context. Leading crops that are certified through the OECD system include maize, wheat, sunflower, barley, and sorghum (OECD, 2020). By promoting high standards in seed production, the OECD Seed Schemes contribute not only to agricultural productivity but also to enhancing the global seed market.

AOSCA Seed Certification System

The Association of Official Seed Certifying Agencies (AOSCA) operates a non-compulsory seed certification system that is widely adopted in countries such as the United States, Canada, Argentina, Brazil, Chile, Australia, New Zealand, South Africa, and India, among others. AOSCA is a pioneer in modern-day seed certification, having played a foundational role in establishing seed quality standards across several nations, including India. The system promotes the coordinated efforts of official seed certification agencies to facilitate the movement of seeds in local, national, and international markets. AOSCA's role in developing seed certification standards, regulations, and procedures helps to streamline seed production and trade, ensuring that seeds are of high quality and free from contamination. It works closely with the OECD to expedite the movement of seeds in international trade, aligning with OECD's standards to ensure uniformity in seed quality across borders. Through these coordinated efforts, AOSCA plays a crucial role in enhancing the availability of high-quality seeds for farmers, fostering agricultural growth, and promoting global seed trade (AOSCA, 2020).

AOSCA's certification is a voluntary system, but its widespread adoption across different countries has made it a crucial component of seed trade and agriculture worldwide. The association's involvement in the development of seed certification regulations, policies, and standards, in collaboration with organizations such as the OECD, ensures uniformity in seed quality across borders.

This collaboration has enabled the development of clear and harmonized procedures that expedite seed movement globally, benefiting farmers who rely on certified seeds to improve crop yields (AOSCA, 2020). By aligning with the OECD's standards and regulations, AOSCA ensures that its certification processes remain relevant and effective in facilitating international seed trade, ultimately promoting agricultural growth.

The AOSCA's system allows countries to adopt seed quality regulations tailored to their specific agricultural needs. This flexibility is crucial in countries like India, where diverse environmental and climatic conditions demand customized solutions for seed production and certification. As a result, AOSCA's system has proven to be an essential framework for nations looking to establish or strengthen their national

seed certification systems, promoting global agricultural sustainability and fostering the movement of high-quality seeds in international markets.

European Union Seed Certification System

The European Union (EU) has developed a robust and comprehensive seed certification system designed to ensure the quality, health, and genetic purity of seeds and propagating materials across its 27 member states. This unified system regulates the marketing of seeds for a wide variety of agricultural, vegetable, forest, fruit, ornamental species, and vines. Distinguishing aspect of the EU's seed certification system is the compulsory registration of seed varieties and the mandatory certification process, which guarantees that seeds sold within the region meet high standards of genetic integrity and disease-free status. The system is designed to provide farmers with the confidence that they are purchasing seeds that are of good quality, genuine, reliable, and well-suited to their specific growing conditions. Another crucial element of this system is the principle of EU seed equivalence, which permits seeds produced outside the EU to be marketed within the region, provided they meet the same strict quality standards applied to EU-certified seeds. This means that seed exporters from countries with EU equivalence such as Argentina, Australia, Canada, Israel, Japan, the United States, South Africa, and others can supply seeds to the EU market, ensuring that the trade remains open while maintaining high quality and health standards. By allowing for this international exchange, the EU fosters a global seed trade that is both competitive and transparent, benefiting farmers within as well as outside the EU while supporting the agricultural development.

The EU seed certification system is supported by 12 specific directives that cover a wide array of crops, from agricultural cereals and vegetables to forest species, vines, and fruit trees. These directives standardize the rules and requirements for seed production, marketing, and certification across the region, ensuring that seeds are of consistent quality no matter where they are sold. This system not only ensures that seeds marketed within the EU are genetically pure and free from seedborne pathogens, but it also streamlines the process for farmers and distributors, reducing complexity and enabling the free movement of certified seeds across borders within the EU. While the EU's seed certification system is comprehensive and compulsory, it also offers flexibility. Member states are allowed to introduce additional measures or regulations tailored to their specific agricultural needs and regional conditions. This adaptability ensures that the certification system can accommodate varying environmental conditions, pest pressures, and crop requirements unique to each member state. It allows for a more tailored approach to seed certification while still adhering to the overarching EU framework.

Seed Certification in Africa and Regional Harmonization

In Africa, seed certification systems are diverse, with many countries having national seed policies, laws, and regulations to govern seed production and marketing. However, some African countries, such as Mozambique, Cape Verde, and the Democratic Republic of the Congo, do not have formal seed laws or regulations. To address this, regional economic blocs like the Common Market for Eastern and Southern Africa (COMESA), ECOWAS, and SADC have developed seed regulations to harmonize seed certification standards across member states. The East African Community (EAC) has also undertaken efforts to harmonize seed regulations among its six member states. These regulations cover key areas such as variety release, seed certification, and phytosanitary control, promoting the free movement of certified seeds within the region. These regional initiatives are vital for enhancing intra-Africa trade in seeds and ensuring that farmers across the continent have access to high-quality seeds that meet international standards (EAC, 2020). Many other regions, such as Central America, the Mercosur countries, and African communities including the East African Community (EAC), Southern African Development Community (SADC), and Economic Community of West African States (ECOWAS), have adopted or are in the process of implementing similar regional seed regulations. These regional frameworks aim to facilitate seed trade within their respective areas while maintaining quality control, promoting cooperation and trade between regional markets.

Seed Certification in the Asian Region

The Asian region presents a mix of voluntary and compulsory seed certification systems, with countries adopting different approaches based on their agricultural needs and regulatory frameworks. In countries such as India, Nepal, China, Thailand, and Cambodia, seed certification is voluntary, and labelling is compulsory. However, there is a lack of pre- and post-control testing, which raises concerns regarding seed quality assurance. In contrast, countries like Pakistan and Bangladesh have mandatory certification for specific crops such as wheat, paddy, and corn. In Japan, seed certification is voluntary, but seed health testing is mandatory to ensure that seeds are free from diseases. The Republic of Korea, the Philippines, and Indonesia have adopted compulsory seed certification systems, which include varietal registration and mandatory pre- and post-control testing. These countries emphasize the importance of maintaining seed health and genetic purity, aligning with global standards for seed certification.

In countries like India has adopted OECD Seed Schemes, whereas, in some counties, making efforts to participate in the OECD Seed Schemes, which aim to promote the international trade of seeds by harmonizing certification standards across

OECD Seed Schemes participating countries. India's participation in OECD seed schemes reflects a growing recognition of the importance of integrating into global seed markets and adhering to internationally accepted certification practices. However, the lack of uniformity in seed certification systems across Asia presents both challenges and opportunities. On one hand, the absence of comprehensive seed quality assurance systems in many countries can hinder the development of a reliable and competitive seed sector. On the other hand, the varying certification models allow countries to tailor their regulatory frameworks to their unique agricultural needs. For instance, countries with large-scale rice or wheat production may prioritize certification for these crops, while others with diverse horticultural or fruit sectors may focus on different varieties.

Therefore, to improve the seed certification systems across the region, it would be beneficial for countries to adopt more standardized and science based regulatory frameworks. There is also a need for greater regional cooperation to harmonize seed certification standards, which would facilitate cross-border trade and improve overall seed quality across the continent. Strengthening collaboration through regional bodies, such as the Asia and Pacific Seed Association (APSA) or through initiatives like the OECD Seed Schemes, can help address the challenges of seed quality and contribute to agricultural growth and food security in Asia. There is significant potential for harmonizing seed certification standards and improving regional cooperation to enhance the quality and availability of seeds, which in turn would contribute to agricultural development, food security, and the growth of international trade in seeds.

Conclusion:

Seed certification systems are integral to global agricultural productivity and seed trade. By ensuring that seeds meet stringent quality standards, these systems serve as a crucial safeguard against the spread of plant diseases, genetic contamination, and other factors that could negatively affect crop yields and food security. The OECD, AOSCA, and EU frameworks have been at the forefront of fostering international cooperation and harmonizing seed certification practices, creating a global environment where seeds of high quality and reliability can be traded across borders. In addition, the regional initiatives in areas such as Africa are making significant strides toward harmonizing seed certification standards to facilitate trade within and between these regions. In Africa, the efforts of organizations like the East African Community (EAC), Southern African Development Community (SADC), and Economic Community of West African States (ECOWAS) are instrumental in aligning seed certification systems and promoting regional agricultural integration. In Asia, countries are adapting their own certification frameworks, with a combination of voluntary and mandatory systems designed to meet the unique needs of their

diverse agricultural conditions. These regional efforts not only enhance trade within these continents but also provide farmers with access to high-quality seeds that are essential for addressing the challenges posed by climate change, population growth, and ever-changing market demands. As global food security challenges continue to grow, the importance of robust seed certification systems becomes even more important. High-quality seeds are fundamental to ensuring food security, improving yields, and achieving sustainable agricultural growth that can meet the needs of a rapidly growing global population.

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Seed Traceability in India: Leveraging the SATHI Portal for Transparency and Quality Assurance

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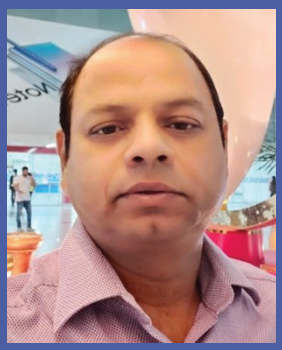

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Later he joined Directorate of Pulses Development, DA&FW, Govt. of India. He worked on Crop Development/Seed Development, Monitoring and evaluation Centrally Sponsored/Sector Seed development schemes.

He then shifted to National Seed Research and Training Centre, Central Seed Testing laboratory, Varanasi as Senior Seed Analyst. His work pertaining to Seed Testing, Seed Certification, Seed Quality Regulation, Monitoring of Seed Law Enforcement across the country and Organization of National Level HRD programs/Congress/ Workshops on seed related issues.

Since 2014, Dr. Srivastava working in Head Quarter, Ministry of Agriculture and

Farmers' Welfare, New Delhi as Deputy Commissioner (Seeds-QC). His work is focused on Seed Development Programs, Certification of Seed, and Seed law enforcement across the country, Seed Testing and Quality control of Seeds.

Dr. Srivastava is Member Secretary of following National Level Committees: Central Seed Committee, DAFW; Central Seed Certification Board (CSCB), Govt. of India. DAFW; Committee for developing Seed Certification standards of other crops including aromatic and medicinal plants; National Task Force on OECD varietal Scheme; Committee for fixing MSP of Bt Cotton Seed under Cotton Seeds Price Control (Order)-2015; Central Sub-Committee on Crop Standards, Notification and Release of Varieties for Agricultural Crops and Horticulture Crops and Co-convenor of state's committees of similar nature.

Dr. Srivastava is also the member of Board of Directors of State Seed Certification Agencies across the country.

Abstract

Seed certification is a quality assurance system whereby seed intended for marketing is subject to quality control and inspection. The Government of India is embarking on a transformative endeavor, the Seed Traceability Project, to build a Digital Ecosystem, to effectively monitor the seed production and distribution chain and to provide complete traceability of the seeds from point of origin till sale. A Centralized Online System for Seed Traceability by the Department of Agriculture & Farmers Welfare (DA&FW). This system encompasses a comprehensive array of features designed to ensure the utmost efficiency, transparency, and quality assurance throughout the seed production chain. Key components of the Seed Traceability Portal include the implementation of QR codes printed on seed packets, facilitating quality assurance and tracking of spurious seeds. The system integrates seven verticals of the seed chain, spanning research organizations, seed certification, licensing, inventory management, sales, and subsidy disbursement. Through this framework, only seeds with valid certification can be sold by licensed dealers to registered farmers, who receive subsidies directly in their pre-validated bank accounts via Direct Benefit Transfer (DBT). Moreover, the system enables real-time monitoring and automation of various processes, from seed certification to inventory management, dealer registration, and license issuance. Each seed packet is tagged with a QR code/barcode containing essential information such as source details, grower information, production details, and relevant regulatory compliance

data. Crucially, the Seed Traceability system harnesses blockchain technology to ensure tamper-proof records and uniformity across the nation. State-specific server nodes communicate with a central blockchain server, enabling secure and immutable data storage. By enhancing traceability and accountability, this initiative promises to revolutionize the seed industry in India, fostering a paradigm shift towards greater transparency and efficiency. To monitor these events an online portal has been already developed and in use with a name SATHI. Purpose of the SATHI Portal is development and hosting of a national portal for Automation of the entire life cycle of seeds which includes Seed Certification, seed traceability and seed supply chain for all the states of India.

Keywords: Seed traceability, SATHI Portal, Seed Certification, seed supply chain, Quality Seed,

Introduction

India is an agricultural country and the agriculture sector has always been a powerful means of strengthening the economy of our country. About 60% of the population of our country gets livelihood from this sector. The changing times have raised a new hope in the minds of the farmers **(Singh & Kadam 2024)**. The farmer has now become prosperous, empowered and self-dependent, and this has become possible because in the last few years, under the leadership of Prime Minister Shri Narendra Modi, the Government of India has not only thought seriously and sensitively about the farmers, but has also taken many welfare measures. Due to the policies and schemes of the government, today the farmers are happy and prosperous. His life continues to prosper. To make the country a superpower, it is very important to make the farmers strong and the government is working fast in this direction.

From seed to market, programs like One Nation-One Market, Per Drop-More Crop, Healthy Earth-Green Farm, One Nation-One Fertilizer have also empowered the farmers. With the use of solar energy, Indian farmers are now known not only as 'Annadata' but also as 'Urjadata'. The agriculture sector heavily depends on the availability and supply of quality seeds for a bumper crop. In fact, improved quality seed is an important factor in increasing farm productivity, making farmers prosperous and providing food security. In this direction efforts have been made by the Government of India to increase the quantity and quality of improved seeds with timely policy programs and modern agricultural technologies.

Seed supply chain is a complex ecosystem involving various stakeholders making it cumbersome to validate several important criteria such as origin of the seed, stages in production, conformance to quality standards such as genetic purity, germination

rate etc. Spurious and low quality seeds enter into the seed supply chain at various stages. Issues related to seed quality has established a need for effective traceability solution. Therefore, Govt. of India has developed a Centralized Online System for Seed Traceability for effective monitoring, efficiency and transparency in seed production and distribution chain **(Dhanya et al., 2024)**.

Seed Authentication, Traceability and Holistic Inventory (SATHI) is a user-oriented centralized portal, envisioned and created by the Ministry of Agriculture and Farmers' Welfare, Govt. of India, in partnership with National Informatics Centre (NIC). SATHI provides a holistic approach to encompass the complete seed life cycle over multiple seed generations. This measure is achieved through automation of the entire seed supply chain, starting from seed production to certification, licensing, seed Inventory, and seed sale by certified dealers to seed growers and includes traceability of seeds.

SATHI portal will ensure quality assurance system and to track the spurious seed in Seed Production Chain. This system will include integrated six verticals of seed chain (Fig.1) viz. Research organization, Seed certification, Seed licensing, Seed inventory, Dealer to farmer sale, Integration with Farmer Database. Seed with valid certification only can be sold by valid licensed dealers to the centrally registered farmers who can get subsidy directly in their pre-validated Bank Accounts through DBT **(Ahuja et. al., 2024).**

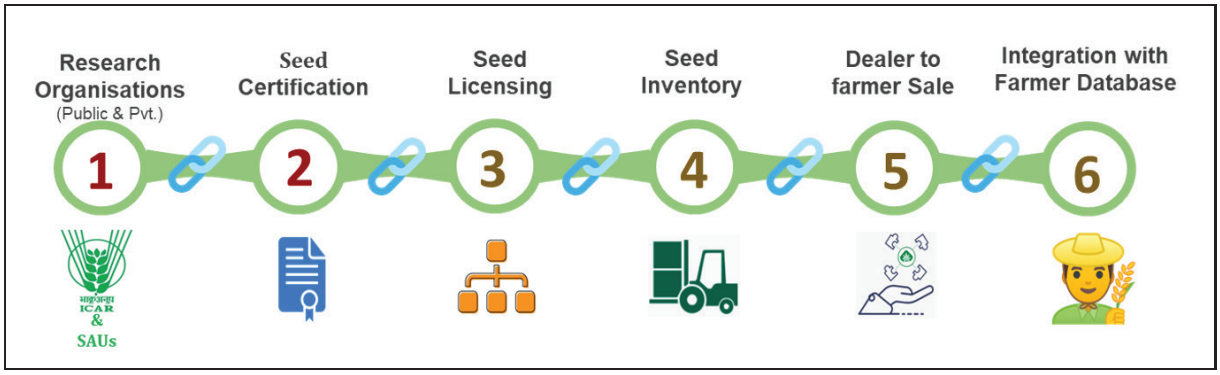

Fig.1. Integrated Six Verticals of Seed Chain

Benefits of the Seed Traceability are identification of a seed source, variety and quality, Automation of manual processes of indent submission, allocation, allotment, lifting etc. for breeder seeds, Real time monitoring of demand, allocation and supply of breeder seeds, Automation of seed certification system involving registration, inspection, testing, certificate issuance, Monitoring of seed inventory and sale to farmers, Automated registration of seed dealers, application renewal and license issuance **(Salah et. al., 2019).**

Farmers and other stakeholders will be able to scan QR Code printed over the packet / bags of seed with their mobile phones and get information regarding Crop, Variety, Source details of Nucleus – Breeder – Foundation Seed, Grower's details, Month-year-code, Production location code, Seed Testing Laboratory Detail, Processing Plant Code, Seed Produce Code, any other mandatory information as per, Environmental Protection Act, 1986 in case of GM/Bt. Cotton etc.

SATHI will

1) Enhance and ensure the quality and purity of seed through the complete digital platform for the seed life cycle
2) Increase accountability with the help of seed traceability through multiple modules
3) Improve the on-field efficiency of SCI by reducing human error and integrating technology into the system
4) Generate GIS-based MIS reports powered by Bharat Map Interface (Fig.2)
5) Reduce transactional time for registration, approval, access to field inspection reports, lab testing reports, and certification
6) Provide an eco-friendlier alternative to carry out operations

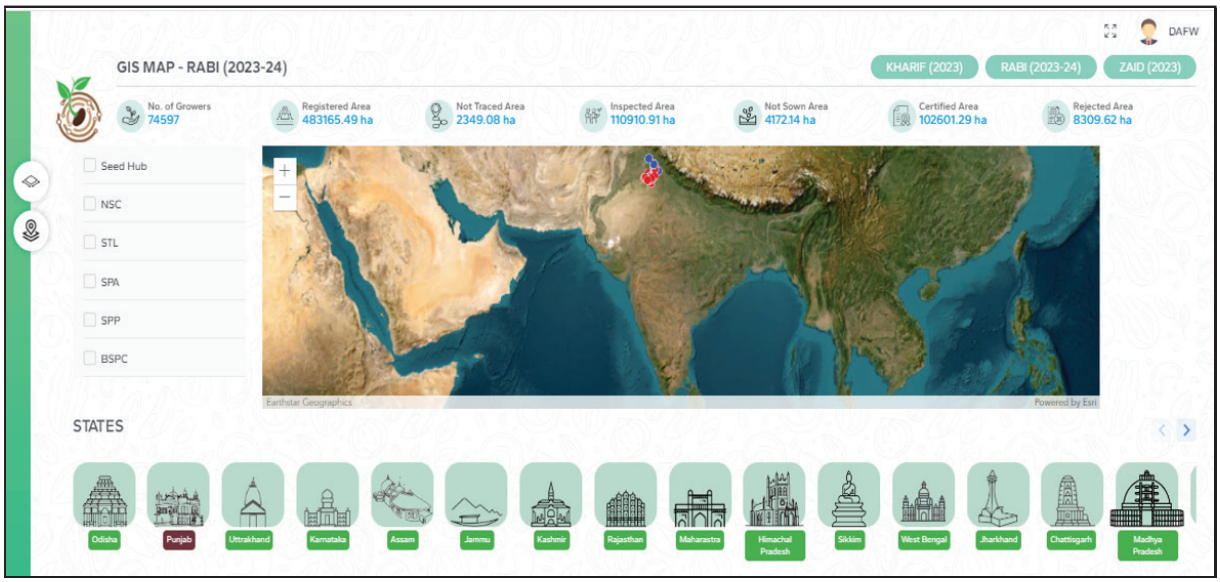

Fig.2 GIS-based MIS reports powered by Bharat Map Interface.

Some of salient features of SATHI which will take seed production and inventory to new heights are:

1) GIS Report based on Bharat Map Interface.
2) Provision of wallet service.
3) Offline friendly and device agnostic mobile application.
4) Quality inspection for the quality check of the inspection process.
5) System generated sample slip on processed verification data.
6) Online forwarding of the samples to seed testing laboratory.
7) Issuing of tag certificate based on digital tag register.

SATHI encompasses following *four modules* based on different stages of Seed Production and Distribution:

1. **Nucleus to Breeder Seed Management: (Fig.3)**

SATHI assists in executing the following with ease by integrating the following to its system:

1) Breeder Seed indent generation to ICAR, SAU, Breeder Seed Production Centre.
2) Registration of Breeder Seed Production Centre.
3) Allocation of breeder seed through programmed functionality.
4) Issuing of Breeder Seed Labels.
5) Lift allocated breeder seed by indenters.
6) Registration of indenters and submission of indents.

2. **Breeder to Certified Seed Certifications: (Fig.3)**

SATHI allows to access and handle all the data from any device, from anywhere by having the following features in its module:

1) Registration of Seed Grower, SPA & SPP
2) Verification of seed source, class and other requirements of the seed used for raising the seed crop.
3) Field inspections to verify seed to the prescribed field standards using offline mobile app.
4) Processing and verification of breeder seed (can be merged and told that data will be uploaded into database.)
5) Sampling, testing and issue of tag for breeder seed.
6) Billing and Accounting module to process information related to management of fees and pro forma updates.
7) Permission module to allow SPAs/ SPPs for interstate permission, small size bag allocation, venturing with other marketing firms.

8) Applying unique and distinct tags to the lots by the help of Tag Register.
9) Reducing wastage of breeder seeds from foundation to certified seeds by Downgrading of Lot-Class.

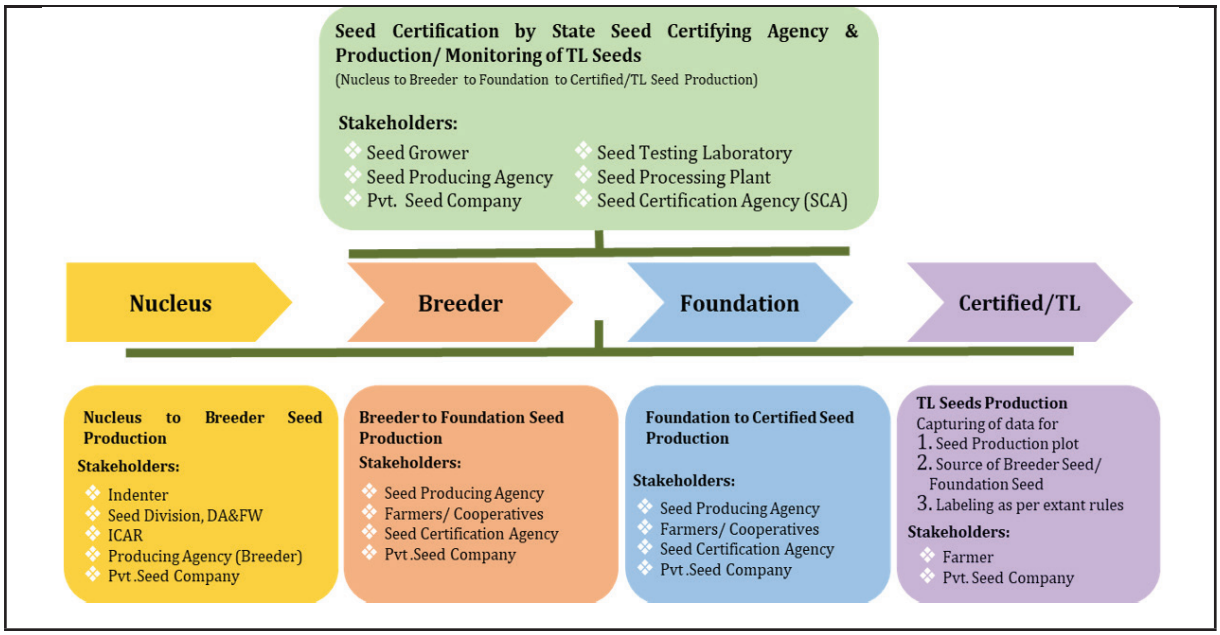

Fig.3. Phase 1 Explaining the movement of Seed during Nucleus Seed to Certified Seed

3. **Seed Dealership (Fig.4.)**

SATHI keeps an extensive record of all the transactions and has auto generated slips in place which ensures following:

1) Ease of doing business between the State level dealer and District level dealer with the help of Dealership Application Module.
2) Issuing of source certificate to district level dealer.
3) The sale of quality and certified seeds by Field Inspection using offline mobile app.
4) Dealers can be held responsible for not following the directives from Block Agriculture Officer with the help of Geo Tagging of Sale Point.
5) Issuance, Return and Rejection of licence for seed dealers.
6) Seed dealers can apply for amendment in their issued licence.
7) Authorization for suspension, revocation and cancellation of seed dealer licence.

4. **Seed Inventory: (Fig.4.)**

SATHI, with its intensive, accurate and up to date records makes tracking and dispatching of inventory easier in following way:

1) Effective way to record and maintain inventory accurately and efficiently with the help of stock management.
2) Inventory that can be easily adjusted when seed lots are damaged by auto blocking of defective los.
3) Availability of livestock report to provide better supervision and management of the seed lots.
4) Management the inventory alongside accounting in one integrated system.
5) Management inventory counts with stock count sheets and reconciliation

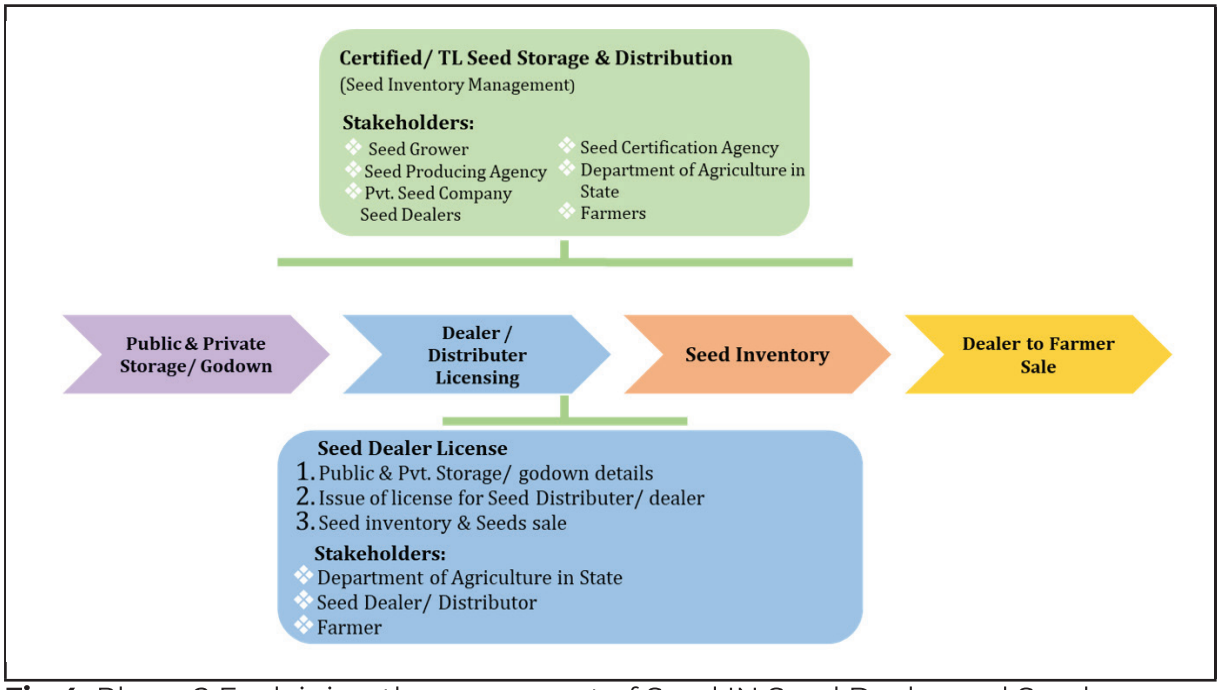

Fig.4. Phase 2 Explaining the movement of Seed IN Seed Dealer and Seed Inventory

This system will help make available quality seed to farmers and make them digitally empowered in tracing the source of seed and keeping spurious seed out of the market. SATHI portal will be Single Nationwide Unified Eco-friendly Digital portal for entire seed value chain **(Liao & Xu 2019).**

Discussions

To make it more efficient, transparent and for effective monitoring and Seed Traceability, Government will develop a web & tablet/mobile based online application

system for the entire life cycle of seeds which includes Seed Certification, Seed Traceability and seed supply chain. Blockchain technology will be used for seed traceability

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Supplementary Photos

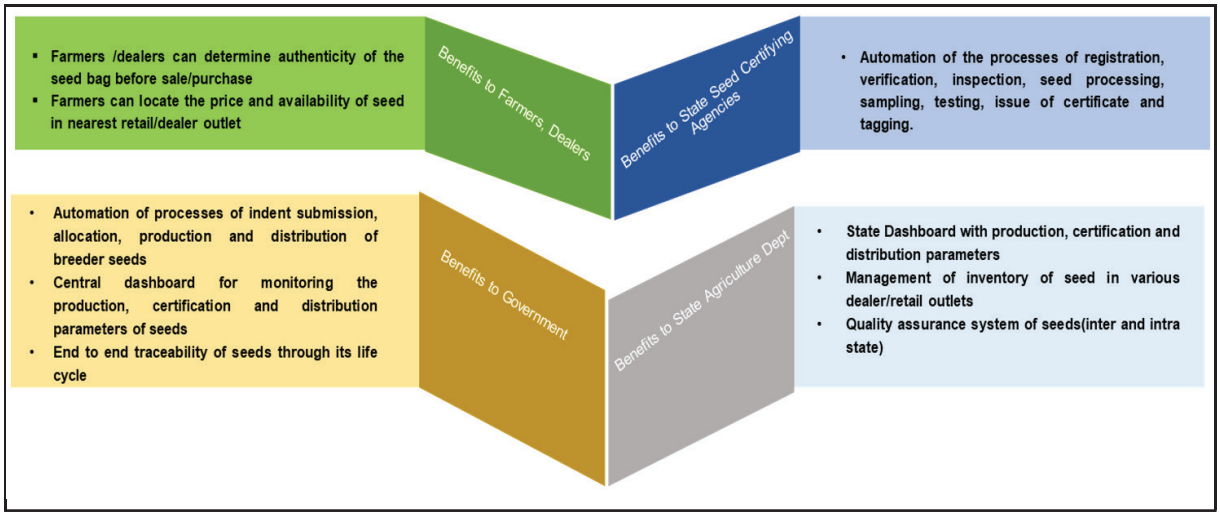
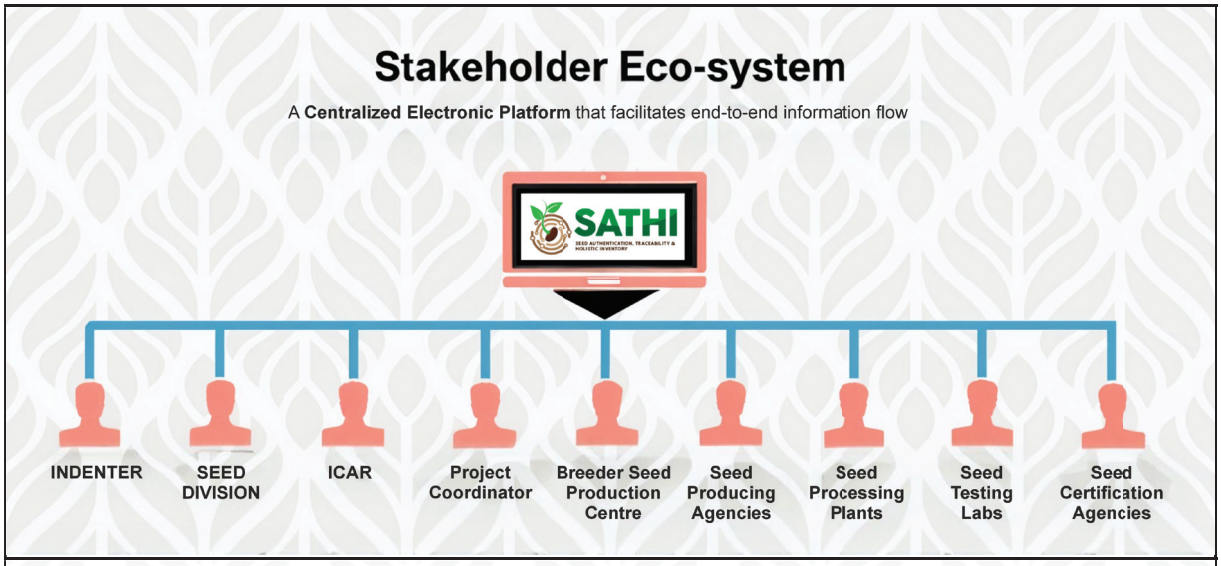
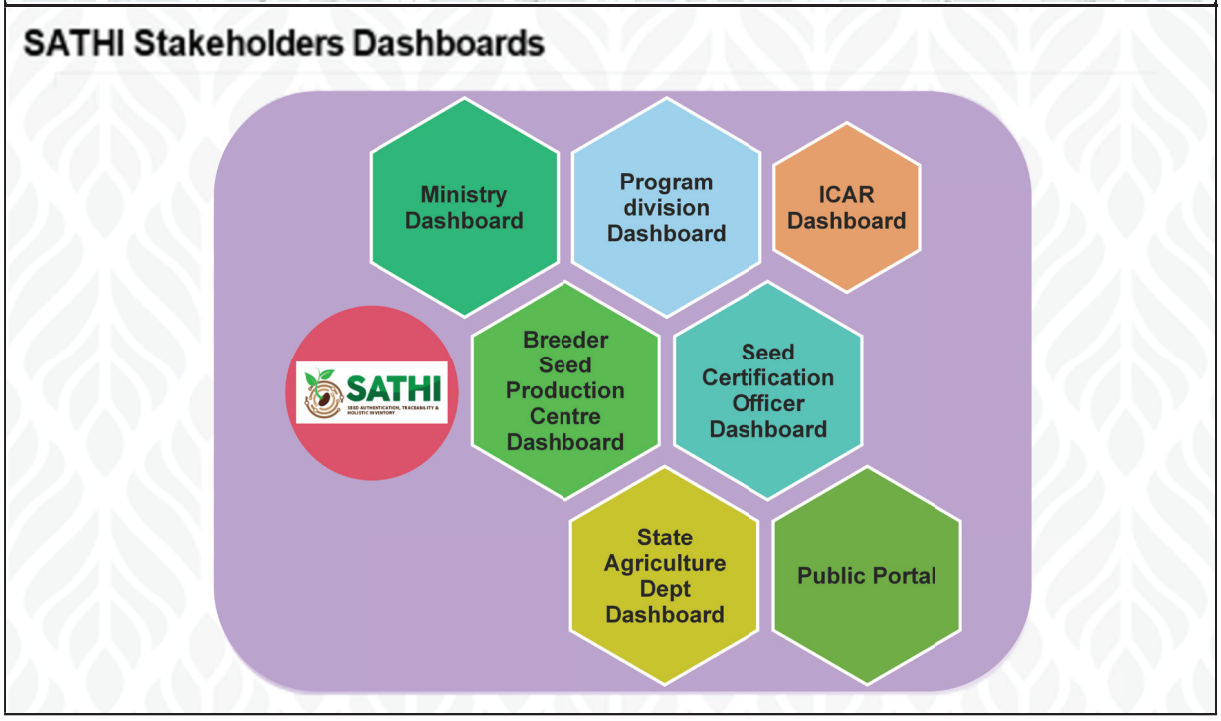


Fig. 5 Showing the benefits to different Stakeholders related to Seed Supply


Stakeholder Eco-system
A Centralized Electronic Platform that facilitates end-to-end information flow
SATHI
INDENTER
SEED DIVISION
ICAR
Project Coordinator
Breeder Seed Production Centre
Seed Producing Agencies
Seed Processing Plants
Seed Testing Labs
Seed Certification Agencies


SATHI Stakeholders Dashboards
Ministry Dashboard
Program division Dashboard
ICAR Dashboard
SATHI
Breeder Seed Production Centre Dashboard
Seed Certification Officer Dashboard
State Agriculture Dept Dashboard
Public Portal

Technical Session V

Technical Session V: Shaping the Future: Policy, IP and Emerging Technologies for a Seed Revolution in India
Time: 11:45 AM - 1:05 PM
Chair- **Mr Sanjay Agarwal**, ADG, ICRISAT and Ex. Secretary, DA&FW, Govt of India
Co- Chair- **Dr. S. K. Malhotra**, Vice Chancellor, Maharana Pratap Horticultural University in Karnal, Haryana
Rapporteur: **Mrs. OK Tara**, Head – IPR & Regulatory Affairs, NSL

11:45 AM - 11:55 AM		**Opening Remarks by Chair/Co-chair**	
SN	**Duration**	**Topic**	**Speaker**
1.	**11:55 AM-12:15 PM**	Policy and Systems for IPR Governance relevant to Indian Seed Industry	**Dr. D. K. Agarwal**, RG, PPV&FRA
2.	**12:15 PM-12:35 PM**	Resetting public private partnership in plant genetic resources utilization - an IPR perspective	**Dr. G. P. Singh** Director, NBPGR
3.	**12:35 PM-12:55 PM**	Strengthening In House R&D set up of Seed Companies for DSIR Recognition	**Dr. Deepika Rohatgi** Scientist-E, DSIR
12:55 PM- 1:05 PM		**Q&A and Closing Remarks by Chair/Co-Chair**	

CHAIR

MR. SANJAY AGARWAL

ADG, ICRISAT
& Ex. Secretary, DAFW, Govt. of India

Mr. Sanjay Agarwal (IAS) brings an illustrious educational background, exemplary government service, and visionary leadership to the table as Assistant Director General at ICRISAT. He also serves as the Chairman of the National Committee on Minimum Support Price, Crop Diversification, and Natural Farming, a role appointed by the Ministry of Agriculture & Farmers Welfare, Government of India. He is also on the Board of the International Potato Centre (CIP), Peru, a notable CGIAR institution.

Mr. Agarwal is a distinguished alumnus of the prestigious Indian Institute of Technology, Kanpur, and graduated with top honors. He is a 1984-batch Indian Administrative Service officer of the Uttar Pradesh cadre. His tenure spanned over 37 years, during which he played pivotal roles in shaping public policy, program implementation, and effective governance. He retired as the Secretary to the Government of India.

As Secretary of Agriculture, Cooperation & Farmers Welfare, Government of India, Sanjay Agarwal led transformative initiatives that elevated agricultural practices and farmer incomes. Notable achievement is championing new schemes such as Pradhan Mantri Kisan Samman Nidhi income support scheme, the Agricultural Infrastructure Fund (AIF), Scheme for promotion of 10000 Farmers Producers Organisations, Oil Palm Mission and National Bee keeping & Honey Mission aimed at enhancing farmers' income. He drove the proposal for declaration of 2023 as International Year of Millets by UN General Assembly.

Mr. Agarwal's commitment to technological advancements in agriculture led to significant achievements, including the facilitative ecosystem for Gene editing in Indis and permitting the commercialization of Nano-Urea. His innovative efforts extended to promoting digital solutions, introducing drones in agricultural operations, and enhancing crop insurance through remote sensing.

CO-CHAIR

DR. S K MALHOTRA

Vice Chancellor,
Maharana Pratap Horticultural University,
Karnal, Haryana

Dr. S K Malhotra had his graduation in; 1984, M.Sc in horticulture from GBPUA&T, Pantnagar in 1986 and Ph. D. from CCS, HAU, Hisar in 1989. Starting his career as Assistant Professor (Vegetable Crops) at HPKV Palampur (1989) and served as Assistant Scientist (Sr. Scale) at CCSHAU, Hisar (1994). He joined ICAR as Senior Scientist (Hort.) in 2000 at NRC Seed Spices, Ajmer and became Principal Scientist in 2007. Subsequently, he served Govt. of India as ADG (Hort), Horticulture Commissioner and Agriculture Commissioner in the Ministry of Agriculture FW and Director (2022-2024), ICAR-Directorate of Knowledge Management in Agriculture. Presently, he is working as Vice Chancellor, at Maharana Pratap Horticultural University, Karnal (Feb 2024 onwards).

Achievements:

As **Agriculture Commissioner**, he steered India's development agenda in agriculture for food, nutrition, and income security through administration of National Food Security Mission. As **Chairman of Insecticide Board Registration Committee, Central Fertilizer Committee, Central Biostimulant Committee and Central Seed Certification Board**, his contributions are immense in formation of policy framework and guidelines for registration and commercialization of novel products and seed regulations. During his tenure as **Horticulture Commissioner**, he architected and implemented Per Drop More Crop- of PMKSY, High value agriculture for Island Agriculture, National Saffron Mission and National Bee Honey Mission, Cluster Development in Horticulture programs. As a **Director ICAR-DKMA**, he revamped the publication system and introduced new version of ICAR e-pub portal, DOI, plagiarism checking, new policy for collaborations for co-publication and brought reforms for enhancement of impact factor of ICAR research journals.

Awards and Honors:

BioAg Asia Policy leadership award-2022, Global Agriculture Leadership Award – ICFA, India-2016, Progressive Horticulture Leadership award-2023, HS Mehta, Young Scientist Award-2011, Dr. RS Paroda award-2015, Dr. G. Kalloo award-2019, Dr. Kirti Singh Award-2017, Hukum Singh Memorial award-2019, PNASF-Young Scientist Gold Medal -2005, JS Pruthi Award-2010, Lakhiram Memorial award-2012; AIFPA-Award-2013, AF-Professional Excellence Award-2014, Horticulture Leadership Award 2021-22. He is Honorary Fellow of eleven professional societies and guiding 4 professional societies as President and Vice President for furtherance of horticulture in the country.

Policy and Systems for IPR Governance relevant to Indian Seed Industry

DR. D. K. AGARWAL

Registrar General,
Protection of Plant Varieties & Farmers' Rights Authority, New Delhi

Dr. D. K. Agarwal is Registrar General, PPVFR Authority, New Delhi.

He had served as acting Director ICAR- Indian Institute of Seed Science and Principal Scientist at ICAR-National Research Centre for Banana.

He has been an active contributor to the crop improvement activities which led to the release/ notification of crop varieties like Fodder & Forages (Bundel Sen Ghas-1, Bundel Dhawalu Ghas-1), Cotton (CNHO 12), Soybean (NRC 86).

Apart from these varieties, he also contributed towards development of a number of breeding lines in crops like Fodder Cowpea, Cotton and Soybean.

He has published more than 52 research papers in National and International journals.

Resetting the Public-Private Partnership in PGR Utilization

DR. GYANENDRA PRATAP SINGH

Director, National Bureau of Plant Genetic Resources, New Delhi

Dr. Gyanendra Pratap Singh is Director, National Bureau of Plant Genetic Resources, New Delhi.

He has held several positions throughout his career, including Scientist at the National Research Centre for Soybean, Indore (1993-94); Scientist at the Central Potato Research Institute, Shimla (1994-96); Scientist and Scientist (Senior Scale) at the Directorate of Wheat Research, Karnal; Senior Scientist and Principal Scientist at the Indian Agricultural Research Institute, New Delhi (2001-2008 & 2009-2016); and Director of ICAR-Indian Institute of Wheat & Barley Research, Karnal (2016-2022).

Awards/Honours: Dr. Rafi Ahmed Kidwai Award, 2015; Dr. Nanaji Deshmukh Team Award, 2018; BGRI Gene Stewardship Award, 2018; Dr. AB Joshi Memorial Award, 2020; Dr. K Ramaiah Memorial Award, 2020; Dr Amrik Singh Cheema Memorial Award, 2019; Agricultural Leadership Award by National Educational Empowerment and Development Foundation, 2019; Outlook Outstanding Scientist Award, 2020; Dr. B.P. Pal Gold Medal Award, 2016; Rao Bahadur Vishwanth Memorial Award, 2016; V.S. Mathur Memorial Award 2014; Indian Society of Genetics and Plant Breeding, New Delhi; AISA National Award for Outstanding Leadership in Agriculture, 2019; Best Scientist Award Young Farmers Association, 2019; Dr. G B Deodikar Memorial Oration Award, Agharkar Research Institute, Maharashtra Association of Cultivation of Science, 2020; Mahendra Samridhi Award, 2016 & 2020, Dr. NN Singh Memorial Outstanding Scientist Award, 2022; President, Indian Society of Genetics and Plant Breeding 2020-2022; President, Society for Advancement of Wheat and Barley 2016-22.

Fellow: Indian National Science Academy, National Academy of Science India, Society of Advancement of Wheat Research, Karnal; Indian Society of Genetics and Plant Breeding, New Delhi, India; Society for Scientific Development in Agriculture and Technology Jhansi

Research Areas: Plant Genetic Resource Management, Wheat improvement, abiotic stress, physiological phenotyping, MARS & MABB

Abstract

To address the dichotomy of stagnating productivity and untapped potential, India's agricultural sector requires every available innovation, technology and genetic resources (PGR) to be fully utilized. Research and development in PGR provide sustainable solutions to mitigate climate impact, diversification and income enhancement. In India, efforts of the public institutions like ICAR, DBT, CSIR and state agricultural universities in developing indigenous solutions are complemented by the private seed industry in the form of introduction, scaling up and popularization of commercializable material and technology.

Despite these specialized strengths, it is surprising that Public-Private Partnerships (PPPs) have not gone beyond examples in limited areas. Despite the rhetoric, the potential of PPPs for sustainable growth and farmer empowerment has not received adequate attention in terms of policy support. If India aims to be a developed country sooner than later, it is imperative that the identity divide between public and private R&D entities should be bridged. Forget USA, Europe and Australia—Brazil and China provide some typical examples in achieving more with partnerships in varietal development. It is not surprising that the best seeds armor the farmers, independent of scale of cultivation, against climate change vagaries and insure them against market fluctuations by providing more options.

Seed industry in India are active in importing germplasm from outside. In fact, ICAR-NBPGR figures show that seed industry has been consistently importing more than double the germplasm accessions imported by all other entities put together. However, this process is often driven by a few seed companies that have parent company and franchises outside India. The import is also restricted to shuttling the breeding lines. ICAR-NBPGR provides a seamless import procedure for importing germplasm for research, and all the big and small seed companies are invited to make the best use of this facility.

In the past 15 years, there have been only 100 instances of germplasm supply from the national genebank to the private seed companies. This is woefully inadequate (<2% of domestic supply) to create any impact. It is understandable that extant regulations discourage seed industry partners in endeavoring to access the germplasm. But these should be resolved by us at the earliest.

In Netherlands, Australia, Japan, etc. genebanks join hands with seed industry partners for multiplication, regeneration and characterization of germplasm accessions conserved in the national genebanks. In India, though, private participation is limited to accessing the germplasm. This must change. The paradigm of PPP in germplasm use should start with trait-specific evaluation. Mutual strengths need to be brought together for trait-discovery in germplasm. Germplasm available with private industry also need be made accessible to public sector researchers. Partnership should begin in the right earnest ensuring benefit to farmers, consumers and creating a win-win landscape for public and private partners. There is no alternative if India aspires to become a developed country.

Strengthening In House R&D set up of Seed Companies for DSIR Recognition

DR. DEEPIKA ROHATGI

Scientist – E
Department of Scientific & Industrial Research, Ministry of Science & Technology, Government of India

Dr Deepika Rohatgi is a biotechnologist by training and was awarded Ph.D in Biotechnology in the year 2011. Dr Rohatgi earned fellowship support from ICAR working at Indian Agricultural Research Institute, New Delhi and her research work was aimed at tagging the gene(s) conferring resistance to nematode *Heterodera avenae* in wheat. She has almost twenty three years of experience working in the stream of science and technology subsequent to her Post Graduation in Botany in the year 2001. Dr Rohatgi has worked on specialized research areas for crop protection & disease management through biotechnological tools in economically important crops like pigeon pea, tomato and rice working at National Research laboratories like Indian Institute of Pulses Research, Kanpur; Indian Agricultural Research Institute, New Delhi & School of Life Sciences, Jawaharlal Nehru University, New Delhi. Dr Rohatgi has good experience in the field of plant functional genomics and the identification of gene(s) controlling traits of interest. She has worked for developing transgenics in tomato & rice for pathogen resistance involving RNAi approach and other constructs like Annexin cDNA etc.

Dr Rohatgi joined the Department of Scientific & Industrial Research, M/o Science & Technology, GoI, New Delhi, as scientist in the year 2012 and since then is actively engaged in the promotion of the schemes/ programs of Department facilitating and fostering industry, institutional and academic research in public funded research institutions. Dr Rohatgi has facilitated industry & start-ups working in sectors like biotechnology; pharmaceutical; engineering; speciality chemicals; agriculture chemicals and seed technology etc. Dr Rohatgi has also worked for

the funding schemes like PRISM, BIRD Crf & PACE which have been instrumental for strengthening the innovation ecosystem in the country & commercialization of technologies. Dr. Deepika Rohatgi has made efforts for enhancing stakeholder satisfaction through her untiring work and has utilized her several years of experience and expertise for knowledge sharing, dissemination of S&T information, technology know-how through her evidence based publications and participations in various national level workshops/congregations/fora.

Dr Deepika Rohatgi has 15 National and International publications, 04 book chapters, 01 Article in Magazine & 16 paper & poster presentations in National/ International conferences to her credit. Dr Rohatgi has won awards & recognition for academic excellence and twice has been placed second for the paper & poster presentations at National Symposiums held in 2005 & 2007 at IARI, New Delhi & Assam Agricultural University, Jorhat respectively. She was also awarded certificate for best poster presentation on Cleanliness Drive at Department of Scientific & Industrial Research, M/o Science &Technology, GoI, New Delhi in May 2018. Dr Rohatgi has contrived **(02)** Policy Papers & prepared several Technology intelligence/ assessment reports for the Promotion of S&T schemes in DSIR. She is a member of several technical advisory committees on S&T & has membership of Institutions like Indian Institute of Public Administration, New Delhi & Centre for Organization Development, Hyderabad. She has also been invited for lectures / lead talks at various platforms on topics mentioned below:

(i) Technology Status Reports for Technology Assessment in Public Funded Research Institutes
(ii) Academia Industry Collaboration and Technology Spill for Societal Accessibility
(iii) Plastic Waste Management and Single Use Plastics
(iv) E-waste and Preventing Apocalypse
(v) Technology Assessment and Evaluation of Commercializable Technologies
(vi) Overview of DSIR Programmes and PRISM: In Supporting Rural Innovations
(vii) PRISM – Nurturing Innovation Ecosystem

ABSTRACT

Department of Scientific and Industrial Research (DSIR), Ministry of Science and Technology, Government of India supports continuous improvement and innovation in the Indian seed industry sector by means of its various schemes and programmes, notable one for which is the In-House R&D recognition for industries engaged in the line of business. The scheme not only provides national level of recognition to industry but also provides avenues for funding from various Government organizations and undertaking national/ international collaborative projects. The scheme of the Department has enabled Indian seed industry sector gain meaningful representation amongst the other industrial sectors within the country and on a global scale, minimizing the mismatch on technological attainments, that some seed companies have been able to create real impact with credibility in their contribution towards Indian economy.

KEY WORDS: ***In-House R&D, DSIR Recognition & Registration, Technology, Market Intelligence***

INTRODUCTION

The Department of Scientific and Industrial Research (DSIR), Ministry of Science and Technology, Government of India fosters and support activities related to indigenous technology promotion, development, utilization and transfer through its regulatory and central sector schemes/ programmes to facilitate industry, scientific institutions, start-ups, MSMEs and individual innovators take up R&D and technological innovations to address national needs bringing new technology in key areas through innovative research, industry partnerships, entrepreneurship, translation research and capacity building. DSIR works extensively towards fulfilling the goal of "Make in India" and "Self-reliant" India with a vision for 2047 as "Viksit Bharat" and as an empowered nation in all industrial sectors of healthcare, drug discovery, energy security, information & communications technology, aerospace, nuclear science, use of artificial intelligence, agriculture and manufacturing technologies.

DSIR is the nodal Department of Government of India for granting recognition/ registration to the In-house R&D centres established by industry in the country. The in-house R&D recognition of industry by DSIR is a primary requirement for the industry to avail fiscal incentives under specified sections of 35 (2AB) of the IT Act, 1961. These incentives are in terms of tax rebate and customs duty waiver on import of equipment, consumables and spares for R&D. Further, Scientific research foundations/ non- commercial organizations in the areas of medical, agriculture, natural and applied sciences and social sciences seek DSIR recognition and registration as Scientific and Industrial Research Organisations (SIROs). DSIR is also the nodal Department for registration of public funded research institutions

(PFRI), Universities, IITs, IISc and NITs, for availing concessional custom duty exemptions on purchase of equipment, goods used for scientific research. The industry and organizations recognized and registered with DSIR can avail Customs Duty exemption on goods imported for R&D. Earlier, rebate in GST on purchases of indigenous goods for R&D was also available to industry & institutions registered with DSIR but now the provision has been discontinued by the Ministry of Finance since July 2022.

The in-house R&D centres of industry applying for recognition to DSIR are expected to be engaged in innovative research & development activities related to the line of business of the firm, such as, development of new technologies, design & engineering, process/product/design improvements, developing new methods of analysis & testing; research for increased efficiency in use of resources, such as, capital equipment, materials & energy; pollution control, effluent treatment & recycling of waste products or any other areas of research. Market research, work & methods study, operations & management research, testing & analysis of routine nature for operation, process control, quality control and maintenance of day to day production, maintenance of plant are not considered as R&D activities. This is the only scheme in the entire government set-up for benchmarking the industrial R&D. Government of India has announced a number of fiscal incentives for research and development by industry from time to time and many of these incentives are implemented through DSIR. In-house R&D units recognized by DSIR are not only eligible for these incentives (wherever applicable) but also for receiving funds for R&D from other government departments and agencies such as Department of Science and Technology (DST), Department of Biotechnology (DBT), Ministry of Electronics and Information Technology (MeitY), Ministry of Environment, Forest and Climate Change (MoEF& CC), Ministry of New and Renewable Energy (MNRE), Ministry of Food Processing Industries (MoFPI), Council of Scientific and Industrial Research (CSIR), Indian Council of Medical Research (ICMR), Indian Council of Agricultural Research (ICAR), where recognition to the in-house R&D centre by DSIR is a requirement. The detailed guidelines and eligibility criteria for the Recognition and Registration of In-house R&D units of Corporate Industries is available at DSIR website: dsir.gov.in. Contract research organizations and companies who have recently started operations with a proven track record of stable business, financial health, annual turnovers in the last three years and who have established dedicated R&D set up with appropriate physical infrastructure, capital investments, R&D manpower and are undertaking research programmes to either function independently or through partnership/ collaborative mode or plug and play model are also encouraged to apply for DSIR recognition / registration.

DSIR SUPPORT TO SEED INDUSTRY SECTOR

Agriculture and seed industry will always be the prime focus of the Indian Government as the burgeoning human and live-stock population, with ever

daunting climate change, depleting land and water resources will continue to have negative impact on the agriculture sector, posing challenges for food security and self- sufficiency for food in the country. India has both the formal and informal sector for agriculture & allied sectors, seed production and varietal development with little use of technology and automation to support the informal seed industry sector constituted largely by the farming community which produces seeds without following the certification procedures and exchange it amongst themselves. The formal system undertaking seed production and development in the country rests largely with the Ministry of Agriculture, Indian Council of Agricultural Research, State Agriculture Universities, Department of Seed certification, National Seeds Corporation, State Seed Corporations, State Farm Corporation of India and some private industry players. Also, there are some seed companies which are engaged in the production of truthfully labelled seeds which are developed/ tested only for physical purity and germination. Development of competitive and novel technologies for scientific production of seeds involving hybrid / varietal development, evaluation and screening of germplasm, maintaining hybrid vigour, seed certification from notified seed testing laboratories, compulsory disclosure of expected performance of the variety to farmer, providing soil health, nutrient analysis, integrated pest management, use of semiochemicals/ eco-friendly crop protection tools and use of natural biodegradable formulations towards certified organic produce is the need of the hour and requires extensive R&D. There are different agencies which certify organic seeds and farmers need to follow the procedures laid down for organic certification such as to register their land with any of the accredited organic certification bodies in India.

Department of Scientific & Industrial research endeavours to support the Indian seed industry for development, deployment, demonstration and commercialization of technologies that support the farming community and Indian seed industry and tries to evolve parameters and benchmarks to regulate the Indian seed industry by enforcing criteria for minimum land size required for R&D farms, providing information for source of collection of germplasm & characterization / evaluation criteria, defining certified/ truthfully labelled seed development cycles with third ;party evaluation reports from any ICAR, State Agriculture University/ laboratory or Krishi Vigyan Kendras, information for germplasm conservation with National research laboratories like National Bureau of Plant Genetic Resources [NBPGR], New Delhi, analytical and validation reports for genetic purity, hybrid vigour of seeds developed or impurity profiling/ degradation studies for any other agriculture related product / chemical developed etc. Department also supports and encourages Indian seed industry/ public funded research institutions and non-commercial organizations who focus on R&D for development of cost-effective, eco-friendly, novel and non-infringing processes. Department encourages Indian seed industry sector engaged in the business of horticulture or field crops, agriculture and allied product sector, agristart-ups involved in providing agro remediation solutions, market intelligence and risk management and who carry out R&D based

on a time plan rolling roadmap with mid-term and long term course corrections using in-house or collaborative efforts to have a technological edge over others. Joint contracts and development projects with foreign collaborators is also encouraged to have benefit of knowledge transfer, seed/ product/ process development, improvement, import substitution and intellectual property generation.

WAY FORWARD

Department of Scientific & Industrial research through its schemes and funding programmes supports technology development and deployment in the Indian seed industry sector but the benefits of the schemes/ programmes/ policies of the Department can be used to the maximum only if the Indian seed industry sector organizes its R&D set up in terms of institutional, professional , financial and socio- economic priorities with identification of technological areas in which the company wants to operate. The representation of the Indian seed industry sector with the Department in comparison to other sectors like automotives, pharmaceuticals, electrical and electronics, speciality chemicals, APIs & bulk drugs, nutraceuticals, food supplements etc needs to be strengthened and it is possible if the seed industry sector also formalizes, follow a strategic roadmap for competitive positioning with other industrial sectors. It is suggested that the Indian seed industry develop and define uniform metrics for undertaking and evaluation of technological projects/ scientific seed production for good quality seeds and qualify for test and demonstration of product/ process developed. Seed testing should be done in a high fidelity laboratory environment or in a simulated operational environment, especially where the seeds are developed for biotic and abiotic stresses. Seed industry sector may also undertake studies of the comparative landscape and the identification of similar technology products, if any, for estimation of market size, positioning of the product and benchmarking.

Department of Scientific & Industrial research perceives the Indian seed industry sector as a means of increasing productivity and income generation and therefore, supports and encourages entrepreneurship in the sector, ruling out any possibilities for risky proposition with the help of its schemes and programmes and various other benefits provided to seed industry as announced by Government of India from time to time. Last but not the least, the Indian seed industry can benefit by maintaining business alignment, imbibing and assimilating the best practises as laid down by the Ministry of Agriculture and other S&T departments for infusing system, technology and mentoring. Seed industry should emphasize more on R&D and only providing services or doing seed production on routine basis may not help sustain in the long run. The target appears to be overly ambitious but may not be very challenging with the kind of support systems that exist from the government at policy level to leverage start-ups in the sector and fund for technology promotion and development.

Technical Session VI

PANEL DISCUSSION

Navigating Challenges and Leveraging Opportunities in Seed Technology through Policy Reforms

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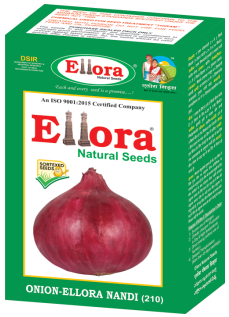
उत्कृष्ट एवंम दर्जेदार प्याज बीज, मक्का बीज व सब्जी बीज देणेवाली भारत की अग्रगन्य कंपनी...!

भिंडी : एलोरा गौसी (5960)

भिंडी : एलोरा प्रियंका (2526)

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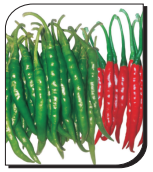
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लौकी : एलोरा सम्राट (7759)


तरबूज : एलोरा महंत (12)


खरबूज: एलोरा सिंधू (596)


बैंगन : एलोरा अतुल


गाजर : देशी रेड


टोमॅटो : अंबूजा (34)


टोमॅटो : एलोरा आरु (12)


फ्रेंचबीन : एलोरा नं.11


वाल : श्रावण (102)


करेला : एलोरा लक्ष्मी (116)

करेला : छोटा भीम - 34

सभी प्रमुख वितरक के पास मौसम के अनुसार उपलब्ध ।

रजि. ऑफिस : प्लॉट नं. ४, गट नं. ११७, नक्षत्रवाडी, एच.डी.एफ.सी. बँक के पास, पैठण रोड, छत्रपती संभाजीनगर (औरंगाबाद) (महाराष्ट्र). ग्राहक सेवा केंद्र :- **7030643643**

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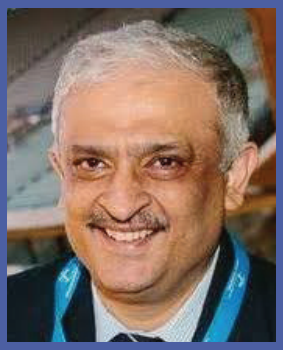

CHAIR

MR. DEVESH CHATURVEDI

Secretary (Agriculture),
DA&FW, MoA&FW, GoI

Mr. Devesh Chaturvedi is a distinguished Indian Administrative Service (IAS) officer of the 1989 batch from the Uttar Pradesh cadre. Currently, He is appointed as the Secretary of the Department of Agriculture & Farmers Welfare, Ministry of Agriculture & Farmers Welfare, Government of India.

Prior to this role, Mr. Chaturvedi held several key positions in the Uttar Pradesh government, including Agriculture Production Commissioner, Additional Chief Secretary of the Agriculture, Agriculture Education & Research Department, and Additional Chief Secretary of the Agriculture Marketing, Agriculture Foreign Business & Export Promotion Department. He also served as the Director General of Training in Lucknow.

At the central level, Mr. Chaturvedi has served as Joint Secretary and later as Additional Secretary in the Department of Agriculture, Cooperation & Farmers Welfare. He has also been a member of the Country Programme Advisory Committee, collaborating with the United Nations World Food Programme to enhance food security and nutrition in India.

Throughout his career, Mr. Chaturvedi has been instrumental in formulating and implementing policies aimed at enhancing agricultural productivity and sustainability, directly impacting the livelihoods of millions of farmers and contributing to economic development.

COORDINATOR

DR. SANJAY KUMAR

Director, ICAR-National Institute of Seed Science & Technology, Mau, Uttar Pradesh

Dr. Sanjay Kumar is Director, ICAR-National Institute of Seed Science &Technology, Mau under Ministry of Agriculture & Farmer Welfare, Govt of India.
He has more than 30 years of research career as different positions of Scientist at ICAR- Indian Agricultural Research Institute, New Delhi [Head, ICAR-IARI Regional Station, Shimla, Incharge, Business Planning and Development Unit, IARI, New Delhi, Head, Seed Production Unit & Nodal Officer (Seed), ICAR-IARI, New Delhi,].

He has developed 42 wheat varieties and 4 barley varieties, registered twelve Germplasm of wheat and barley for different characteristics, published more than 120 research papers in National and International journals, developed different models for commercialization of Crop Varieties and other Agri-technologies and dveloped entrepreneurship & business incubation system in ICAR and pioneer in creation of FPO's for seed business.

Awards/Honours:
Nanaji Deshmukh ICAR Award for Outstanding Interdisciplinary Team Research in Agricultural and Allied Science, Fellows of Indian Society of Genetics and Plant Breeding, and Indian Society for Advancement of Wheat Research. Presently President of Indian Society of Genetics and Plant Breeding (2023-25)

PANELIST

Mrs. Maninder Kaur Dwivedi,
Additional Secretary (NRM, INM, AM & RKVY), MoA&FW and CMD, NSC

Dr. M. Prabhakar Rao,
Chairman & Managing Director,
Nuziveedu Seeds Ltd

Mr. Ajeet Mulay,
Managing Director,
Green Gold Seeds

Mr. Ajai Rana,
CEO and Managing Director,
Savannah Seeds Pvt Ltd

Dr. Manish Patel,
Executive Director,
Incotec India Pvt Ltd

Mr. Rajvir Rathi,
Director Public Affairs, Science and Sustainability (South Asia) & Lead – Traits Licensing Business, Bayer CropScience

INVITED ARTICLE

Scope and Need for Seed Programs for Indigenous-Traditional Varieties [ITVs] and Land Races [LRs]

DR. V. SANKARAN

Retired General Manager (Production)/ Consultant (Production & Marketing), National Seeds Corporation, New Delhi and Retired Director (PE&QM)/Mentor, Krishidhan Seeds Ltd, Jalna, Maharashtra

A doctorate in Agriculture Seed Technology from TNAU, Dr. V. Sankaran is a legendary personality with over 57 years of professional experience in the Indian seed industry. He had a bright academic career with a Gold Medal in Post-graduation from TNAU. Having joined the premier seed organisation of the country, the National Seeds Corporation (NSC) in the initial inception period - 1965 itself, he held various positions in the organisation, with significant devotion towards the performance of the corporation and also the seed sector development in the country. During his tenure with the Krishidhan Seeds, Jalna (Maharashtra) as Vice President (Tech), Director and also as Mentor from 2007 to 2015, he contributed significantly in standardising and applying the technical norms and procedures in the company.

He has been Member of a number of committees, core groups and seed study missions, to quote a few, Technical assistance to the Govt. of India's Seed Review Team [1968], supporting the Member of the Seed Group of the National Commission on Agriculture [1976] and in the two Member NSC's Seed Certification Consultancy Team for the GOI in 1980. He also extended his consultancy support to the Govt. of India in finalizing the National Seed Mission Document during October 2009 to September 2010. Dr. Sankaran is a Founder Member of Indian Society of Seed Technology [ISST] since inception in 1971 and has served as Councillor, Editor, President and Fellow during different periods.

Dr. Sankaran also has to his credit 45 papers including 4 books as co- author, the latest being NSC publication "NSC's Journey in the Service of Farmers- August, 2020'' released by the Hon'ble Union Minister of Agriculture, Shri Narendra Singh Tomer on the 28th January, 2021. After getting relieved of the formal organizational engagement with Krishidhan Seeds in 2015, he is still actively sharing his knowledge and experience on honorary basis through seed related trainings, especially for the next generation of seed professionals, advisory support to the seed industry and also with number of articles for development of seed sector in the country.

1. Introduction

India is one of the 12 mega gene centres/regions of diversity of crop plants in the world. Though India is rich in genetic resources, there is a severe threat to genetic diversity due to population explosion resulting in increased pressure on land for food and shelter. Due to rapid agro-ecological changes, many species, old and primitive cultivars, landraces and their wild relatives endowed with superior genes are getting rapidly eroded. They include a wide range of agricultural and horticultural crop species. Most of the Medicinal & Aromatic species fall in this category seriously affecting the availability of quality raw herbal material for the pharma sector. The situation is alarming. Therefore, collection, conservation, evaluation, and utilization of Indigenous -Traditional Varieties and Land Races [ITVs/LRs] assume considerable significance, especially in view of the rapid environmental degradation and exploitation of the available plant wealth.

2. An ITV/LR of a crop can be defined as a variable population usually with a local name. It lacks "formal" crop improvement, is characterized by a specific adaptation to the environmental conditions of the area of cultivation (tolerant to the biotic and abiotic stresses of that area) and is closely associated with the traditional uses, knowledge, habits, dialects, and celebrations of the people who developed and continue to grow it.

3. ITVs/LRs are valuable sources of crop species diversity. Their utilization in plant breeding may lead to increased yield and enhanced quality traits, as well as resilience to various stresses. New approaches based on the rapid advances in genomic technologies have greatly facilitated the exploitation of genetic resources in modern plant breeding.

4. General features that characterize an ITV/LR

i. Morphologically distinctive and identifiable (i.e. has particular recognizable characteristics or properties), yet remains "dynamic".

ii. Genetically adapted to withstand the conditions of the local environment, including climate, disease and pests and even cultural practices.

iii. Not the product of formal breeding programs, and may lack systematic selection, development and improvement.

iv. Maintained and fostered less deliberately than a standardized genotype.

v. Has a historical origin in a specific geographic area usually having its own local name(s) and often classified according to the intended purpose.

vi. Will show yield stability under adverse conditions too.

5. Why / how are ITVs/LRs threatened? The main factors that contribute to the genetic erosion of ITVs/LRs diversity include:

i. Changes in agricultural practices; use of fertilizers, pesticides and herbicides; replacement of traditional varieties by modern, uniform cultivars with narrow diversity;

ii. **Medicinal Plants are the worst affected**. For, 80% of medicinal / herbal raw materials are gathered from the wild; 69% are collected by using destructive farming practices; indiscriminate harvests from the wild populations results in rapid loss / degradation of the natural biodiversity-ITVs/LRs- coupled with poor regeneration. Damage is more where / when the seed-propagating material itself is the 'herbal medicine 'or the 'raw material' for the final formulation. 65 species are in Endangered, Vulnerable, and Threatened categories. Urgent action is required to attend to this disturbing / painful situation.

iii. Once any ITV/LR is replaced by modern cultivars, unless it is conserved ex- situ, the unique combination of genetic diversity is unavailable to breeders; as a consequence, the total number of different varieties grown is reduced and/or cultivars grown by farmers become increasingly similar to each other;

iv. ITV/LR growers do not usually register their varieties as the process is relatively expensive for the limited returns; and if farmers are encouraged to switch to registered varieties, gradually their ITV/ LR material is lost;

v. Subsidy schemes that promote the use of uniform varieties; incentives by government agricultural advisory services to promote modern cultivars;

vi. Constant decrease of rural populations due to migration;

vii. lack of research programmes with ITVs/LRs and their associated knowledge and uses;

viii. Ageing of farmers and failure to pass on ITVs/LRs and associated knowledge from one generation to the next;

ix. Changes in consumption habits; [food standards that limit entry of ITVs/LRs and products into markets; and

x. Climate change directly affecting the cropping patterns resulting in extinction of traditional varieties.

6. Practical consequences of ITVs/LRs genetic erosion: Decrease in genetic diversity means genes and alleles will not be available to breeders to develop improved varieties and thereby can affect the efforts to meet changing consumer demands, changing environmental conditions and to exploit new markets, provide food security etc.

7. The foregoing narration adequately justifies the urgent need to not only preserve the ITVs/ LRs and use them in crop improvement efforts, but also organise planned seed programs in a manner similar to the seed programs already in the Indian seed sector.

8. Many ITVs / LRs already have GI-Tag Recognition under the *Geographical Indications of Goods (Registration and Protection) Act,1999* effective from 15th September 2003. GI protects the Product's distinctiveness, unique features, qualities, traditional methods/knowledge, and reputation linked with the location; ensures quality; and enhances customer satisfaction, producer's income, employment in the region and export market scope. Table 1 [at the end] presents the list of crop products / varieties awarded with GI Tag/Recognition -until Nov'24**. To reap the benefits of GI Tag recognition for the ITVs/LRs, sound seed programs are needed for the genotypes/varieties concerned.**

9. In this context, to enable the seed sector make a beginning, Titles of 30 **Success Stories of Conserving Traditional /Indigenous Crops -Varieties and Land Races** as reported in the Press in the recent years are listed below. Details of the conservation efforts including the names of ITVs/ LRs involved therein can be had by '*Google Search*' using the Titles listed here under:

i. How 250 gm seeds -in Orissa-created a millet movement in India:

ii. Aamon: Tribal women in violence-hit Bengal province triple incomes with organic rice; revive traditional varieties

iii. How Assam's organic farmer is conserving 1,000 varieties of native paddy and vegetable seeds

iv. Bengal farmer revives native paddy variety; earns Rs120 per kg with organic farming

v. Debal Deb: Seed warrior who has conserved 1,480 traditional rice varieties &

shared them for free with over 7,600 farmers

vi. This septuagenarian Odisha couple has saved 1072 native rice varieties; shares seeds free with farmers

vii. Odisha schoolgirl saves 260 varieties of native paddy and millet seeds

viii. Odisha scientist quits job to grow and conserve native paddy varieties; helps farmers adopt natural farming

ix. Odisha Tribal Women Save Traditional Rice Variety From Extinction

x. Odisha's tribal farmers bring back pigmented rice varieties

xi. Farmers in Odisha's tribal-dominated districts bet big on little millets

xii. Odisha man declines government job to conserve native paddy seeds; saves 1200 varieties

xiii. Adivasi farmers in Maharashtra are reviving indigenous crop varieties to withstand climate change

xiv. Kerala couple turns barren land into organic paddy farm, sells native rice at up to Rs225 per kg

xv. Return of the native: How Maruvan is restoring Rajasthan's desert habitat

xvi. Madhya Pradesh Farmer Grows 7-Foot-Long Bottle Gourd, Earns Rs 30 Lakh Annually.

xvii. Seed conservation: This Madhya Pradesh farmer grows 115 native varieties of rice over just 2 acres; gives seeds free to other farmers

xviii. V Priya Rajnarayanan: This MBA has saved over 500 varieties of native vegetable seeds; gives them free to farmers & gardeners

xix. Sahaja Samrudha's campaign to save agro-biodiversity empowers 10,000 Karnataka farmers

xx. Sahaja Seeds a Mysuru-based Startup Encourages Farmers to Produce Indigenous and Patent-Free Seeds of a Variety of Crops

xxi. From 300 Rupees to 300 Seed Varieties: Inspiring Journey of Arun Salai in Sustainable Farming and Seed Conservation

xxii. Seeds from the past

xxiii. Snehakunja: Preserving biodiversity through empowerment of tribals in Western Ghats of Karnataka

xxiv. How Tamil Nadu's aeronautical engineer-turned-farmer is creating native seed bank to promote organic farming

xxv. This techie quit TCS for the love of social work; has conserved over 250 varieties of native seeds

xxvi. Top 5 Highly Beneficial Local Rice Varieties You Must Know

xxvii. How tribal women farmers are conserving native seeds & ensuring nutritional security- *indigenous seeds 30stades*

xxviii. Udaipur's Jovaki empowers tribal women by processing wild fruits & vegetables

xxix. New Study Uncovers 62 Desiccation-Tolerant Plant Species in India's Western Ghats

xxx. Reviving Exotic Indigenous Seeds Lost in Time: A Boon for Biodiversity & Food Security.

10. Several local level institutions, NGOs, organizations, associations etc of which 30 are listed below are also involved in handling the ITVs / LRs. Their details can be had by *Google Search* using the Titles given below:

i. Desi Bihan Surakhya Samiti

ii. Anubhav Seed Bank in Bargarh

iii. Sugan Seed Bank, Kutenpali of Bargarh.

iv. Maheswari Seed Bank, Bargaon and Ramchandi Seed Bank, Kuibhal bordering Subarnapur Dt

v. LANDRACE-Assam

vi. Aamon

vii. Navdanya Trust –Delhi based NGO

viii. Kaliyaganj Krishi Udyog Producer Company Limited

ix. Pabhoi Greens -self-help groups (SHGs) in Arunachal Pradesh's Thembang village and Khonoma village, about 20 km from Kohima

x. Sagar Krishnanagar Swami Vivekananda Youth Cultural Society, West Bengal

xi. Rashtriya Desi Beej Kosh at The Art of Living International Center

xii. The Art of Living's Sri Sri Agri Sciences and Technology Trust

xiii. Salim Ali Foundation-Kerala

xiv. Maruvan, a not-for-profit organisation, Jodhpur Dt. Rajasthan

xv. MS Swaminathan Research Foundation (MSSRF), Jeypore

xvi. Odisha Rural Development and Marketing Society (ORMAS)

xvii. Sabari Producer Group -Machhara [Orissa]

xviii. Kendrigenda in Bari village, Koraput

xix. Jaivik Sri Farmer Producers Company Ltd , Koraput

xx. Sahaja Samrudha Organic Producer Company Ltd,Karnataka

xxi. BAIF Development Research Foundation

xxii. NGO Vaagdhara –Rajasthan

xxiii. Agarkar Research Institute (ARI), Pune

xxiv. Kalsubai Parisar Biyanee Savardhan Samiti, Akole, Ahmednagar district,.

xxv. Khola/Canacona Chilli Cultivators Group, Khola village, South Goa

xxvi. Nammalvar Ecological Foundation, Karur [TN]

xxvii. Living Farms, Bissam cuttack and Muniguda blocks of Rayagada.

xxviii. Snehakunja Trust

xxix. Aadhiyagai Biodiversity and Ecological Farm

xxx. Social enterprise HOOGA Seed Keepers' Collective. HOOGA stands for 'Helping Of Oppressed Generation Of Agriculturists.'

The Contacts listed in the preceding paras [9&10] should help the Seed Sector to proceed further for launching seed programs for ITVs/ LRs.

11. Way Forward—Issues for Action by Seed Sector

i. Choice of species / varieties from among the ITVs, LRs, GIs and MPs- in active consultation with ICAR, SAUs, DAs etc;

ii. Release of DUS-features for roguing, inspection etc during seed production;

iii. Status of commercial crop production of the concerned species/ vars etc;

iv. iv. Estimates of the total quantity of seed sown, net seed requirement for the crop /variety;

v. Sources for quality seed in the commercial crop production/marketing

locations;

vi. Estimates of the total seed quantity usually produced/ sold - crop / product wise;

vii. Assessment of the likely scope available for the Seed Sector to take up seed production and marketing as a commercial activity;

viii. Estimates of the net seed demand to be met;

ix. BS Sources for the varieties/genotypes identified for the seed program;

x. Identification of ideal seed production locations;

xi. Seed Production Techniques / seed crop husbandry practices for the sps/ vars identified for Quality Seed Production /Handling;

xii. Seed quality specifications- for field / seed stages and precise verification procedures and arrangements thereof;

xiii. Seed processing-conditioning, storage and packaging specifications and procedures for the items taken up for the seed program;

xiv. Seed production economics, seed pricing issues / policies – for seed production-procurement / sales;

xv. Need oriented training to all concerned;

xvi. Consolidation of research information with special reference to Seed Science & Technology aspects;

xvii. PG programs / Research studies in Seed Science & Technology of ITVs/ LRs;

xviii. National / State Level plans for cultivation of selected items to generate seed requirement;

xix. Seed Plans/Schemes to make available required quantities of quality seed through the BS-FS-CS chain; and

xx. Strong linkages between the Seed Sector and the ITVs/LRs Seed Saviours, GI product producers, herbal industry, research sector etc to facilitate seed program planning/implementation, assured off take of quality seed produced and production of quality raw produce.

12. In the light of the foregoing, it is earnestly hoped that the subject matter presented here will generate interest among the Indian Seed Sector [both public and private] to move towards launching ***" Seed Programs for ITVs- LRs, GI Products, Medicinal Plants and Local-Indigenous Crop Varieties"*** with some recognized /prominent ITVs / LRs in typically seed propagated crops to start with. If this activity is taken up,

the seed organisation[s] involved in the activity will be contributing significantly to the production and availability of the ultimate Product'; and thereby boosting the economic gains for all those involved in the activity. Thus a totally an unexplored, untouched, unreached area is available for the Indian Seed Sector to attend to immediately.

Let us go' Vocal for Local 'and 'Aatmanirbhar Bharat

Table-List of Crop Species / Products with GI Tag Recognition [as on 20th Nov, 2024]

S.No	Crop	State	GI Products -Names	No.
1	Rice	Punjab / Haryana / HP / Delhi / Uttarakhand / UP / J & K	Basmati	1
		Arunachal	Khaw Tai (Khamti)	1
		Assam	Joha , Chokuwa, Boka Chaul	3
		Bihar	Katarni,Marcha	2
		Chattisgarh	Nagri Dubraj, Jeeraphool	2
		J&K	Mushqbudji	1
		Kerala	Navara,Palakkadan Matta, Pokkali , Wayanad Jeerakasala ,Wayanad Gandhakasala ,Kaipad	6
		MP	Balaghat Chinnor	1
		Maharashtra	Ajara Ghansal,Ambemohar; Bhandara Chinoor	3
		Manipur	Black Rice [Chak Hao]	1
		Nagaland	Chak Hao	1
		Odisha	Koraput Kalajeera	1
		Tamil Nadu	Jeeraga Sambha	1
		Uttar Pradesh	Kalanamak,Adamchini Chawal	2
		Uttarakhand	Lal Chawal	1
		West Bengal	Gobindobhog, Tulaipanji,Kalonunia	3
2	Wheat	Gujarat	Bhalia	1
		MP	Sharbati Gehu	1
		UP	Bundelkhand Kathiya Gehu	1
3	Jowar	Maharashtra	Mangalwedha Jowar,Dagdi Jowar of Jalna	2
4	Ragi	Uttarakhand	Uttarakhand Mandua	1

S.No	Crop	State	GI Products -Names	No.
5	Barnyard Millet	Uttarakhand	Uttarakhand Jhangora	1
6	Millet	Arunachal	Angnyat Millet [Coix sp]	1
7	Redgram	Karnataka	Gulbarga Tur Dal	1
		Maharashtra	Navapur Tur Dal,Borsuri Tur Dal	2
		Kerala	Attappady Thuvara	1
		Telengana	Tandur Redgram	1
		Uttarakhand	Uttarakhand-Pahari Toor Dal	1
8	Horse gram	Uttarakhand	Uttarakhand-Gahat	1
9	Sesame	Kerala	Onattukara Ellu	1
10	Soybean	Uttarakhand	Uttarakhand Kala Bhat[Black soybean]	1
11	Grain Amaranth	Uttarakhand	Uttarakhand Chaulai[Rajgira]	1
12	Chilli	AP	Guntur Sannam Chilli	1
		Goa	Khola Chilli **,Harmal Chilli	2
		Kerala	Edayur Chilli	1
		Karnataka	Byadagi Chilli	1
		Maharashtra	Bhiwapur Chilli and Nandurbar Mirchi	2
		Manipur	Sirarakhing Hathei Chili	1
		Mizoram	Mizo Chilli	1
		Nagaland	Naga Mircha	1
		Sikkim	Dalle Khursani	1
		TN	Ramnathapuram Mundu Chilli	1
		Uttar Pradesh	Banaras Lal Bharwamirch (Red Pickle Chilli)	1
		Uttarakhand	Almora Lakhori Mirchi	1
			Chilli Total	14
13	Brinjal	Goa	Agasaim Agsechi Vayingim	1
		Karnataka	Udupi Mattu Gulla Brinjal	1
		Maharashtra	Jalgaon Bharit	1
		Odisha	Nayagarh Kanteimundi	1
		TN	Vellore Spiny Brinjal	1
		Uttar Pradesh	Ramnagar Bhanta	1

S.No	Crop	State	GI Products -Names	No.
14	Bhindi	Goa	Sat Shiro Bheno [Bhindi]	1
15	Beans	Kerala	Attappady Aattukombu Avara	1
16	Rajma	Maharashtra	Waghya Ghevada	1
		J&K	Bhaderwah Rajmash	1
		UttaraKhand	UttaraKhand Munsyari Razma	1
17	Cucumber	Kerala	Kodungatlur Pottuvellari	1
		Nagaland	Naga Cucumber	1
18	Onion	Karnataka	Bangalore Rose Onion	1
		Maharashtra	Lasalgaon Onion, Alibaug White Onion	2
19	Garlic	Kerala	Kanthalloor-Vattavada Veluthulli	1
		MP	Ratlam Riyawan Lahsu	1
		TN	Kodaikanal Malai Poondu	1`
20	Coriander	Maharashtra	Kasti Coriander	1
21	Cumin	HP	Himachali Kala Zeera	1
22	Turmeric	Maharashtra	Waigaon Turmeric, Vasmat Haldi , Sangli Turmeric	3
		Meghalaya	Lakadong Turmeric	1
		Odisha	Kandhamal Haladi	1
		TN	Erode Manjal	1
23	Ginger	Assam	Karbi Anglong	1
		Arunachal	Adi Kiker Ginger	1
		Mizo	Mizo Ginger	1
			Grand Total	**91**

Others with GI Tag - mostly from the Horticultural Crops viz Guava: Allahabad Surkha Guava; Litchi: Assam Tezpur Litchi and Shahi Litchi of Bihar; MS--Sholapur Pomegranate; Sapota Dahanu Gholvad Chikoo; Nasik Grapes; and Mahabaleshwar Strawberry. Tripura Queen Pineapple, Kashmir Saffron; Gujarat-Kachchhi Kharek [Dates]; and Many types in Banana, Mango, Lemon/Orange, Fig, Coconut, Cardamom, Coffee, Tea, Jasmine, Tomato-Naga Tree Tomato, Betel.

HYGRO
TECH ENGINEERS
we treat moisture

Hygro Tech Engineers an ISO 9001-2015 Indigenous manufacturing company with 2 decades of experience in providing humidity solutions, arrived to treat moisture problems in the applications like Food Industries, Seed Industries, Agro, Pharma, Defense, Eng Aerospace etc...

Hygro Tech is an application company involved in air control and stimulation to sustain the desired environment with their unique air treatment products like Dehumidification systems, Seed dryers, Product drying chambers, Low RH dry rooms, Low temperature drying systems etc. Hygro Tech is a global supplier with their HO, Works & R&D based in Bangalore, KA and having a sales and after sales services PAN India and across south asian countries.

HYGRO CONDITIONED SEED BOX DRYER

The Hygro conditioned box dryer is a closed installation with which the seed is dried to the desired moisture content at the desired humidity & temperatures. This can be freshly harvested seed, or coated seeds or the seed that needs to be brought to a lower moisture content before shipping.

HYGRO CONDITIONED SEED DRUM DRYER

The Hygro Seed drum dryer comes with a very unique air flow design where the Dehumidified conditioned dry & cool air (desired conditions) pass inside each drum and exits to the Inner chamber from the fine mesh of the drums which improves the seed drying efficiency and uniform drying.

This seed drum can be used as a logistic solution for different seed processes. With the Hygro drying design, the dry air will get contact with the entire seed quantity inside the drums and that will ensure the perfect drying at minimum drying time.

HYGRO DEHUMIDIFCATION SYSTEM

The Inbuilt Dehumidification & AC system in all dryers are designed to achieve the desired conditions at as low as 10% RH @ 20 to 30 deg C temperatures with specific Rh & temp settings, programming for each drying cycles etc...

The seed dryers are specially designed with a closed air flow pattern to achieve the uniform seed drying regardless of the outside conditions. Works 24 x7.

HYGRO CONDITIONED SEED TRAY DRYER

The Hygro Seed tray dryers consists of a chamber with trays for keeping the seeds to be dried and a desiccant dehumidifier with cooling arrangement which feeds a continuous dry & cool air to the chamber. The Tray dryer unique dry air distribution pattern optimises the seed drying capacity and drying time.

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For more details or enquiries please visit our website
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