National Seed Association of India

14TH INDIAN SEED CONGRESS
26th - 28th February, 2026
SEED INNOVATIONS-REACHING GLOBAL
Duangjitt Resort & Spa, Phuket, Thailand

Seed Innovations-Reaching Global

14th INDIAN SEED CONGRESS

26th – 28th February, 2026, Phuket, Thailand

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Preface

The Indian seed industry has played a vital role in ensuring farmers' continued access to quality seeds while strengthening food, nutritional, and livelihood security for a rapidly growing population. Through advanced breeding technologies such as marker-assisted and genomic selection, the industry has developed high-performance crop varieties that enhance productivity, sustainability, and market competitiveness. These innovations have not only supported farm-level outcomes but have also driven the expansion of seed business, strengthened domestic and international seed trade, and reinforced India's position in the global seed market. 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 14th edition of its flagship event, the Indian Seed Congress 2026 on 27th and 28th February, 2026 in Phuket, Thailand. In recognition of the transformative role of emerging technologies in driving the next agricultural revolution through quality seeds and sustainable production systems, the theme of ISC 2026 has been aptly chosen as **"Seed Innovations – Reaching Global."** The theme highlights the importance of global collaborations and partnerships to leverage modern breeding, genomic innovations, precision agriculture, and biotechnology to accelerate the development and commercialization of superior seed products. It emphasizes expanding market opportunities, strengthening international seed trade, and enhancing the global competitiveness of the Indian seed industry.

The ISC 2026 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 global seed business development issues which are going to be the core attraction of ISC. For various technical sessions, the organizing committee has identified the best subject matter experts to present their views in alignment with the theme of the congress.

The Souvenir brought out on this occasion contains topics on seed and related areas of agriculture contributed by the esteemed speakers of the ISC 2026. The articles covered in the Souvenir includes 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 professionals 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

Chairman, Technical Committee, ISC-2026

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शिवराज सिंह चौहान
SHIVRAJ SINGH CHOUHAN

D.O. No. 39 /AM

सत्यमेव जयते

कृषि एवं किसान कल्याण और
ग्रामीण विकास मंत्री
भारत सरकार
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Minister of Agriculture & Farmers Welfare and Rural Development
Government of India
Krishi Bhawan, New Delhi

संदेश

मुझे यह जानकर खुशी हो रही है कि भारतीय राष्ट्रीय बीज संघ (NSAI), जो भारतीय बीज उद्योग का सबसे बड़ा संगठन है, अपने प्रमुख कार्यक्रम, **इंडियन सीड कांग्रेस 2026** (**ISC 2026**)के 14वें संस्करण का आयोजन फुकेट, थाईलैंड में 26 से 28 फरवरी 2026 तक कर रहा है।

भारतीय बीज उद्योग ने, एक मजबूत अनुसंधान प्रणाली और निजी क्षेत्र के विकास के लिए अनुकूल सरकारी नीतियों के समर्थन से, कृषि को मजबूत करने और किसानों की आजीविका को बेहतर बनाने में महत्वपूर्ण भूमिका निभाई है। प्लांट ब्रीडिंग, बायोटेक्नोलॉजी और आधुनिक बीज उत्पादन टेक्नोलॉजी में प्रगति ने उच्च उपज देने वाली और जलवायु के प्रति लचीली फसल किस्मों के विकास को संभव बनाया है जो देश की खाद्य सुरक्षा जरूरतों को पूरा करने में सक्षम हैं।

भारत की समृद्ध कृषि-जैव विविधता और उभरते इनोवेशन को देखते हुए, भारतीय बीज क्षेत्र न केवल किसानों की मदद कर रहा है, उनकी आय बढ़ा रहा है, बल्कि बीजों के लिए एक निर्यात केंद्र बनने और वैश्विक बीज बाजारों तक पहुंचने के विशाल अवसर की संभावनाओं को भी तलाश रहा है। इसलिए, मैं NSAI की सराहना करता हूं कि उन्होंने **ISC 2026** का मूल विषय **"सीड इनोवेशन – रीचिंग ग्लोबल"** रखा है, जो काफी उपयुक्त है। इस कांग्रेस के आयोजन स्थल के रूप में थाईलैंड का चयन इस मूल विषय के साथ मेल खाता है, क्योंकि इस जगह को वैश्विक बीज आदान-प्रदान और कृषि व्यापार के लिए एक प्रमुख केंद्र के रूप में व्यापक रूप से स्वीकार किया जाता है।

मुझे उम्मीद है कि **ISC 2026** नए व्यापारिक सहयोगों और साझेदारियों को जन्म देगा और भारतीय बीजों के लिए नए बाजारों की तलाश करेगा ताकि देश की बीज अर्थव्यवस्था को और मजबूत किया जा सके।

मैं भारतीय राष्ट्रीय बीज संघ (NSAI) को इंडियन सीड कांग्रेस 2026 के सफल आयोजन के लिए अपनी शुभकामनाएं देता हूं ।

(शिवराज सिंह चौहान)

भागीरथ चौधरी
BHAGIRATH CHOUDHARY

सत्यमेव जयते

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संदेश

यह अत्यंत हर्ष का विषय है कि नेशनल सीड एसोसिएशन ऑफ इंडिया अपने प्रमुख कार्यक्रम 14वें भारतीय बीज कांग्रेस 2026 का आयोजन 26 से 28 फरवरी 2026 के दौरान फुकेत, थाईलैंड में "बीज नवाचार - वैश्विक पहुंच" (Seed Innovation - Reaching Global) विषय के अंतर्गत कर रहा है।

भारत का बीज क्षेत्र देश की खाद्य अर्थव्यवस्था में महत्वपूर्ण भूमिका निभाता रहा है। पौध प्रजनन, जैव प्रौद्योगिकी तथा आधुनिक बीज प्रसंस्करण में हुए नवीनतम विकासों ने भारतीय बीज कंपनियों को उच्च गुणवत्ता, जलवायु-अनुकूल एवं उत्कृष्ट प्रदर्शन वाले बीज उपलब्ध कराने में सक्षम बनाया है, जो न केवल घरेलू आवश्यकताओं को पूरा करते हैं, बल्कि विश्व के विभिन्न कृषि-जलवायु क्षेत्रों के लिए भी उपयुक्त हैं। एशिया, अफ्रीका तथा अन्य विकासशील बाजारों में भारतीय बीजों की बढ़ती स्वीकार्यता उद्योग की गुणवत्ता, विश्वसनीयता और किफायतीपन के प्रति प्रतिबद्धता को दर्शाती है।

बीज निर्यात न केवल नए व्यापारिक अवसर और विदेशी मुद्रा अर्जन को बढ़ावा देता है, बल्कि वैश्विक खाद्य एवं पोषण सुरक्षा में भारत के योगदान को भी सुदृढ़ करता है। अंतरराष्ट्रीय गुणवत्ता मानकों के अनुरूपता, नियामक ढांचे को मजबूत करने तथा वैश्विक साझेदारियों को प्रोत्साहित करने के माध्यम से भारतीय बीज उद्योग अपने निर्यात विस्तार के लिए सक्षम स्थिति में है और एक विश्वसनीय वैश्विक बीज आपूर्तिकर्ता के रूप में उभर सकता है।

मुझे पूर्ण विश्वास है कि यह कांग्रेस वैश्विक सहयोग को प्रोत्साहित करेगी और भारत के बीज निर्यात विस्तार हेतु रणनीतियों को आकार देने में महत्वपूर्ण योगदान देगी।

मैं "बीज नवाचार - वैश्विक पहुंच" जैसे प्रासंगिक और दूरदर्शी मूल विषय पर आधारित भारतीय बीज कांग्रेस 2026 के आयोजन हेतु नेशनल सीड एसोसिएशन ऑफ इंडिया को हार्दिक बधाई एवं शुभकामनाएं प्रेषित करता हूं।

(भागीरथ चौधरी)

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डॉ. देवेश चतुर्वेदी
सचिव
Dr. Devesh Chaturvedi
Secretary

सत्यमेव जयते

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कृषि एवं किसान कल्याण विभाग
Government of India
Ministry of Agriculture & Farmers Welfare
Department of Agriculture & Farmers Welfare

Message

I am happy to learn that the National Seed Association of India (NSAI) is organizing the 14th edition of its flagship event, the **Indian Seed Congress 2026**, from **February 26 to 28, 2026 in Phuket, Thailand** on the theme **"Seed Innovations – Reaching Global."**

India's transformation from a food-deficient nation to a food-surplus country stands as a remarkable achievement, largely driven by the success of the Green Revolution and the widespread adoption of high-yielding and improved seed varieties. Over the years, the Indian seed industry has emerged as one of the most dynamic and resilient sectors of agriculture, supported by strong public–private partnerships, a robust R&D ecosystem, and the integration of advanced technologies in plant breeding, seed production, processing, testing, and quality assurance.

Today, with growing global demand for high-productivity quality seeds, climate-resilient varieties, and sustainable agricultural solutions, India is well-positioned to emerge as a key player in the global seed trade. Innovations in genomics, biotechnology, digital agriculture, and seed health management are opening new opportunities for Indian seed companies to expand their footprint in international markets, particularly in Asia, Africa, and Latin America. The theme "Seed Innovations – Reaching Global" aptly reflects India's aspirations to leverage innovation, regulatory harmonization, and market access to enhance seed exports and strengthen its role in ensuring global food and nutritional security.

I hope that the deliberations during the Indian Seed Congress 2026 will help chart a clear roadmap for strengthening global collaborations, unlocking export potential, and positioning India as a trusted hub for high-quality seeds worldwide.

I wish the **Indian Seed Congress 2026** a grand success.

(Dr. Devesh Chaturvedi)

New Delhi
January 14, 2026

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सत्यमेव जयते

डॉ .एम.एल .जाट
DR. M. L. JAT
सचिव (डेयर) एवं महानिदेशक (आईसीएआर)
Secretary (DARE) & Director General (ICAR)

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GOVERNMENT OF INDIA
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MESSAGE

National Seed Association of India (NSAI) has been contributing significantly towards strengthening the Indian seed industry by way of policy advocacy and facilitating technology support. Today, the Indian seed industry is characterized by strong research capabilities, widespread adoption of modern technologies, and a responsive farming ecosystem. These strengths are enabling India to position itself as a competitive and reliable partner in the global seed trade, while contributing to food and nutritional security beyond its borders.

The organization of this seed congress on the theme **"Seed Innovations-Reaching Global",** in Phuket, Thailand during **26th to 28th February 2026**, signifies the increasing global orientation of the seed industry and India's growing engagement with international markets. I am confident that the deliberations at the Indian Seed Congress 2026 will help address emerging challenges faced by the Indian and global seed sectors, foster meaningful international collaboration, knowledge transfer and expand India's seed export potential.

My best wishes for the successful outcome of the **Indian Seed Congress 2026**.

(M. L. Jat)

Dated the 27th January, 2026
New Delhi

ICAR
डॉ. देवेन्द्र कुमार यादव
उप महानिदेशक (फसल विज्ञान)
Dr. Devendra Kumar Yadava
Deputy Director General (Crop Science)

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Indian Council of Agricultural Research
Department of Agricultural Research & Education
Ministry of Agriculture and Farmers Welfare
Govt. of India, Krishi Bhawan, New Delhi-110001

MESSAGE

It is a matter of great pleasure to note that the National Seed Association of India (NSAI), apex industry body representing stakeholders across the Indian seed sector, is organizing the 14th edition of its flagship event, **Indian Seed Congress 2026** from **27th to 28th February 2026 in Phuket, Thailand**, on the theme **"Seed Innovations – Reaching Global."**

Over the past decades, remarkable progress in plant breeding has reshaped global agriculture. Conventional breeding, supported by molecular tools such as marker-assisted selection, genomic selection, and gene editing, has enabled the development of crop varieties that are high-yielding, climate-resilient, and tolerant to major biotic and abiotic stresses. These scientific advances are helping farmers adapt to drought, heat, salinity, floods, and emerging pest and disease threats.

Importantly, India is no longer only a consumer of global seed technologies—it is increasingly becoming a **contributor to the global seed value chain**. With its vast genetic diversity, scientific expertise and cost-efficient seed production systems, India has immense potential to emerge as a global hub for seed research, multiplication, and exports. In the context of increasing global demand for high-quality seeds and sustainable agricultural solutions, India holds immense potential to expand its presence in international seed trade. The theme **"Seed Innovations – Reaching Global"** aptly captures the sector's vision to leverage innovation, technology, and international collaboration to enhance seed exports and contribute meaningfully to global food and nutritional security.

I wish all the success to ISC 2026.

देवेन्द्र कुमार यादव

(D. K. Yadava)

Dated: January 14, 2026
Place: New Delhi

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सत्यमेव जयते

AJEET KUMAR SAHU, I.A.S.
Joint Secretary
Government of India
Ministry of Agriculture & Farmers Welfare
Department of Agriculture and Farmers Welfare
Krishi Bhawan, New Delhi-110001

MESSAGE

"I am delighted to learn that the National Seed Association of India (NSAI) is organizing the 14th edition of its flagship event, the **Indian Seed Congress (ISC-2026)**, in Phuket, Thailand.

India's transformation into a food-surplus nation is a tribute to the resilience of our farmers and the continuous innovation within our seed sector. Today, our vision has evolved beyond mere food security to ensuring **Income Security for our farmers**. As the world's fifth-largest seed economy, the Indian seed industry plays a pivotal role in this journey. By providing climate-resilient, high-yielding, and affordable seeds, we are empowering our farmers to overcome the challenges of climate change and rising input costs.

The "Reaching Global" aspiration is not just about trade; it is about positioning India as a global hub for quality seeds that can bring prosperity to fields both at home and abroad.

I compliment NSAI for choosing a theme that highlights the importance of global integration while remaining rooted in domestic agricultural strength. I am confident that the deliberations at ISC-2026 will pave the way for strategic partnerships that strengthen the entire value chain—from the scientist's lab to the farmer's market.

I wish the Congress every success."

(Ajeet Kumar Sahu)

New Delhi
February 02, 2026

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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 350 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.

Technological innovations in the seed sector have accelerated the development of high-yielding, climate-resilient varieties and hybrids, strengthening their commercial value and relevance for global markets. The industry's growing focus on biotechnology, precision breeding, and advanced seed treatments has enhanced product differentiation, shortened development cycles, and improved competitiveness. These advancements are enabling seed companies to expand market reach, strengthen international trade, and deliver superior seed products with traits such as drought tolerance, pest resistance, and higher yield potential driving sustained business growth and reinforcing India's position in the global seed industry.

It is therefore, very timely to organize the 14th edition of the Indian Seed Congress 2026 on the theme, "Seed Innovations-Reaching Global". I hope the Indian Seed Congress will offer delegates a valuable platform to assess the latest advances in plant breeding, biotechnology, processing technologies, seed treatments, and policy frameworks that impact the seed business. It will also facilitate in-depth discussions on industry experiences in adopting new technologies and expert perspectives, helping to generate actionable recommendations to enhance business performance, service delivery to farmers, and the overall contribution of the seed sector to strengthen Indian seed sector both nationally and globally.

On behalf of the National Organizing Committee of the event, I welcome all the delegates and participants of ISC-2026 and look forward to productive deliberations which can help in sustainability, unceasing improvement not only in the sustainable growth of Indian seed industry but opening avenues for Indian seeds in global seed market.

Dr. M. Prabhakar Rao

President-NSAI

Message

FROM THE DESK OF DIRECTOR (TECHNICAL)

The seed industry has experienced strong and sustained growth, driven by continuous innovations, effective collaboration, and the ability to adapt to evolving market dynamics. Advances in crop breeding, biotechnology, and seed treatment technologies have led to the development of superior varieties with higher yield potential, improved disease resistance, and greater tolerance to environmental stresses, creating substantial opportunities for commercial expansion and enhanced global competitiveness.

Strategic partnerships among researchers, policymakers, regulators, farmers, and industry stakeholders have strengthened the exchange of knowledge, genetic resources, and advanced technologies, thereby accelerating innovation, product commercialization, and cross-border seed trade. The industry's proactive response to changing agricultural practices and emerging market demands highlights its critical role in global food security, while also opening new avenues for seed business growth and international market integration. Regulatory harmonization governmental policies supporting cross border seed trade also play a prominent role in fostering global partnerships on seed development and exchange.

The National Seed Association of India (NSAI), representing over 350 seed companies across large, medium, and SME segments, is working relentlessly to enable genetic improvement of crops, strengthen regulatory and trade facilitation frameworks, and position India as a competitive hub for seed business and global seed trade.

The **14th Indian Seed Congress 2026** being organized by NSAI on the theme **"Seed Innovations- Reaching Global" at Duangjitt Resort & Spa, Phuket, Thailand, on 27–28 February 2026** is going to serve as a strategic platform for global business engagement, facilitating dialogue on emerging seed technologies, market expansion, and international partnerships. Through advancements in breeding, genomics, biotechnology, regulatory/ policy alignment and digital agriculture, ISC 2026 aims to generate new business opportunities, reinforce India's position in the global seed value chain, and promote sustainable growth in international seed trade.

Dr. R. K. Tripathi

Director (Technical) - NSAI

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INDIAN SEED CONGRESS 2026

Seed Innovations-Reaching Global
(Technical Programme)

Day 1-Friday, 27th February, 2026

Time	Event
8:30 AM-9:30 AM	Registration
9:30 AM-10:15 AM	Opening Session and Inauguration of Trading Table/Exhibition Hall
10:15 AM-10:45 AM	Tea Break

Technical Session I: Research & Innovation- Driving Global Seed Competitiveness
Time: 10:45 AM – 1:00 PM
Chair: Dr. D. K. Yadava, DDG (CS), ICAR
Moderator: Dr. Sanjay Kumar, Advisor, Beej Anusandhan Kendra, IFFCO, Gandhinagar

10:45 AM – 10:55 AM		Opening Remarks by Moderator	
SN	Duration	Topic	Speaker
1.	10:55 AM – 11:25 AM	Next-Generation Breeding Technologies for Global Markets	**Dr. Yunbi Xu** Senior Research Professor, Peking University Institute of Advanced Agricultural Sciences, China
2.	11:25 AM – 11:55 AM	Preparing for Future: Advancements in Product Evaluation	**Dr. Taweesak Pulam** Managing Director, Thai Seed Research Company Limited
3.	11:55 AM – 12:25 PM	Public Private Partnership in Seed Innovation	**Dr. Sadawud Koonmanee** Executive Vice President, Charoen Pokphand Produce Co., Ltd., Thailand
4.	12:25 PM – 12:40 PM	Interaction of Moderator with Panelists on Key Industry Issues	
12:40 PM – 1:00 PM		Q&A and closing remarks of the Chair	
Lunch: 1:00 PM – 2:30 PM			

Technical Session II: Disruptive Technologies in Seed Innovations and Quality Management
Time: 2:30 PM – 4:30 PM
Chair: Dr. P. K. Singh, Agriculture Commissioner, DAFW, MoAFW, GoI
Moderator: Dr. K. Keshavulu, Immediate Past President, ISTA

2:30 PM – 2:40 PM		Opening Remarks by Chair/Co-chair	
SN	Duration	Topic	Speaker
1.	2:40 PM – 3:10 PM	Smart Seed Technologies for Seed Quality Enhancement	**Mr. Johan Van Asbrouck** (Ex-Chair, APSA Standing Committee for Seed Technology), Executive President, Rung Rueng Consulting Co., Ltd. (Rhino Research), Bangkok, Thailand
2.	3:10 PM – 3:40 PM	Strengthening Seed Testing Laboratories and Quality Assurance for meeting Global Standards : A Strategic Roadmap for 2026	**Dr. Damrongvudhi Onwimol** Associate Professor, Department of Agronomy, Faculty of Agriculture Kasetsart University, Bangkok, Thailand
3.	3:40 PM – 4:10 PM	Interaction of Moderator with Panelists on Key Industry Issues	
4:10 PM – 4:30 PM		Q&A and Closing Remarks by Chair	
Tea Break: 4:30 PM – 05:00 PM			
4:30 PM – 5:30 PM		Close group meeting with Taiwan Seed Trade Association/ Industry Representative (On Registration Basis)	
5:30 PM – 7:00 PM		Trading/Business Activities	
7:00 PM Onwards		Cultural Program & Welcome Dinner	

Day 2- Saturday, 28th February, 2026

9:30 AM – 11:00 AM	Industry Business Showcase
10:30 AM – 11:30 AM	Close group meeting with Thailand Seed Association/ Industry Representative (On Registration Basis)
Tea Break- 11:00 AM-11:30 AM	

Technical Session III: Policy and Regulatory Frameworks for Seed Trade
11:30 AM – 1:15 PM
Chair: Dr. Ravi Khetarpal, Executive Director, APAARI
Moderator: Mrs. K. K. Tara, Head IP & Regulatory Affairs, NSL Hyderabad

11:30 AM – 11:40 AM		**Opening Remarks by Moderator**	
SN	**Duration**	**Topic**	**Speaker**
1.	**11:40 AM – 12:00 Noon**	Strengthening India's Seed Policy Architecture and Opportunities for Global Alignment	**Mr. Ajeet Kumar Sahu** Joint Secretary (Seeds), GoI
2.	**12:00 Noon – 12:20 PM**	Global Regulatory Trends Shaping Seed Innovation, IPR & Trade	**Mr. Rajvir Rathi** Vice Chairman, Federation of Seed Industry of India
3.	**12:20 PM – 12:40 PM**	Building Sustainable Business Growth Ethically, with Strong Adherence to IPR and Legal Compliance	**Dr. Kirtan Y. Patel** Director (Research), Moti Seeds Pvt Ltd.
4.	**12:40 PM – 12:55 PM**	Interaction of Moderator with Panelists on Key Industry Issues	
12:55 AM – 1:15 PM		**Q&A and Closing Remarks by Chair**	
Lunch: 1:15 PM – 2:30 PM			

Technical Session IV: Global Opportunities, Investments & Future Growth of the Seed Sector
Time: 2:30 PM – 4:15 PM
Chair: Dr. M. Prabhakar Rao, President, NSAI
Moderator: Mr. Chetan Joshi, Managing Director, BBSSL

2:30 PM – 2:40 PM		**Opening Remarks by Moderator**	
SN	**Duration**	**Topic**	**Speaker**
1.	**2:40 PM – 2:55 PM**	Global trends in Seed & Agri Biotech Innovations & Investments: What It Means for India	**Dr. G. Chaluvaraju** Asia Head- R&D-BASF NUNHEMS, India
2.	**2:55 PM – 3:10 PM**	Structural Competitiveness and Strategic Trajectory of India's Seed Export Sector	**Dr. S. Rajendra Prasad** Ex-Vice Chancellor, University of Agricultural Sciences, Bengaluru
3.	**3:10 PM – 3:25 PM**	The role of National/Regional Associations in Exploring Global Opportunities for the Seed Sector to Achieve Sustainable Growth	**Ms. Francine Sayoc** Executive Director, APSA
4.	**3:25 PM – 3:40 PM**	Artificial Intelligence for Agricultural Development and Farmers' Prosperity with Special Reference to Seed Supply Chain	**Dr. Kavya Dashora** Associate Professor, Centre for Rural Development and Technology, Yardi School of Artificial Intelligence, IIT, Delhi
3:40 PM – 3:55 PM		Interaction of Moderator with Panelists on Key Industry Issues	
3:55 PM – 4:15 PM		**Q&A and Closing Remarks by Chair**	
Tea Break: 4:15 PM – 4:45 PM			

4:15 PM – 5:15 PM	Close group meeting with African Seed Trade Association (AFSTA)/ Industry Representative (On Registration Basis)
5:15 PM – 6:15 PM	**Valedictory Session and Award Ceremony**
7:00 PM Onwards	**Cultural Program & Gala Dinner**

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Technical Session I

Technical Session I: Research & Innovation- Driving Global Seed Competitiveness **Time: 10:45 AM – 1:00 PM** **Chair:** Dr. D. K. Yadava, DDG (CS), ICAR **Moderator:** Dr. Sanjay Kumar, Advisor, Beej Anusandhan Kendra, IFFCO, Gandhinagar			
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4.	**12:25 PM – 12:40 PM**	Interaction of Moderator with Panelists on Key Industry Issues	
12:40 PM – 1:00 PM		Q&A and closing remarks of the Chair	

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CHAIR

DR. D. K. YADAVA

Deputy Director General (Crop Science),
ICAR, New Delhi

Dr. Devendra Kumar Yadava, Deputy Director General (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 regular Assistant Director General (Seed) from 2021 to 12th February 2025, when he took over as DDG (Crop Science).

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 2025, 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 than100 research papers in high impact factor journals.

MODERATOR

DR. SANJAY KUMAR

Advisor, Beej Anusandhan Kendra,
IFFCO, Gandhinagar

Dr. Sanjay Kumar, born in a farming family of Bihar obtained his agricultural degrees, B.Sc. Ag & A.H, M.Sc. Ag & Ph.D. in Genetics & Plant Breeding from G. B. Pant University of Agriculture & Technology, Pantnagar. He has more than 34 years of research career commencing from Wheat breeder at IARI, New Delhi to Director, ICAR- National Institute of Seed Science & Technology, Mau, U.P. He served at different position in IARI New Delhi as Head, IARI, Regional Station, Shimla, Incharge, Business Planning & Development Unit, IARI and Head, Seed Production Unit, IARI, New Delhi.

He has competence in the areas of Seed System, Seed Technology Research, Genetics & Plant Breeding with robust track record in Strategic Leadership and Stakeholder Engagement. He has developed 42 wheat and 4 barley varieties, registered 12 germplasm of wheat & barley for different characteristics and published more than 120 research papers in National & International Journals. Reorganised seed production system (mainly breeder seed production) with significant reduction in varietal mismatch (24.3% to 11.4%) and Varietal replacement rate from 65% to 90%. Developed different models for commercialization of crop varieties and robust IP protection and Licensing system in ICAR. Facilitated creation of FPO's mainly for seed business and fostering innovation and commercialization.

He is recipient of many awards and honour including, Nanaji Deshmukh Award for Outstanding Interdisciplinary Team Research in Agriculture and Allied Science, Chaudhary Devi Lal Outstanding Award for Best AICRP, Fellows of Indian Society of Genetics & Plant Breeding and Indian Society for Advancement of Wheat Research. Hs had been President of Indian Society of Genetics and Plant Breeding(ISGPB) and Society for Extension, Education and Development of Seed (SEEDS).

Next-Generation Breeding Technologies for Global Markets

YUNBI XU[1,2]

[1]State Key Laboratory of Wheat Improvement, Peking University Institute of Advanced Agricultural Sciences, Shandong Laboratory of Advanced Agricultural Sciences in Weifang, Shandong 261325, China

[2]State Key Laboratory of Crop Gene Resources and Breeding, National Key Facility for Crop Gene Resources and Genetic Improvement, Institute of Crop Science, Chinese Academy of Agricultural Sciences, Beijing 100081, China

DR. YUNBI XU

Senior Research Professor,
Peking University Institute of Advanced Agricultural Sciences, China

Dr. Yunbi Xu is a distinguished agricultural scientist with extensive international experience. He holds a B.S. from Huazhong Agricultural University, an M.S. and Ph.D. from Zhejiang Agricultural University, and completed postdoctoral training at Cornell University. Dr. Xu currently serves as a Senior Research Professor at Peking University Institute of Advanced Agricultural Sciences, and as a Research Professor at the Institute of Crop Science, Chinese Academy of Agricultural Sciences. He was recruited as an International Expert for China under the national talent program. His previous appointments include Assistant and Associate Professor at Zhejiang Agricultural University, Rice Molecular Breeder at RiceTec, Inc. (USA), Research Associate at Cornell University, and Principal Scientist at the International Maize and Wheat Improvement Center (CIMMYT). Dr. Xu has made significant contributions to editorial service, having served on the editorial boards of eight international journals, including an Editor for *Molecular Breeding* and *Theoretical and Applied Genetics*,

and Deputy Editor-in-Chief of *The Crop Journal*. Throughout his scientific career, Dr. Xu has dedicated himself to advancing the theories, technologies, platforms, and application systems of molecular breeding. He is the author of two influential books: *Molecular Quantitative Genetics* (China Agriculture Press, 1994) and *Molecular Plant Breeding* (CABI, 2010), the latter of which has been widely adopted as a textbook internationally. He has published over 180 SCI-indexed papers with more than 20,000 citations. He was ranked #2 among the Best Scientists in Mexico for 2023 and has been recognized as a Highly Cited Chinese Researcher annually since 2021.

Traditional breeding has formed the foundation of agricultural improvement for millennia, following a well-established pipeline that begins with variation identification, proceeds through recombinant recreation and rigorous selection, and culminates in multiple environmental trials before final variety release. This systematic approach has achieved remarkable successes, producing high-yielding varieties that have fed billions and transformed global agriculture. Looking forward, traditional breeding will continue to play indispensable roles in future breeding programs, particularly in handling complex polygenic traits, maintaining genetic diversity, and serving as the essential validation step for varieties developed through advanced technologies, ensuring that new cultivars perform robustly across diverse real-world conditions.

The advent of advanced breeding technologies has revolutionized genetic improvement across multiple dimensions. Marker-assisted breeding, encompassing marker-assisted backcrossing, genomic selection, and genomic-enviromic selection, enables precise tracking and prediction of desirable alleles across generations. Genome editing technologies such as CRISPR-Cas9 offer unprecedented precision in modifying target genes, while transgenic breeding continues to provide solutions for traits unavailable within species gene pools. The development of universal doubled haploid (DH) breeding technologies applicable across multiple species has dramatically accelerated homozygosity attainment. Speed breeding addresses temporal constraints through accelerating plant growth—including shortening the juvenile phase in forest trees—and streamlining breeding procedures to achieve multiple generations annually. Plant factory breeding enables year-round cultivation independent of seasonal and geographic limitations. Breeding by molecular design represents a paradigm shift, facilitating creation of new varieties, new species, and cultivars specifically tailored for target

environments through predictive modeling. Artificial intelligence now assists and increasingly drives breeding decisions, from phenotype prediction to cross design. Integrated breeding platforms incorporating genotype-phenotype-envirotype -spatiotemporality (G-P-E-S) information provide comprehensive decision support. The emergence of contract research organizations (CROs) has restructured the breeding landscape, enabling medium and small companies to access specialized capabilities without massive infrastructure investment. Envirotyping, recognized as one of seven transformative concepts in crop genetic improvement since the 1990s, enables precise characterization of target environments and predictive matching of varieties to specific agro-ecological niches.

Future breeding will transcend terrestrial boundaries and conventional biological constraints. Space breeding represents the ultimate frontier, developing crop varieties capable of sustaining human life on Mars and other celestial bodies, thereby supporting humanity's evolution into a multiplanetary species. Synthetic biology will enable de novo design of biological systems, potentially creating entirely novel organisms with optimized metabolic pathways for food, fuel, and material production. Ultimately, these technological trajectories suggest a profound transformation: as crop production becomes fully automated and breeding achieves predictive perfection through comprehensive biological understanding and artificial general intelligence, traditional concepts of crop production and breeding may eventually exit the stage of history, supplanted by sustainable food systems that generate nutrition directly from molecular and cellular processes without conventional agriculture.

Preparing for Future: Advancements in Product Evaluation

DR TAWEESAK PULAM

Managing Director,
Thai Seed Research Company Limited

Dr. Taweesak Pulam, born in 1951, completed his B.Sc. (Hons) from Kasetsart University, Thailand, in 1972, followed by a Ph.D. in Agronomy and Soil Science from the University of Hawaii in 1978. In 2022, he was awarded a Ph.D. (Hons) by Kasetsart University.

He began his career as a Lecturer in the Department of Agronomy at Kasetsart University during 1978–1979. From 1980 to 1991, he served as Research Station Manager at Pioneer Overseas Corporation (Thailand), where he led breeding programs in sorghum hybrids and field corn. Since 1992, he has been the Managing Director of Sweet Corn Products Co., Ltd., and has also served as Plant Breeder, Managing Director, and Owner of Sweet Seeds Co., Ltd. He later held the position of Sweet Corn Business Manager for Asia-Pacific at Syngenta Seeds from 1997 to 2008. In addition, he has been the Plant Breeder, Managing Director, and Owner of Thai Seed Research Co., Ltd. since 2006, and Managing Director and Owner of Sweet Corn Co., Ltd. since 2010.

Beyond his corporate leadership, Mr. Pulam has made significant contributions to professional associations and industry development. He served as President of the Plant Improvement and Crop Multiplication Association of Thailand for three consecutive terms from 2003 to 2008.

His outstanding contributions have been widely recognized through numerous

prestigious honors, including Taguchi Award for Best Biotechnology Company, Kasetsart University (1996), Outstanding Alumni, Dept of Soil Science, Kasetsart University (1999), Outstanding Citizen for Economic Development selected by Prime Minister Office of Thailand in 1999 (The Award was granted by the Crown Princess who represented the King of Thailand considered the most prestigious award for any Thai citizen), Outstanding Alumni, Kasetsart University (2000), Outstanding Plant Breeder, Plant Improvement and Crop Multiplication Association of Thailand (2010), Outstanding Alumni, College of Agriculture, Kasetsart University (2011) and Qilu Friendship Award, Shandong Provincial Government (2019).

TAWEESAK PULAM

Education:

1972 B. Sc. (Hons), Kasetsart University, Thailand

1978 Ph.D. Dept of Agronomy and Soil Science, University of Hawaii

2022 Ph.D. (Honorary) Kasetsart University, Thailand

TAWEESAK PULAM

Professional Work:

1978-1979 Lecturer at Dept of Agronomy, Kasetsart University

1980-1991 Research Station Manager, Pioneer Overseas Corporation (Thailand), breeding sorghum hybrid and field corn

1992-pres Managing Director, Sweet Corn Products Co., Ltd.

1992-pres Plant Breeder, Managing Director, and Owner Sweet Seeds Co., Ltd.

1997-2008 Sweet Corn Business Manager for Asia-Pacific, Syngenta Seeds

2006-pres Plant Breeder, Managing Director, and Owner, Thai Seed Research Co., Ltd.

2010-pres Managing Director and Owner, Sweet Corn Co., Ltd.

TAWEESAK PULAM

Many awards from my career

-Outstanding Soil Science Alumni
-Outstanding KU Alumni
-Recognized alumni U of Hawaii
-Taguchi Award
-Research Council Award for Inventing ATS-2
-Outstanding Citizen Award by Prime Minister Office and given by the Crown Princess
-Qilu Friendship Award, Shandong, PRC

I would like to thank to organizing committee to invite me to talk online to this meeting.

I was requested to talk on Products advancement in evaluation processes.

Plant breeding is both art and science.

Product advancement is also both art and science.

Plant breeding processes
-prebreeding or germplasm development
-line development
-line evaluation
-hybrid formation
-hybrid evaluation
-commercialization

I will talk on line and hybrid evaluation and advancement of the products.

Line advancement
-F2 to S1: individual plant
-S1 to Sn: family basis and per se
-Sn to Coded line: GCA with other lines
-Coded lines to parental lines: GCA and SCA

Line advancement is an art in the first few steps.
Later, it has science behind.

Cautions in Line advancement
-advance only good plants in good family
-drop any family if it does not perform well
-continue breeding with poor family will not be efficient
-discard about 50% of breeding lines

Before we do to hybrid evaluation we should know hybrid stages.
Different organization use different product stages.
Some starts from line development.
Few just start from hybrids which is the easiest one.

Product stages
-new hybrids R1
-retest hybrids R2
-advanced retest hybrids R3
-precommercial R4
-commercial R5

Testing system

Testing is the most expensive part of plant breeding program.

Nature of testing

-multi stage
-multi location
-large variation in environment

Product evaluation processes

@ First year testing
@ Second year testing
@ Third year testing
@ Wide area test and commercialize preparation
@commercialization

4- 6 years

1000
200
50
10
2
1 or 2 hybrids

On research station

Wide area test in farmer's field

Product advancement in public organization

- -standard experimental designs
- -ANOVA R1 to R2
- -ANOVA R2 to R3
- -ANOVA and Stability R3 to R4

Release to public.

Small and Large Plant Breeding Programs

All individual plant breeding programs are small and exist as private and government organizations

They have similar characters

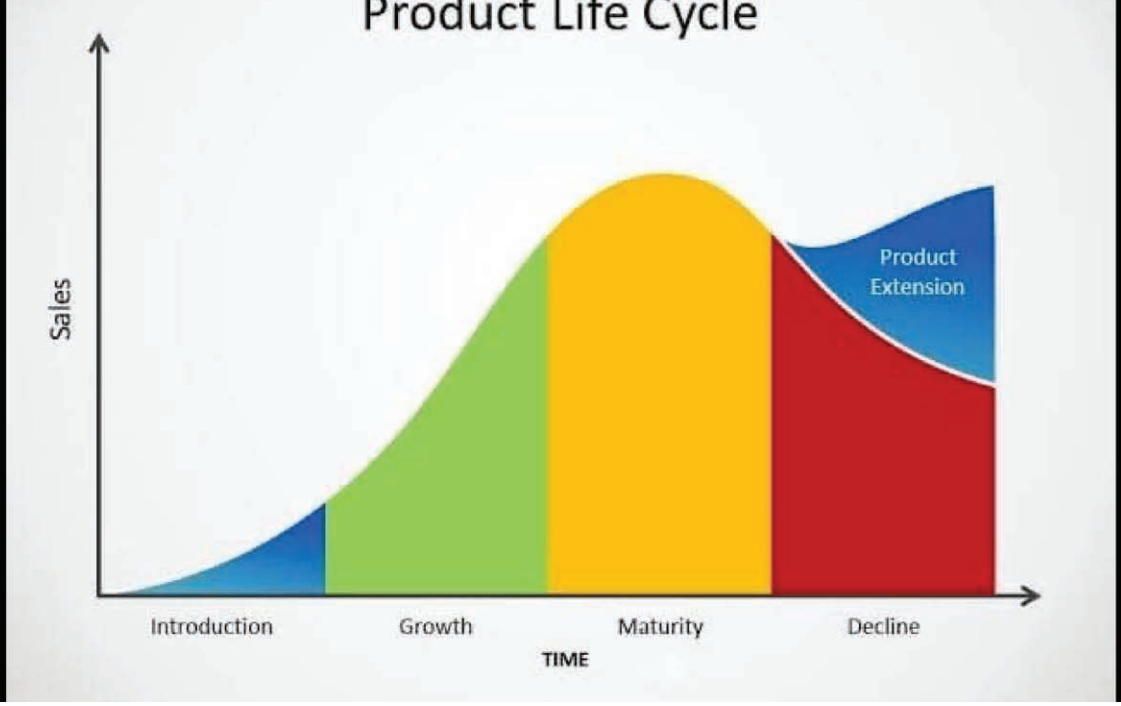
- -small budget
- -work as a single organization

In large private organizations, the program at a single research is small. But, the joint efforts among many research stations make a very big and efficient breeding program.

Product advancement in large international organization

- -R1 to R2: standard experimental designs that will accommodate large number of new hybrids
- -R2 to R3: multi-location trial using ANOVA and Stability
- -R3 to R4:
  - *similar and more locations
  - *strip test in farmer's field using side by side comparison
  - *cooperation from various department at this stage
- -R4 to R5: market test and market response

Products go into PLC management.



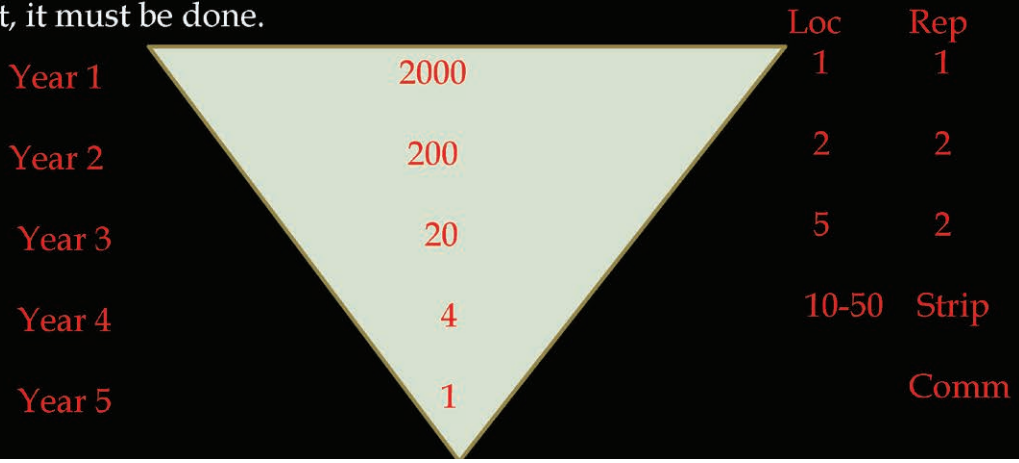
Product advancement in small organization
-simple evaluation of new hybrid in RCBD
-use ANOVA to advance R1 to R2
-multi location to advance R2 to R3
-strip test in farmer's field to advance R3 to R4
-market response to advance R4 to R5

Product advancement in my own organization
My organization
-small company works on 5 kinds of corn
*sweet corn
*high quality sweet corn
*red super sweet corn
*waxy corn
*grain corn

Hybrid testing…

-the most difficult process
-take long time
-most expensive

But, it must be done.



Product advancement in my own organization
-R1 to R2: 1 rep of running check
-R2 to R3: 2 rep, 1 loc
-R3 to R4: strip test in farmer's field
-R4 to R5: small market test and production test

Product advancement in my own organization

We do things differently from other small organizations.

- -we use experimental design to control error .
- -we don't do ANOVA to see difference
- -we use simple statistic like mean , minimum and maximum
- -we use minimum acceptable values of each trait to advance R1 to R2.

This is rarely done in plant breeding.
But, independent culling is always used in animal selection.

Product advancement in my own organization

-simple statistics behind
-use all historical data
-win and loose in strip test

Product advancement in my own organization

We do things differently from other small organizations.
- -we use mean of several location and season to advance R2 to R3
- -we use mean of all strip test to move R3 to R4
- -we use market response to move R4 to R5

Our method is not very well accept by academic people and many commercial people.

Few things to remember in hybrid evaluation
- -drop hybrids as soon as disvover bad points
- -testing will not make better hybrid
- -consider production points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Public Private Partnership in Seed Innovation

DR. SADAWUD KOONMANEE

Executive Vice President,
Charoen Pokphand Produce Co., Ltd., Thailand

Dr. Sadawud Koonmanee is currently Executive Vice President, R&D Department, Charoen Pokphand Produce Co. Ltd, Thailand. He holds a Ph.D. in Tropical Agriculture (Research in maize doubled haploid technology) from Kasetsart University, Thailand (2013–2018). He also earned an M.Sc. in Agronomy (Genetics and Plant Breeding) from Kasetsart University (1993–1997), and a B.Sc. in Plant Science from King Mongkut's Institute of Technology Ladkrabang (KMITL), Thailand (1991–1993).

He began his professional career as an Assistant Researcher in the Corn Breeding Program at the National Corn and Sorghum Research Centre (Suwan Farm), Thailand, where he worked from 1993 to 1996. He then joined Inter Asian Seeds Co. Ltd. (CP Group) at Sawankhalok, Thailand, contributing to the Specialty Corn Breeding Program from 1996 to 2004. In 2004, he moved to Charoen Pokphand Seeds (India) Pvt. Ltd. (CP Group), where he has been serving as a Maize Breeder and Head of R&D for South Asia. Since 2018, he has also been working with Charoen Pokphand Produce Co. Ltd. (CP Group) as Head of R&D for Seeds and Plant Nutrition.

His key achievements include the development of several successful specialty corn hybrids, including three baby corn hybrids (CP IB9710, CP B468, and CP B472 male sterile), two sweet corn hybrids (Wantong 1 and Wantong Super), two popcorn hybrids (CP VIP 01 and CP 167), and one waxy corn hybrid (KNSW 1). He has also played a major role in developing and improving commercial maize hybrids released in India and other regions to support seed business across South Asia, Southeast Asia, and Africa. These include CP 818 (2004), CP 828 and CP 848 (2006), CP 808

(2007), CP 838 (2009), and several newer releases such as CP 801, 802, 804, 858, 111, 222, 333, 555, 999, 389, 535 etc. In addition, he developed corn inbred lines by using Conventional Breeding, Doubled Haploid Technology and MAS.

He has actively contributed to strengthening company R&D capabilities by establishing a biotechnology laboratory to support seed research and business in India. He has also led efforts to scout and acquire new products and technologies by visiting and collaborating with international institutions and companies across China, Indonesia, Brazil, Argentina, Romania, Ukraine, the USA, and several African countries.

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Technical Session II

Technical Session II: Disruptive Technologies in Seed Innovations and Quality Management
Time: 2:30 PM – 4:30 PM
Chair: Dr. P. K. Singh, Agriculture Commissioner, DAFW, MoAFW, GoI
Moderator: Dr. K. Keshavulu, Immediate Past President, ISTA

2:30 PM – 2:40 PM		**Opening Remarks by Chair/Co-chair**	
SN	**Duration**	**Topic**	**Speaker**
1.	**2:40 PM – 3:10 PM**	Smart Seed Technologies for Seed Quality Enhancement	**Mr. Johan Van Asbrouck** (Ex-Chair, APSA Standing Committee for Seed Technology), Executive President, Rung Rueng Consulting Co., Ltd. (Rhino Research), Bangkok, Thailand
2.	**3:10 PM – 3:40 PM**	Strengthening Seed Testing Laboratories and Quality Assurance for meeting Global Standards : A Strategic Roadmap for 2026	**Dr. Damrongvudhi Onwimol** Associate Professor, Department of Agronomy, Faculty of Agriculture Kasetsart University, Bangkok, Thailand
3.	**3:40 PM – 4:10 PM**	Interaction of Moderator with Panelists on Key Industry Issues	
4:10 PM – 4:30 PM		**Q&A and Closing Remarks by Chair**	

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CHAIR

DR. P. K. SINGH,

Agriculture Commissioner,
DAFW, MoAFW, GoI

Dr. P. K. Singh is the Agriculture Commissioner, Ministry of Agriculture and Farmers' Welfare.

He worked as Registrar, Protection of Plant Varieties & Farmers' Rights Authority, Govt. of India, Ministry of Agriculture, New Delhi.

He also served as Nodal Officer-II for DUS Testing of Sugarcane at IISR, Lucknow and Nodal Officer for Seed Production of Sugarcane under ICAR Seed Project.

His Contribution to the Scientific Advancement includes Publications in Research Journals (31), Presentations in Seminar/Symposia (50), Book Chapters, Bulletins, Lead Papers, *etc* (25), Seminar/Symposia/Workshops etc (80), Varieties Developed under AICRP(S) testing (09), Germplasm Registration (02) and Germplasm under Maintenance (284).

MODERATOR

DR. K. KESHAVULU

Immediate Past President,
International Seed Testing Association (ISTA)

Dr. K. Keshavulu is the immediate Past President of the International Seed Testing Association (ISTA), Switzerland, Former Director, Telangana State Seed and Organic Certification Authority and former Managing Director, Telangana State Seed Corporation.

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 President of ISTA, he led seed quality assurance initiatives and played a key role in setting global seed testing standards to meet the evolving requirements of the international seed industry.

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 strove to accomplish ISTA's mission and promoted awareness and knowledge of ISTA worldwide, particularly in the Asia region, while also supporting the Indian seed sector in strengthening its global presence.

Smart Seed Technologies for Seed Quality Enhancement

MR. JOHAN VAN ASBROUCK

(Ex-Chair, APSA Standing Committee for Seed Technology), Executive President, Rung Rueng Consulting Co., Ltd. (Rhino Research), Bangkok, Thailand

Mr. Johan Van Asbrouck, born in Belgium and now living in Thailand, is an agricultural technology expert specializing in seed drying, storage, longevity, and quality testing. He holds degrees in Agricultural Engineering, Biochemistry, Safety Engineering, and an MBA.

He has extensive experience in developing analytical tools for seed quality testing and sorting, and possesses strong expertise in seed development, germination, physiology, molecular biology, and agricultural biotechnology. He has also been actively involved in re-engineering technologies related to seed production, processing, quality assessment, and postharvest systems, along with studying the evolution of seed-related technologies over time.

In the area of training and education, he has led several seed technology training programs across Asia and the Pacific, including “Train the Trainer” initiatives for APSA. He successfully established 12 one-week seed technology courses over a period of three years and has been serving as a lecturer for the Wageningen Master Class since 2009. Additionally, he delivered around six guest lectures per year for Master’s and PhD-level seed technology programs.

Professionally, he has held key roles with Advanta Seeds, ASTEC Group, and Centor Group. He is the Founding President of the International Seed Academy and also serves as the Founding and Executive President of Rhino. He has contributed significantly to global seed sector governance as the former ISTA Chair of the

Advanced Technologies Committee (2010–2013) and APSA Chair of the Seed Technology Committee (2014–2022). He has also made multiple contributions to seed technology research through publications and patents.

Smart Seed Technologies, developed by **Rhino Research Seed Technology**, focuses on advanced solutions for seed quality enhancement through precision science and digital innovation. At the core of this approach is **RhinoVision**, an intelligent seed analysis platform that combines imaging technology and data analytics to assess seed quality, uniformity, and performance potential. By enabling rapid, non-destructive evaluation, RhinoVision supports better decision-making across seed processing, research, and quality control. Smart Seed Technologies aims to improve seed consistency, optimize resource efficiency, and support sustainable agricultural productivity through reliable, technology-driven seed assessment.

Strengthening Seed Testing Laboratories and Quality Assurance for meeting Global Standards : A Strategic Roadmap for 2026

DR. DAMRONGVUDHI ONWIMOL

Associate Professor,
Department of Agronomy, Faculty of Agriculture,
Kasetsart University (KU), Bangkok, Thailand

Dr. Damrongvudhi Onwimol is currently Associate Professor, Department of Agronomy, Faculty of Agriculture, Kasetsart University (KU), Bangkok, Thailand. He specializes in seed science, seed vigor, seed priming, non-thermal plasma technology, rice and maize seed physiology, and stress tolerance in crops.

His research expertise includes seed germination, seed deterioration, seed longevity, cold plasma and nonthermal plasma applications, hydropriming and osmopriming, hyperspectral imaging, machine learning for seed vigor classification, soil and salinity stress, rice seed storage, and sustainable rice production systems. He also works on advanced technologies such as deep learning, computational fluid dynamics, and seed quality enhancement techniques.

He has authored **43 publications**, holds **4 intellectual properties**, with a **Scopus h-index of 8** and **226 citations**. He has received **2 research/invention awards** and **9 conference awards**.

He serves as a **Board of Directors member of the Seed Association of Thailand** and as **Deputy Head of Department for Student Affairs, Information and Organization Communication**.

His educational background includes a **PhD in Agricultural Biotechnology**, **MSc in Horticulture**, and **BSc in Silviculture (Forestry)** from Kasetsart University.

Executive Summary

As the international seed industry gathers in Phuket for the 14th Indian Seed Congress, the sector finds itself at a pivotal juncture. The stable certainties of the past two decades—shaped by hyper-globalization and comparatively open trade borders—are yielding to a "polycrisis" marked by economic slowdown, geopolitical fragmentation, and the strategic use of trade standards as instruments of coercion. For the Indian seed industry, the aspiration to evolve from a primarily domestic entity into a prominent global export centre necessitates a comprehensive redefinition of its quality assurance (QA) infrastructure. This topic contends that Seed Testing Laboratories should transform from passive regulatory checkpoints into proactive, AI-powered data centres. By implementing "Digital Twin" technologies—particularly Hyperspectral Imaging (HSI) and Convolutional Neural Networks (CNNs)—laboratories can deliver objective, non-destructive, and real-time verification essential for establishing confidence in fractured markets. Furthermore, it is essential to incorporate agricultural precision into commercial production through logistical innovations such as the "Dry Chain" to maintain the physiological integrity of our genetic resources. Drawing upon the strategic insights of industry, this paper delineates a roadmap for 2026–2030. It advocates a transition from commodity-focused trading to value-driven marketing (the "New 4Ps"), positioning India not merely as a supplier of seeds but as a provider of certified, climate-resilient agricultural solutions.

1. The Geopolitical and Economic Landscape of 2026

The seed remains the fundamental element of agricultural security; however, by 2026, it has also emerged as a strategic component in geopolitics. The period of "neutral" agricultural trade is coming to an end. Governments worldwide are implementing "Techno-Nationalist" policies, considering agricultural data—such as genomic sequences, phenotyping records, and germplasm repositories—as sovereign assets essential to national security [1].

1.1 The Emergence of Regulatory Disparities

The most immediate threat to the international seed trade is not tariffs, but Regulatory Divergence. As conventional tariffs have stabilized, countries are progressively relying on Sanitary and Phytosanitary (SPS) measures and Technical Barriers to Trade (TBT) to govern imports[2]. Since 2020, more than 18,000 discriminatory trade measures have been implemented worldwide. For an Indian exporter, this manifests as a consolidation of borders. A seed lot of hybrid rice certified for export

to Kenya may be denied by Vietnam, not owing to a deficiency in biological quality, but due to discrepancies in testing protocols, variations in pest lists, or incompatible documentation formats. This divergence operates as an exclusionary barrier, disproportionately impacting developing economies by elevating compliance costs to prohibitive levels.

1.2 Strategic Approach: Harmonization as a Catalyst for Competitiveness

In this fragmented environment, technical harmonization remains the sole effective remedy. This is where India's strategic leadership within the International Seed Testing Association (ISTA) assumes a critical role. Under the leadership of Dr. K. Keshavulu, the first Asian to occupy this position (2022–2025/26), ISTA has strategically shifted its focus towards the Global South. The strategic objective for Indian laboratories is to attain and sustain ISTA accreditation. An ISTA Orange International Seed Lot Certificate functions as a universally acknowledged credential. It guarantees that a test result produced in a laboratory in Hyderabad is technically equivalent to one obtained in Zurich or Iowa. By advocating for "Uniformity in Seed Quality Evaluation," India not only adheres to established standards but also contributes to their development, especially for tropical and sub-tropical commodities that have traditionally been underrepresented in international regulatory frameworks [3, 4].

2. The Paradigm Transformation: Transitioning from Wet Laboratories to Digital Twins

Conventional seed testing—dependent on manual visual assessment by human analysts and destructive laboratory biological analysis—is nearing its limitations. The process is excessively sluggish, with germination tests requiring 7 to 21 days; it is also overly subjective, as analyst fatigue can influence purity evaluations, and it tends to be detrimental, thereby failing to satisfy the requirements of contemporary, high-speed supply chains [5]. The prospective trajectory resides in Non-Destructive Evaluation methodologies and the development of Digital Twins.

2.1 The Physical Foundations of Spectral Intelligence

In order to modernize, it is imperative to transition from examining the external morphology of a seed to scrutinizing its internal chemical composition through the application of light-based techniques.

- Multispectral Imaging: Records between three and thirty distinct spectral bands of electromagnetic radiation. Comparable to perceiving the environment through particular colour filters, MSI offers a cost-efficient

and expedient solution, rendering it suitable for rapid sifting operations on processing lines (e.g., eliminating discoloured seeds) [6, 7].

- Hyperspectral Imaging: This technology represents a revolutionary advancement for research and development as well as for high-precision quality assurance. HSI acquires hundreds (approximately 100 to over 1000) of narrow, contiguous spectral bands for each pixel within the source image. The outcome is a Hypercube (x, y, λ), whereby each spatial pixel encompasses a continuous spectrum. This technique enables us to observe chemical bonds with precision [8-10].

2.2 The Brain: Convolutional Neural Networks (CNNs)

The extensive volume of data produced by HSI (the so-called 'Curse of Dimensionality') necessitates computational capabilities that surpass those of conventional statistical methods. This pertains to the field of Deep Learning, with particular emphasis on the CNNs.

In contrast to conventional Machine Learning, which depends on human expertise to explicitly specify features such as "search for roundness," CNNs independently collect characteristics from unprocessed data. Multiple layers of convolutional filters recognize edges, textures, and spectral gradients in spectral pictures.

- Integration of Spatial and Spectral Data: Importantly, the CNN simultaneously scrutinizes the chemical composition (spectrum) and the spatial configuration (morphology). In the identification of a fungal infection such as *Fusarium* in maize, the artificial intelligence system evaluates not solely the presence of a fungal indicator but also its precise localization within the tissue (for instance, on the embryo versus the endosperm) [11].
- Performance: In complicated tasks such as differentiating between visually indistinguishable aromatic and non-aromatic rice varieties or assessing the viability of waxy maize, CNN models have attained accuracy rates exceeding 97.5%, thereby considerably surpassing human evaluators [12].

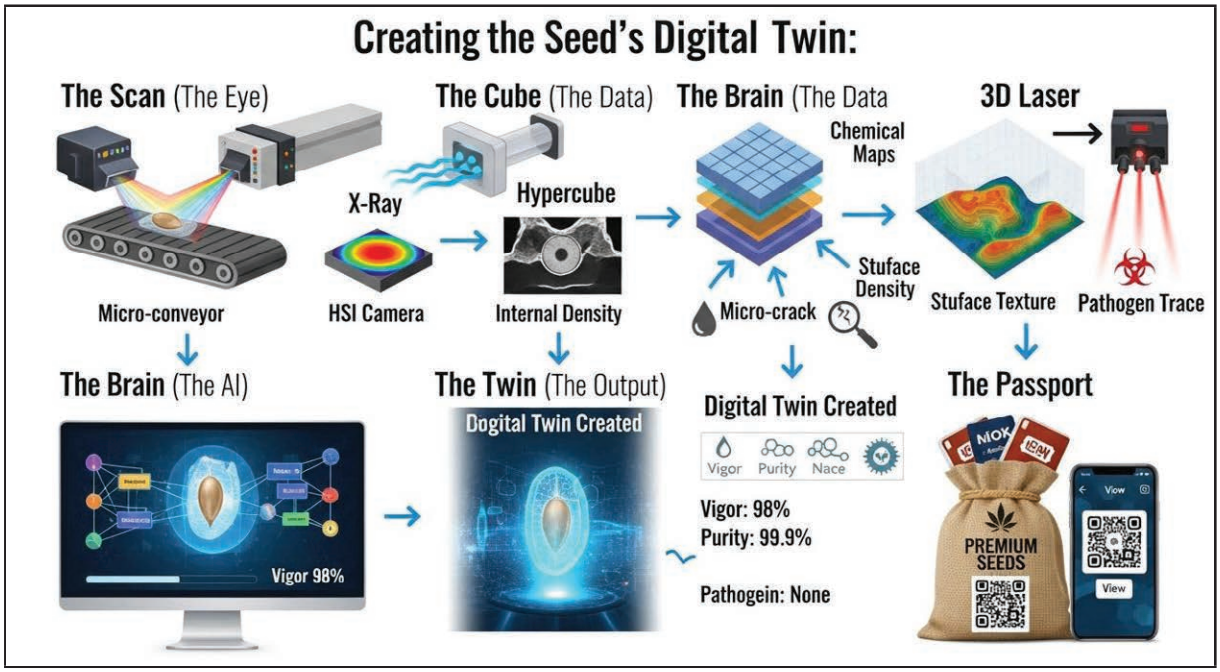
3. Commercial Seed Cultivation: Integrating Agronomic Science with Technological Advancements

Although laboratories ascertain quality, it is the field that actualizes it. Our primary emphasis here is on the two predominant commercial crops: rice and maize.

3.1 Rice: Achieving mastery of the "Nick" technique

In commercial hybrid rice production, "Nicking"—the synchronized flowering of the Cytoplasmic Male Sterile female line and the Restorer male line—determines the harvest.

- Predictive Modelling: Advanced growers no longer use calendar-based sowing plans. Growing Degree Day models use historical phenological data and real-time climatic forecasts to correctly predict flowering dates, allowing sowing period changes for optimal synchronization.
- Drone Assisted Pollination: UAVs are replacing "rope pulling" for additional pollination. Drone rotor aerodynamic downwash effectively disperses pollen from the R-line to the A-line, increasing seed set by 12–15% and reducing rural labour shortages [13, 14].



3.2 Corn: Accuracy in Selection and Purity Standards

Maize cultivation necessitates stringent genetic regulation. Robotic Detasseling: In order to avert self-fertilization, the male tassel should be excised from the female progenitor. Robotic detasselers operated under computer vision guidance are supplanting manual labour, attaining an accuracy exceeding 99.5% while avoiding the leaf damage typically caused by mechanical cutters.

- The Dilemma of Shelling: Post-harvest shelling constitutes an essential stage for quality assurance. Mechanical shelling frequently induces micro-cracks within the pericarp, which are imperceptible to the unaided eye yet function as entry points for pathogenic organisms.
- Solution: HSI systems are now capable of examining corn kernels during the in-flow process, identifying the spectral signatures indicative of sub-surface injury, and thereby eliminating damaged kernels prior to packaging [15, 16].

4. Strategic Marketing in 2026: The New 4Ps

The marketing of seeds has evolved from a commodity exchange to a technology transfer. The traditional "4Ps" of marketing—Product, Price, Place, Promotion—must be reinterpreted for the Industry 4.0 era.

The Evolution of Seed Marketing Mix (4Ps)

Marketing Element	Traditional Approach (Pre-2020)	Strategic Approach 2026 (Industry 4.0)	Key Technology Enabler
1. Product	Physical Asset: A bag of grain with a purity tag. Focus on germination % and physical purity.	Integrated Solution: "Seed + Technology + Data." Includes genetic potential (CRISPR), physical enhancements (coating/pelleting), and a Digital Product Passport containing HSI quality data and carbon footprint.	Digital Twins, Seed Coating Technology, Blockchain
2. Price	Cost-Plus: Production cost + Margin. A commodity pricing model susceptible to undercutting.	Value-Based (Outcome) Pricing: Price determined by the ROI/Yield gain delivered to the farmer. Premium pricing for "High Vigor" indexed seeds or "Stress Tolerant" traits.	Vigor Indexing (SVRICE), Predictive AI Models
3. Place	Physical Network: Reliance on brick-and-mortar dealer/ distributor networks. Limited reach in remote areas.	Omni-Channel & Dry Chain: Hybrid of digital ordering (apps) and physical delivery. The Dry Chain allows seeds to be stocked in remote village hubs for months without losing viability, solving the "last mile" problem.	Zeolite Drying Beads, Hermetic Storage, E-commerce Platforms (ONDC)
4. Promotion	Awareness: Field days, posters, radio ads. "Push" marketing.	Digital Extension & Trust: "Pull" marketing via QR Codes. Farmers scan to see "Seeing is Believing" videos, verify authenticity (anti-counterfeiting), and access real-time agronomic advice.	Smartphones, Augmented Reality (AR) Packaging, Social Media

Post-Harvest Innovation: The Dry Chain Transformation

Post-harvest deterioration represents the "leaky bucket" within the seed value chain in humid tropical regions. Elevated temperatures and humidity levels expedite metabolic processes, resulting in a swift decline in vigour. The Dry Chain, provides a reliable solution that does not depend on unstable electricity grids for refrigeration [17]. Seed longevity doubles with every 1% reduction in moisture content. By reducing seed moisture content to very low levels (equilibrium relative humidity of 20–30%) through the use of ZeoliteDrying Beads, seeds attain a "glassy state." In this condition, the cytoplasm becomes viscous, halting metabolic processes and inhibiting chemical degradation. After drying, seeds must be stored in hermetic (airtight) containers. This inhibits the re-absorption of moisture. This technology enables high-quality seed to be preserved at ambient tropical temperatures for more than a year without substantial decline in germination rates, representing a significant logistical benefit for market access in Africa and Southeast Asia.

6. Geopolitical Resilience: Policy Recommendations

To ensure the Indian seed industry's prosperity by 2026, a conducive policy environment that acknowledges laboratories as critical strategic assets is essential.

6.1 Harmonization and Digital Commerce

The most efficacious approach to mitigating non-tariff barriers is the implementation of universal standards.

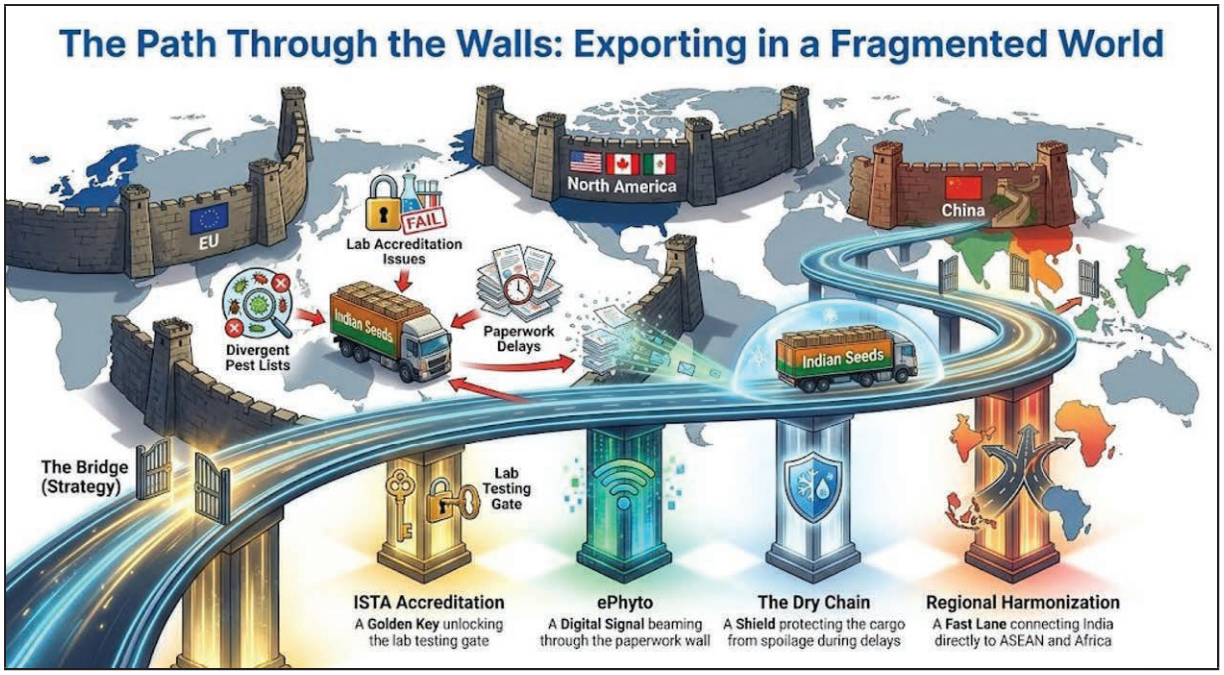
- ePhyto: India should expedite the complete integration of the ePhyto (Electronic Phytosanitary Certificate) Hub. The shift from paper-based processes to secure XML data exchange mitigates fraudulent activities, accelerates border clearance procedures, and minimizes rejection rates.
- Regional Cooperation: Building upon the precedent set by the COMESA Seed Harmonization Implementation Plan (COMSHIP) in Africa, Indian policymakers should actively pursue comparable regulatory harmonization initiatives within BIMSTEC and ASEAN. The introduction of a variety in India should automatically qualify it for testing and potential release in Thailand or Vietnam, thereby establishing a streamlined regional market.

6.2 Policy Recommendations

- Capital Subsidies for Laboratory Modernization: The Ministry of Agriculture

& Farmers Welfare (MoA&FW) should offer capital subsidies to private laboratories to facilitate upgrades to High-Sensitivity Imaging (HSI) and Artificial Intelligence (AI) systems. These laboratories function as the prospective export inspection agencies.

- Promote High-Value Crops: Initiatives such as the proposed Center of Excellence for Broccoli are essential. Diversifying the export portfolio to include high-value vegetables, in addition to cereals, mitigates the sector's vulnerability to fluctuations in commodity prices.



7. Conclusion

For the Indian seed industry to achieve global reach, a two-pronged transformation is required. In order to protect the physiological integrity of our genetic material, it is essential that we understand the biological foundations of this domain and optimize output by utilizing drones and Dry Chain technology. In addition, it is important that we incorporate the digital landscape of the laboratory, utilizing spectral imaging and artificial intelligence to produce the transparent, objective data that is essential for encouraging confidence in a distrusted and fragmented global marketplace. To transform regulatory compliance from an obstacle to a source of competitive differentiation, we can leverage India's current prominence in ISTA and align our national standards with international best practices. The platform for this objective is the 14th Indian Seed Congress. Technological capabilities are present; the policy landscape is changing; the potential for success is within our abilities.

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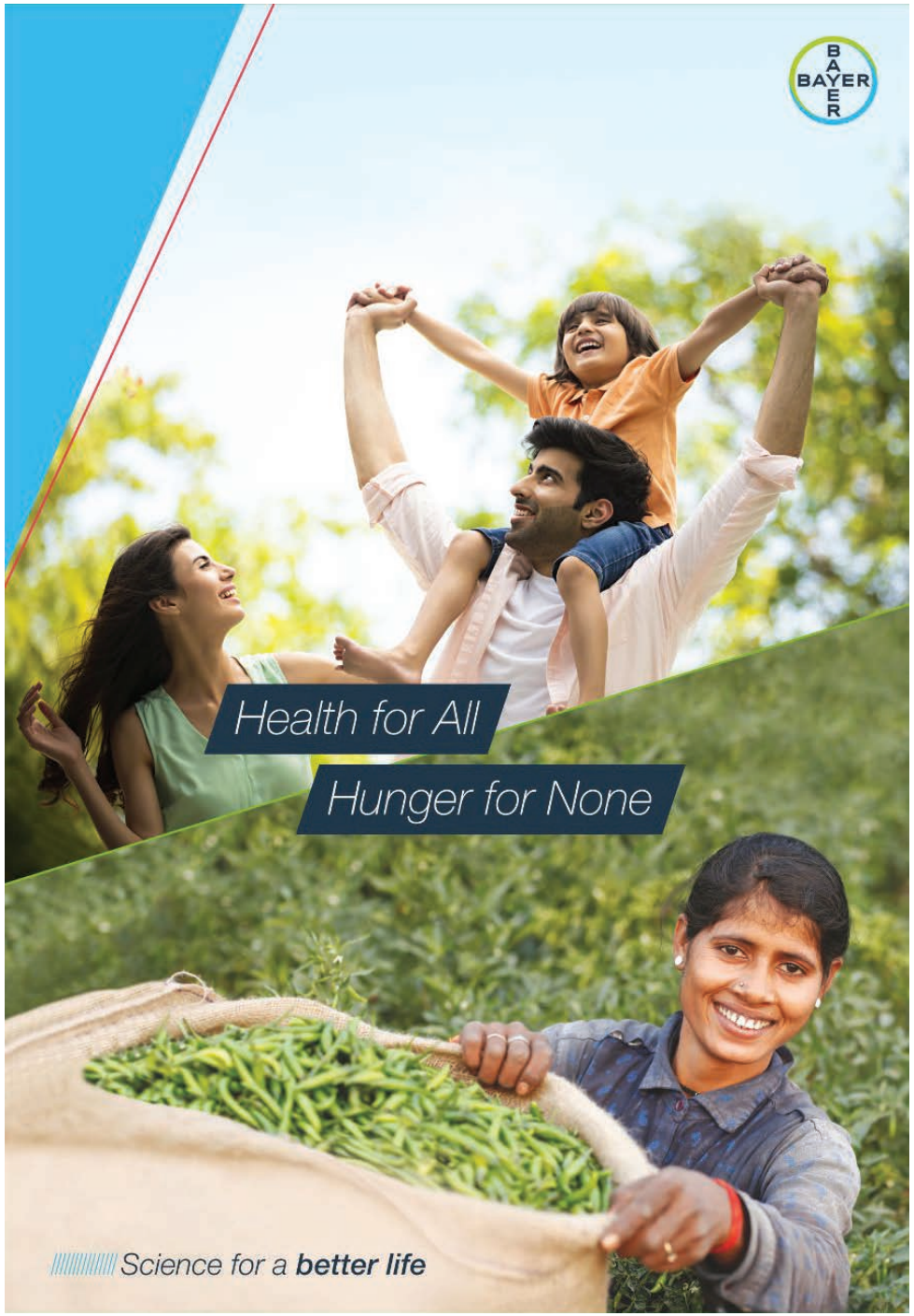

Technical Session III

Technical Session III: Policy and Regulatory Frameworks for Seed Trade **11:30 AM – 1:15 PM** **Chair:** Dr. Ravi Khetarpal, Executive Director, APAARI **Moderator:** Mrs. K. K. Tara, Head IP & Regulatory Affairs, NSL Hyderabad			
11:30 AM – 11:40 AM		**Opening Remarks by Moderator**	
SN	**Duration**	**Topic**	**Speaker**
1.	**11:40 AM – 12:00 Noon**	Strengthening India's Seed Policy Architecture and Opportunities for Global Alignment	**Mr. Ajeet Kumar Sahu** Joint Secretary (Seeds), GoI
2.	**12:00 Noon – 12:20 PM**	Global Regulatory Trends Shaping Seed Innovation, IPR & Trade	**Mr. Rajvir Rathi** Vice Chairman, Federation of Seed Industry of India
3.	**12:20 PM – 12:40 PM**	Building Sustainable Business Growth Ethically, with Strong Adherence to IPR and Legal Compliance	**Dr. Kirtan Y. Patel** Director (Research), Moti Seeds Pvt Ltd.
4.	**12:40 PM – 12:55 PM**	Interaction of Moderator with Panelists on Key Industry Issues	
12:55 AM – 1:15 PM		**Q&A and Closing Remarks by Chair**	

CHAIR

DR. RAVINDER (RAVI) KHETARPAL

Executive Director
Asia-Pacific Association of Agricultural Research Institutions (APAARI)
Bangkok, Thailand

Dr. Ravinder (Ravi) Khetarpal is Executive Director of Asia Pacific Association of Agricultural Research Institutions (APAARI), Bangkok since 2017.

- Engaged in strategic planning for institutional growth and facilitates and promotes networking, capacity building, policy interventions, knowledge management and partnerships in the region for agri-food system transformation.
- Co-ordinating and executing a number of regional/ global projects sponsored by USDA, WTO, FAO, ACIAR, EU, GFAiR etc in Asia and the Pacific countries, including projects on agricultural innovation system, inclusive digital transformation, phytosanitary compliances to WTO norms, collective action on forgotten foods, strengthening sanitary and phytosanitary compliances for International seed movement, pesticide risk mitigation and so also on One Health.
- Worked for National Agricultural Research System in India for three decades mainly contributing towards biosecurity, plant quarantine and germplasm health. Served for CABI – South Asia as Regional Director for seven years. Also served as Consultant for 12 projects of FAO, UNDP, USDA and World Bank on compliances of SPS Agreement of WTO.
- Serving as the Chairman of Global Forum of Agricultural Research and Innovation and member of IPPC Implementation and Capacity Building Committee.

MODERATOR

MRS. K. K. TARA

Head – IP & Regulatory Affairs
at Nuziveedu Seeds Ltd. (NSL), Hyderabad

Mrs. K. K. Tara is an accomplished professional with 28 years of diverse experience in the arenas of life sciences, technology management, socioeconomic studies, intellectual property (IP) and seed regulatory landscape. She is currently serving as Head – IP & Regulatory Affairs at Nuziveedu Seeds Ltd. (NSL), India, where she leads IP portfolio management, IP strategy, institutional collaborations, technology transfers, policy advocacy, IP litigation management and seed regulatory ecosystem. She has been pivotal in digital platform development for IP and germplasm management and structured SOPs that strengthened organizational governance.

Her earlier role as a Researcher at ICARNAARM involved policy research, IP analytics, incubation support and facilitation for technologies, socioeconomic studies. She has coauthored fact sheets and reports for nationallevel ASTI indicators, published books, reports, research papers and contributed to capacity building in technology and IP management.

Before this, she held leadership and academic roles in higher education, including Academic Head at Avanthi Group of Institutions, India, where she established *state-of-art laboratories for under graduation and graduation programs, initiated NAAC accreditation & compliances, led academic administration and strengthened industryinstitution linkages. She held various positions in her initial spell of career as Environmental Microbiologist in Institute of Preventive Medicine, Government of Andhra Pradesh and as Head of Department of Microbiology at Sree Vani Degree College.*

She is a registered Patent Agent, Trademark Agent, certified in multiple WIPO courses, and holds degrees including LLB, PGDTMA, MSc Microbiology. Her contributions in IP were instrumental in receiving ASSOCHAM IP Excellence Award (2024), Appreciation Certificate from PPV&FR Authority, MOAFW (2025) for highest PPV Registrations to NSL and is recognized for her strategic leadership, stakeholder engagement, regulatory expertise, and innovationoriented mindset. She is also an active participant and invited speaker in national IP and policy forums. She is a leading contributor to policy reforms and actively collaborates with NGOs and seed associations.

Strengthening India's Seed Policy Architecture and Opportunities for Global Alignment

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 oversees 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.

Global Regulatory Trends Shaping Seed Innovation, IPR & Trade

MR. RAJVIR RATHI

Vice Chairman, Federation of Seed Industry of India

Mr. Rajvir Rathi is a distinguished agriculturist with gold medal of merit to his credit from the prestigious CCS Haryana Agricultural University Hisar Haryana with major in Agricultural Entomology. Through his interest in agriculture and policy development he contributed in planning, shaping and executing the corporate affairs of Agricultural industry and championed inter and Intra governmental-Industry association, regulatory and scientific affairs, Public Affairs, corporate communications and agri- product stewardship spanning over more than two decades. He had been a pioneer in scientific communications on all aspects of agriculture and agri-trade promotion.

Governmental Affairs

Having started his professional career with Bayer, Mr. Rathi has played an pivotal role for past twenty-five years in designing, developing and delivering quality output in the areas of sales, new molecule registrations, regulatory approvals, public–private partnerships, etc through collaboration and coordination with various national and state stakeholders. He had been instrumental in setting up functions of impactful linkages between Corporate, Industry and Government Affairs. Over more than two decades, these functions have become an integral and a crucial part of any progressively forward-looking organization

Advocating and Promoting Sustainable Agriculture Policy

Over the last decade, Mr Rathi has fostered very impactful linkages among various key agricultural stakeholders. Thoroughly stood the test of time, these linkages have now flourished as the platforms for various Public Private Partnerships, innovations and combined initiatives. His scientific competence speaks volumes as he lead the entire crop biotechnology innovation cycle of a new product from conceptualizing to commercially managing the first product stewardship team in India. He also carefully monitored and prevented value drain of intellectual property in the larger Interest of Indian Agri – Input industry.

Awareness generation

He has always been a proponent of sustainability in any endeavour he has initiated. The basic criterion of having a win - win situation for all the stakeholders in the industry has been the foundation for his ideology. Value capture at all the stages ranging from product conceptualization, Innovation, commercialization, cultivations and returns to the farmers has been his forte till date. He is a strong voice on different print and electronic media, fora and on ground to raise the awareness on sustainable farming, its policies and technical way forward.

Honorary roles in agricultural promotion

Mr Rathi holds senior and prime positions in several committees of Asian and Indian Industry Chambers. He is Vice- Chairman of Federation of Seed Industry of India and member of CropLife India, Bayer Foundation India and Agriculture Skill Council of India. He is also General Secretary of Agro Chemical Federation of India. Totally driven out of passion, Mr Rathi, spends a considerable time to strengthen these organizations at national and global scale for agriculture promotion.

Rajvir is a Leadership Team member of Crop Science Division for India Bangladesh and Sri Lanka Cluster of Bayer Crop Science

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1. International Legal Frameworks Influencing Seed Innovation & Trade

TRIPS Agreement (WTO) Global IPR Baseline

- The Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPS) sets minimum global standards for IP protection (including patents and plant variety protections) for WTO members like India.

- TRIPS influences national laws and is often a bargaining baseline in trade negotiations, shaping how countries balance innovation incentives with access/farmers' rights.

UPOV & Plant Variety Protection Systems

- The International Union for the Protection of New Varieties of Plants (UPOV) provides a model for plant breeders' rights regimes.
- Many free trade agreements (FTAs) pushed by the EU, USA, Japan, and UAE include UPOV-style requirements, pressuring countries (especially in the Global South) to adopt stricter seed IP regimes.

International Treaty on Plant Genetic Resources (ITPGRFA)

- Known as the Plant Treaty, it creates a multilateral system for access and benefit-sharing of plant genetic resources, alongside recognition of farmers' rights.
- Negotiations continue to potentially expand the list of covered crops — affecting both global germplasm exchange and India's obligations.

2. Trends in Intellectual Property Rights and Seed Innovation

Stronger IP Frameworks to Stimulate Innovation

- Globally, markets are progressively strengthening patent & plant variety protection to attract investment and stimulate research.
- Protection encourages private R&D, leading to more innovative seed varieties and competitiveness in international trade.

Technological Frontiers – AI, Digital Tools & IP

- Emerging technologies like AI and blockchain are being integrated into IP systems to improve transparency, speed up processing, and enforce rights (e.g., AI-powered searches, digital registries).
- India, for instance, rolled out AI/ML tools for trademark search and IP support, aligning domestic practice with global trends.

Balancing Innovation with Access & Farmers' Rights

- Strict IP can enhance private innovation but may limit farmers' traditional practices like saving and exchanging seeds — it is therefore critical to strike the right balance between breeders' and farmers' rights.

- Instruments such as the Plant Treaty seek to strike a balance by combining IP with equitable benefit-sharing and farm-level rights.

3. India — Regulatory Priorities & IPR Dynamics

Domestic Seed Regulation Reform

- India is revisiting its Seeds Act (1966) and Protection of Plant Varieties and Farmers' Rights Act (PPVFRA) to modernize standards, improve quality control, and align with global best practices.
- Proposed changes could enhance traceability and compliance while still protecting farmers' rights under India's socioeconomic context.

Strengthening IPR for Seed Innovation

- Industry groups and government stakeholders are advocating stronger enforcement of IPR in seeds to attract R&D investment, curb piracy/ counterfeiting, and bolster exports.
- The PPVFRA framework specifically aims to protect both breeders' rights and farmers' rights, supporting innovation without undermining traditional practices.

Boosting Global Trade Competitiveness

- With regulatory reform, experts believe India's seed sector could grow from around 1% to 10% of global share by 2035, unlocking export potential and new varieties for climatic resilience.

Key Takeaways for India

- Regulatory modernization is crucial for aligning Indian seed IPR and trade regimes with global standards, while upholding farmers' rights.
- IPR enforcement fosters innovation and export growth but requires careful calibration to avoid undue burden on farmers.
- Tech integration in IP systems can accelerate processing, improve transparency, and attract global R&D.
- Active engagement in global treaties (TRIPS, UPOV, ITPGRFA) will shape India's future seed innovation and trade landscape.

Building Sustainable Business Growth Ethically, with Strong Adherence to IPR and Legal Compliance

DR. KIRTAN Y. PATEL

Director (Research)
Moti Seeds Pvt Ltd.

Dr. Kirtan Y. Patel completed his B.Sc. (Agriculture) in 2002 from Anand Agricultural University (AAU), Anand. He subsequently obtained his M.Sc. (GPB) in 2006 and Ph.D. (GPB) in 2010.

Thereafter, he joined Moti Seeds Pvt. Ltd., Gujarat, a company established by his father, where he is currently serving as Research Director.

He has been a member of the Governing Council of the Gujarat Seed Industry Association since 2013. He also served as a Governing Council member of the National Seed Association of India (NSAI) from 2021 to 2023, and has again been co-opted as a Governing Council member for the tenure 2025 to 2027.

Building Sustainable Business Growth Ethically

A Framework for the NSAI Ethics Committee & Code of Conduct

Dr. Kirtan Y Patel
Member, GC (NSAI)
&
Director (R&D)
Moti Seeds Pvt Ltd

The Current Crisis: Why We Need a Guardian

The seed industry faces a crisis of confidence driven by spurious seeds and fragmented regulations.

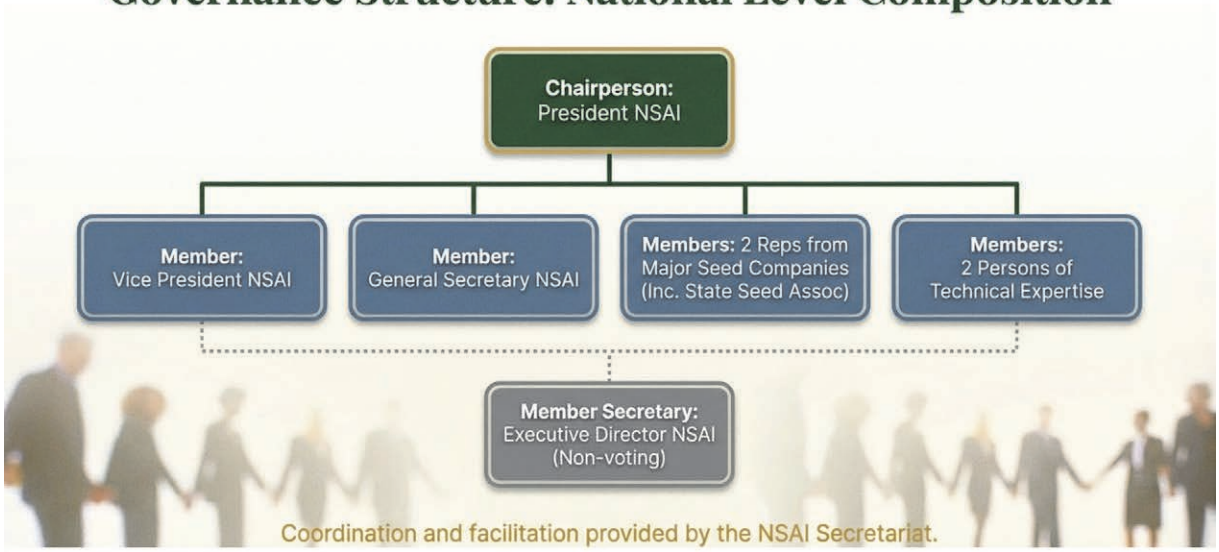
1. **Erosion of Trust:** Spurious seeds undermine farmer confidence and livelihoods.
2. **Economic Loss:** Unethical poaching and quality violations hurt the organized sector.
3. **Regulatory Fragmentation:** Varying regulations across states create compliance chaos.
4. **IPR Violations:** Misleading marketing and intellectual property theft threaten integrity.

Strategic Insight: Collaboration between R&D and Marketing companies is vital to restore a congenial environment.


The Strategic Objective: Ethical Business Growth
Sustainable Ecosystem
Farmer Protection
Identification and mitigation of spurious seeds. Swift compensation mechanisms.
Quality Assurance
Preventing exploitation. Ensuring environmental safety and fair trade.
Global Standards
Aligning with the New Seed Bill 2025. International collaboration.
Moving beyond compliance to proactive image restoration.


The Role of the Ethics Committee (EC)
Enforcing strong adherence to IPR and Legal Compliance.
Regulatory & Self-Regulation
Adopting SATHI Portal traceability. Ensuring adherence to Seeds Act & PPV&FRA.
Seed Sovereignty
Protecting biodiversity and the rights of the farming community.
The Ethics Committee
Policy Advocacy
Recognized face of the industry for government liaison and tech support.
The 'No' to Harmful Products
Discouraging products that fail norms or impact the environment.

Governance Structure: National Level Composition

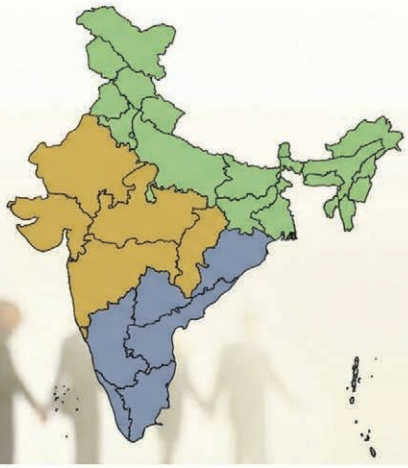


Membership Eligibility Standards

Criteria for appointing Guardians of the Industry

Future Roadmap: The Zonal Framework

Expansion after successful National implementation



Zone A: UP, Punjab, Haryana, WB, Bihar, NE States

Zone B: Andhra, Telangana, Karnataka, TN, Odisha

Zone C: Gujarat, Maharashtra, MP, Chhattisgarh

Each Zonal Committee: Max 7 members, chaired by a GC member or leading State Seed Company

Core Ethical Principles & Guidelines

APPROVED DENOMINATIONS
Use only GEAC/ICAR approved names. No unauthorized synonyms.

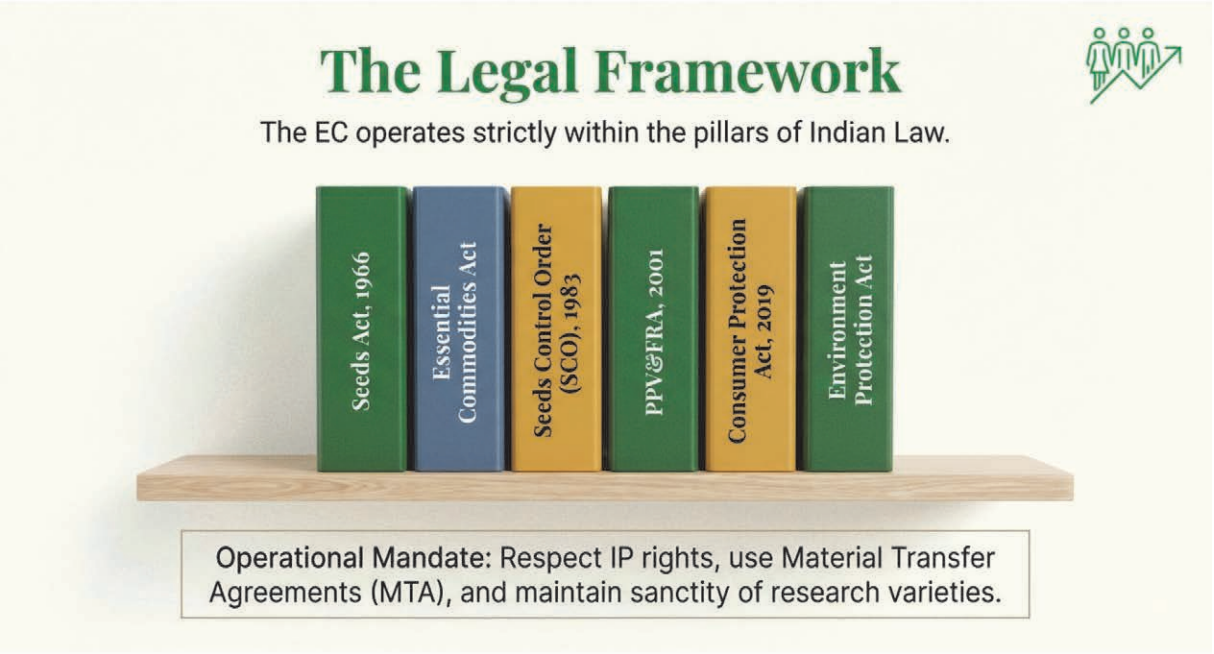
ZERO TOLERANCE
No sale of unapproved GM events or products.

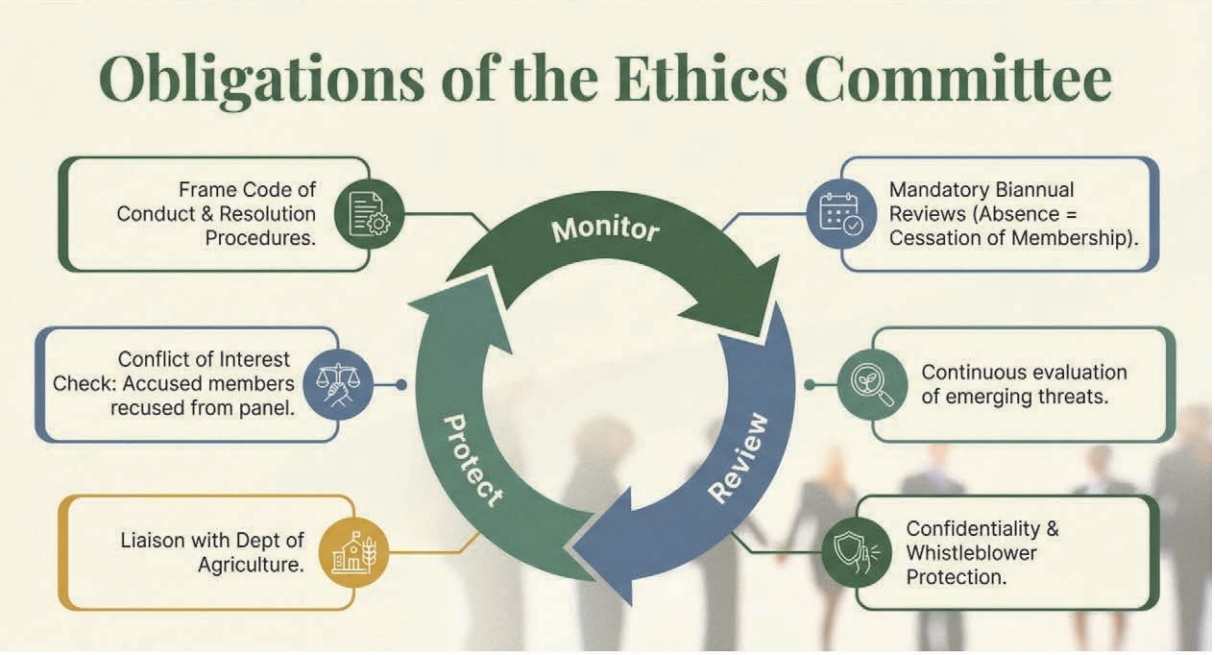
ANTI-FLY-BY-NIGHT
Curb operators exploiting the market. Support Dept of Agriculture.

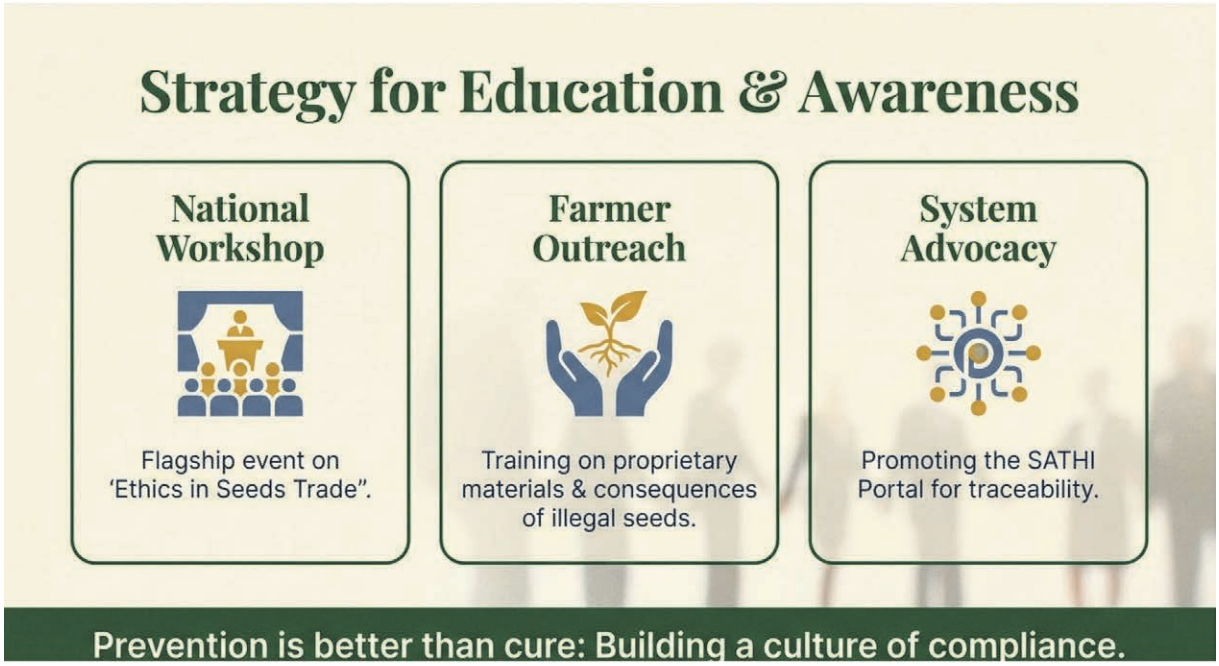
TRUTH IN MARKETING
Zero misrepresentation or false propaganda.

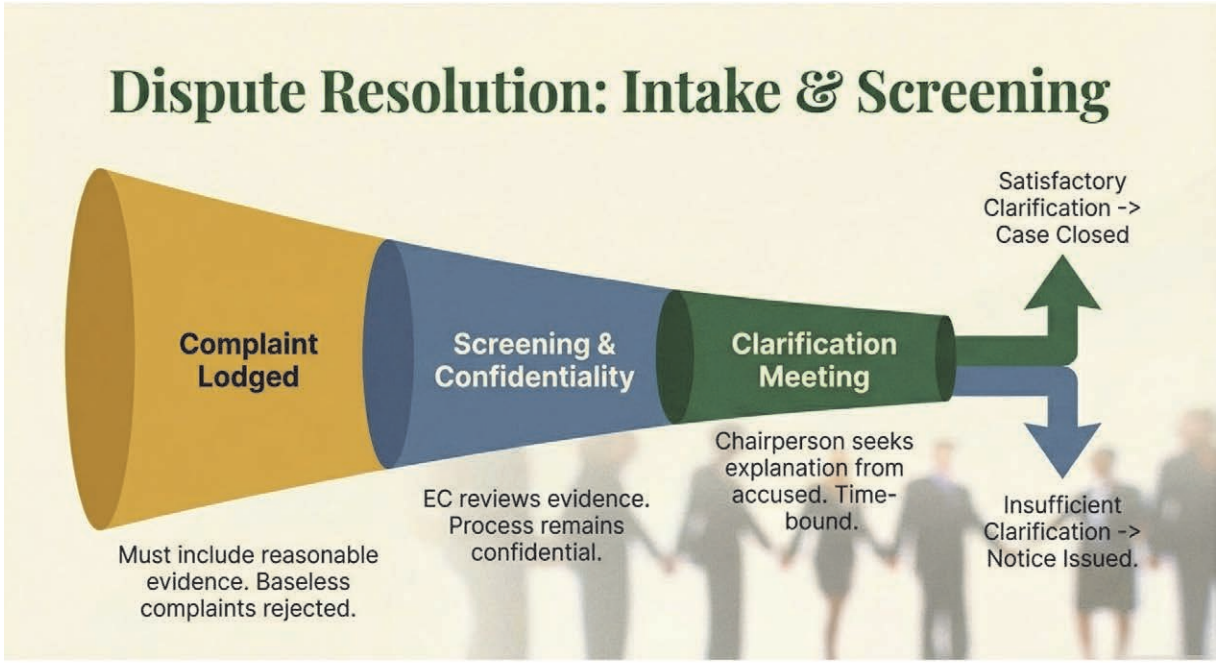
TRACEABILITY
Mandatory implementation of the SATHI Portal.

COMMITMENT
Undertaking of ethical practice required for membership renewal.

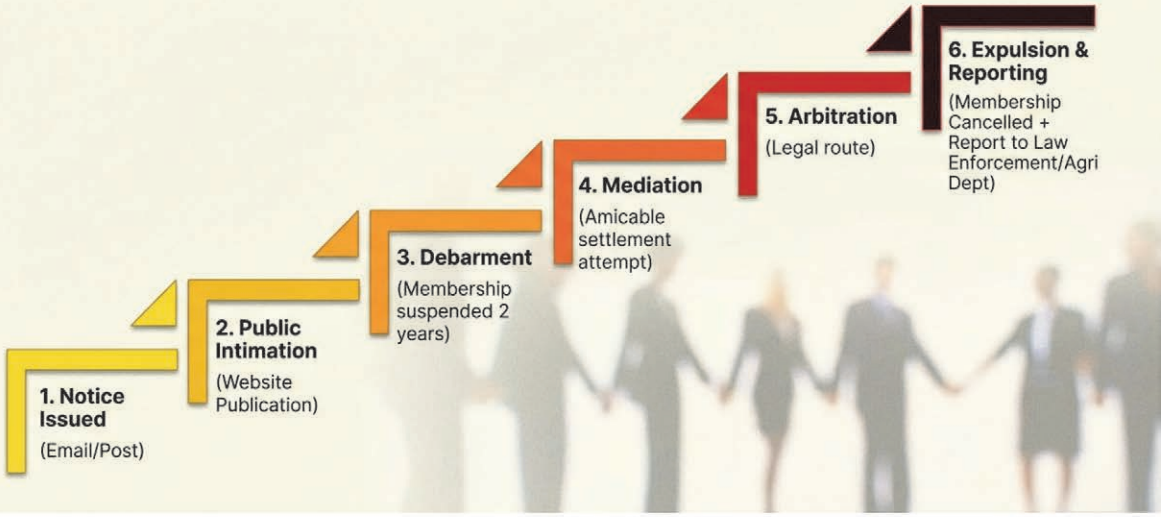

The Legal Framework
The EC operates strictly within the pillars of Indian Law.
Seeds Act, 1966
Essential Commodities Act
Seeds Control Order (SCO), 1983
PPV&FRA, 2001
Consumer Protection Act, 2019
Environment Protection Act
Operational Mandate: Respect IP rights, use Material Transfer Agreements (MTA), and maintain sanctity of research varieties.


Obligations of the Ethics Committee
Frame Code of Conduct & Resolution Procedures.
Conflict of Interest Check: Accused members recused from panel.
Liaison with Dept of Agriculture.
Monitor
Review
Protect
Mandatory Biannual Reviews (Absence = Cessation of Membership).
Continuous evaluation of emerging threats.
Confidentiality & Whistleblower Protection.


Strategy for Education & Awareness
National Workshop
Flagship event on 'Ethics in Seeds Trade".
Farmer Outreach
Training on proprietary materials & consequences of illegal seeds.
System Advocacy
Promoting the SATHI Portal for traceability.
Prevention is better than cure: Building a culture of compliance.


Dispute Resolution: Intake & Screening
Complaint Lodged
Must include reasonable evidence. Baseless complaints rejected.
Screening & Confidentiality
EC reviews evidence. Process remains confidential.
Clarification Meeting
Chairperson seeks explanation from accused. Time-bound.
Satisfactory Clarification -> Case Closed
Insufficient Clarification -> Notice Issued.

Dispute Resolution: Escalation & Enforcement



Ensuring Fair Competition & Contract Honor

- **Contract Adherence**: Members must honor all valid contracts regarding production and marketing.
- **Facilitation**: EC acts as a mediator for disputes.
- **Anti-Collusion**: EC actively prevents collusion by demanding transparency.
- **Fair Play**: A commitment to no trust violations.


The Way Forward
1. Trust Building through unbiased resolution.
2. Continuous Improvement of EC procedures.
3. Partnership with Central/State enforcement machinery.
4. Digital Adoption for awareness.
Let's make it together.

Technical Session IV

Technical Session IV: Global Opportunities, Investments & Future Growth of the Seed Sector **Time: 2:30 PM – 4:15 PM** **Chair:** Dr. M. Prabhakar Rao, President, NSAI **Moderator:** Mr. Chetan Joshi, Managing Director, BBSSL			
2:30 PM – 2:40 PM		**Opening Remarks by Moderator**	
SN	**Duration**	**Topic**	**Speaker**
1.	**2:40 PM – 2:55 PM**	Global trends in Seed & Agri Biotech Innovations & Investments: What It Means for India	**Dr. G. Chaluvaraju** Asia Head- R&D-BASF NUNHEMS, India
2.	**2:55 PM – 3:10 PM**	Structural Competitiveness and Strategic Trajectory of India's Seed Export Sector	**Dr. S. Rajendra Prasad** Ex-Vice Chancellor, University of Agricultural Sciences, Bengaluru
3.	**3:10 PM – 3:25 PM**	The role of National/Regional Associations in Exploring Global Opportunities for the Seed Sector to Achieve Sustainable Growth	**Ms. Francine Sayoc** Executive Director, APSA
4.	**3:25 PM – 3:40 PM**	Artificial Intelligence for Agricultural Development and Farmers' Prosperity with Special Reference to Seed Supply Chain	**Dr. Kavya Dashora** Associate Professor, Centre for Rural Development and Technology, Yardi School of Artificial Intelligence, IIT, Delhi
3:40 PM – 3:55 PM		Interaction of Moderator with Panelists on Key Industry Issues	
3:55 PM – 4:15 PM		**Q&A and Closing Remarks by Chair**	

CHAIR

DR. MANDAVA PRABHAKAR RAO

President, NSAI and Chairman & Managing Director, Nuziveedu Seeds Limited

Dr. Mandava Prabhakar Rao is President, NSAI and Chairman & Managing Director, Nuziveedu Seeds Limited

Dr. M. Prabhakar Rao is an alumnus of the Institute of Agricultural Science, Banares Hindu University, with a Gold Medal and Merit Scholarship in his post-graduation studies. Acknowledging his Pioneering Contributions to Agriculture and the Seed Industry, he was awarded an Honorary Doctorate by Chandrasekhar Azad University of Agriculture & Technology (CSAUAT), Kanpur, in 2024 and by Krishna University in 2025. Dr. Rao took over the reins of Nuziveedu Seeds (NSL) Limited in 1982, started by his illustrious father in 1973, and has nurtured and developed the NSL Group of companies, which is today a conglomerate of businesses in Seeds, Textiles, Sugars, Infrastructure and Renewable power.

Apart from managing diversified businesses of NSL Group, Dr. Rao participates actively in various Industry Bodies. He has been leading the seed sector of India in the capacity of President, NSAI, since 2013. During his tenure, the organization has achieved a number of milestones, notably, he provided policy leadership and guided the association through critical regulatory issues on pricing frameworks, trait value, biosafety, and intellectual property. He actively engaged with the Government and statutory bodies to ensure a balance between innovation incentives and farmer affordability, while advocating for science-based and predictable regulations for seeds and biotech traits. Additionally, he contributed to national platforms such as the Protection of Plant Varieties and Farmers' Rights Authority (PPV&FRA) and the Cotton Advisory Board, bringing valuable field-level perspectives to policy formulation. NSAI had the honour to organize the Asian Seed Congress during 16-20 November 2015 at Goa and 17-21 November 2025 at Mumbai in Association with the APSA.

Dr. Rao has also been holding several other prestigious positions,

President, Indian Sugar & Bio Energy Manufacturers Association and Andhra Pradesh Seedsmen Association and President-CEO of Clubs India, Hyderabad.

Member of ICAR-National Agricultural Education Accreditation Board (NAEAB); Protection of Plant Varieties and Farmers Rights Authority (PPVFR Authority); Cotton Advisory Board, Ministry of Textiles, Govt. of India; Textiles Committee; Central Seed Committee, Ministry of Agriculture, Govt of India; Board of ISF representing India; Central Seed Certification Board, Govt. of India.

Chairman, FICCI – Andhra Pradesh State Council; Committee on Agriculture, Federation of Indian Chambers of Commerce & Industry (FICCI).

Board Member- Acharya N.G Ranga Agricultural University, Hyderabad.

MODERATOR

MR. CHETAN JOSHI

Managing Director,
Bharatiya Beej Sahakari Samiti Ltd. (BBSSL)

Mr. Chetan Joshi is the **Managing Director of Bharatiya Beej Sahakari Samiti Limited (BBSSL), New Delhi, India**, a national cooperative institution promoted under the Ministry of Cooperation, Government of India. Since assuming this role in **April 2024**, he has been leading India's flagship initiative to strengthen farmer-owned, professionally governed seed systems and to enhance national seed security through the cooperative network.

With over **25 years of leadership experience in the global seed sector**, Mr. Joshi brings deep expertise across seed business strategy, agronomy, product development, and large-scale market deployment. He has held senior leadership roles with leading multinational and Indian seed companies, including Mahyco, Pioneer Hi-Bred (Corteva), Advanta, and Monsanto, with responsibilities spanning India as well as **Africa and Southeast Asia**. His professional experience covers major field crops such as rice, maize, wheat, cotton, millets, and oilseeds, with a strong track record in building scalable seed businesses, managing P&L, and driving farmer-centric market access models.

As a panellist at this international conference, Mr Joshi represents the **Indian cooperative seed movement**, offering a unique perspective on how national seed cooperatives can integrate science, markets, and farmer ownership to build resilient, inclusive, and sustainable seed systems. His participation reflects India's growing engagement with global seed sector dialogue and cooperation, particularly in the context of food security, smallholder inclusion, and long-term agricultural sustainability.

Global trends in Seed & Agri Biotech Innovations & Investments: What It Means for India

DR. G. CHALUVARAJU

Asia Head – R&D, BASF Nunhems India

Dr. G. Chaluvaraju is a seasoned leader in the seed and agri input industry, bringing over 25 years of expertise across R&D, product development, production, and quality management. Currently serving as APAC Head of Research & Development at BASF | Nunhems, he drives regional innovation, talent development, and market focused hybrid advancement. Previously, he served as Global Head of Production at BASF/ Bayer, overseeing large, multicultural teams across five continents and establishing strategic production hubs worldwide. His earlier roles in production, quality assurance, and seed health were instrumental in shaping robust seed systems across APAC. He holds a Ph.D. in Applied Botany, MPhil in Seed Technology, and an Executive MBA from ISB with international programs at Wharton and London Business School. A passionate mentor, he actively contributes to ISF, APSA, and other industry platforms.

The global seed and agricultural biotechnology sector is increasingly shaped not only by scientific breakthroughs but also by capital flows, intellectual property (IP) systems, and geopolitical priorities. The seed market, valued at around USD 70 billion in 2024, is projected to reach USD 100–110 billion by the early 2030s, driven by technologies that improve climate resilience, input efficiency, and the speed of product development.

A convergence of genome engineering, digital and predictive agronomy, and biological inputs is transforming the competitive landscape. Major row crops—maize, rice, wheat, soybean, and cotton—account for nearly 85% of global market value and R&D investment, owing to their scale and suitability for trait stacking. The remaining share, including vegetables, pulses, and oilseeds, is supported by faster innovation cycles in controlled environments and higher-value niche markets.

Scientific advances and breakthrough research continue to boost investor confidence. Gene editing—especially CRISPR-Cas systems—and molecular breeding are now central tools for accelerating breeding cycles. CRISPR applications have expanded rapidly, enabling precise modification of yield related genes, improvement of drought/heat/salinity tolerance, enhanced disease resistance through susceptibility gene knockouts, and targeted improvements in nutritional quality. At the same time, AI and machine learning integrated with genomics are powering predictive breeding, while speed breeding and automation are redefining what is achievable within a single breeding cycle.

A small group of leading global companies continue to invest high single to low double digit percentages of annual sales into discovery and product development pipelines. Public research institutions and CGIAR centres are advancing predictive breeding and gene editing programmes, while domestic agri input companies in many countries are prioritizing incremental trait improvements within specific crops.

Digital technologies—spanning IoT, AI/ML, remote sensing, and soil metagenomics—has become a critical enabler for input optimization and precise trait deployment. The global digital agriculture sector is expected to reach USD 40–50 billion by 2031. Seed technology investment is also strengthening in areas such as biological seed treatments, microbial solutions, bio stimulants, and nanocoating's. Venture capital activity in AgTech surged in recent years but possibly will undergo a correction phase as markets stabilize.

Regional Dynamics Shaping Agri Biotech Capital Flows

North America and parts of Europe continue to draw the largest share of private sector investment in agri biotechnology—benefiting from strong intellectual property protection, predictable regulatory environments, and long established seed and biotech markets. By contrast, the Asia–Pacific region has become the fastest growing hub for agricultural biotechnology investment, propelled by expanding market demand and national priorities centred on food security, climate resilience, and sustainable productivity gains. In Latin America, particularly Brazil

and Argentina, investment momentum is closely tied to large scale commercial production of crops such as corn and soybean, where biotech adoption and trait stacking continue to accelerate. Across Africa, investment is driven largely by efforts to strengthen smallholder farming systems, improve productivity, and enhance food security, positioning the continent as an emerging destination for technologies tailored to resource constrained environments.

India: Strong Science, but a Capital and Commercialization Gap

India has tremendous scientific strength but experiencing capital gap. It has one of the world's strongest public agricultural research systems and is a global leader in crops such as rice, millets. Recent approvals of genome edited crops in 2025 marked a major regulatory shift, signalling openness to next generation breeding technologies while avoiding the political baggage associated with transgenic GMOs. However, India's investment intensity in seed R&D remains significantly lower than that of China or Western markets. Private capital is constrained by fragmented seed markets, policy implementation issues, and uncertain returns on intellectual property. While public investment sustains foundational research, scaling innovation to the farm level often lags due to limited commercialization pathways.

Learning from China: Scale, State Capital, and Strategic IP

China is focussing on Scale, providing State Capital, and Strategic IP. it is the largest public investment effort in agricultural biotechnology globally. Over the past decade, the country has dramatically expanded funding for seed security, biotechnology research, and domestic germplasm development, positioning seeds as a matter of national strategic importance. Large scale public funding, state backed consolidation of the seed sector, and accelerated approvals for biotech crops have allowed China to close technological gaps rapidly. Its approach to intellectual property is also evolving. Historically criticized for weak enforcement, recent reforms have strengthened plant variety protection (PVP), extended protection periods, and increased penalties for infringement. These changes are explicitly aimed at encouraging private R&D in the country.

The IP Challenge: Innovation Without Protection

Intellectual property protection is becoming one of the biggest constraints on seed innovation in Asia. Unlike pharmaceuticals or software, seeds can be easily reproduced, making IP enforcement naturally difficult. In India, Plant Variety Protection laws exist, but enforcement is inconsistent due to fragmented policies,

varied interpretations, and state–centre overlaps. This weakens incentives for private companies to invest in expensive, long cycle breeding programs, keeping much of India's innovation incremental rather than breakthrough.

Compared with global leaders, India's IP system offers less enforcement strength and commercial certainty. Although India's public research institutions are world class, weak IP protection limits the growth of a strong, innovation driven private seed sector. To unlock the full potential of next generation breeding technologies and accelerate innovation to farmers, India will need stronger and more predictable IP enforcement supported by clear, consistent regulation.

Digital Agriculture: A Partial Equalizer

Digital agriculture is one area where India is rapidly narrowing the gap with global leaders. Worldwide investment in digital farming technologies is expected to push the sector beyond USD 40–50 billion by 2031, with Asia contributing a major share of new adoption. Digital tools—such as soil intelligence systems, remote sensing, and AI driven advisory platforms—reduce dependence on proprietary genetics by lowering entry barriers for innovation.

High resolution soil mapping, predictive agronomy models, and digital advisory platforms now expanding across Asia help farmers match existing varieties more precisely to local conditions. This improves productivity even without major breakthroughs in seed genetics, making digital agriculture a powerful equalizer for regions facing constraints in R&D investment or IP protection.

Structural and Regulatory Headwinds

Despite global progress, several structural challenges continue to slow innovation in the seed and agri biotech ecosystem across the globe. Regulatory fragmentation—especially around emerging breeding technologies—creates uncertainty and delays cross border deployment of new varieties. Data governance and cybersecurity concerns complicate the adoption of digital agriculture, particularly where standards for data sharing and privacy are unclear. Increasing climate volatility raises the cost and complexity of multi location field trials, heightening R&D risk and slowing product advancement. For India, the key will be aligning IP policy, seed pricing regulations, and private sector investment incentives to create a more innovation friendly environment.

A Shifting Center of Gravity

The global seed and agri biotech landscape is entering a phase where capital, policy frameworks, and intellectual property systems are becoming as influential as scientific innovation itself. China's scale driven, state supported model and India's science rich but capital constrained ecosystem illustrate two divergent development pathways. How these models evolve—and whether India can successfully convert its scientific strength into investable, commercially scalable innovation—will shape not only the trajectory of Asian agriculture but also the future balance of power in global food systems. Global capital is gravitating toward ecosystems that execute well: where policy, institutions, and IP enforcement convert science into scalable outcomes. India possesses strong science and credible policy intent. By strengthening execution, harmonizing Centre–State delivery, and speeding IP resolution, it can shift from being primarily a source of ideas to a preferred destination for Agri biotech investment over the next decade.

Going forward, it will be valuable to offer farmers integrated, one stop solutions where digital ready farms receive both inputs and advisory services from a single platform. Global companies can partner with local and niche technology providers to combine their strengths and deliver these complete, easy to use solutions, helping farmers adopt new technologies faster and improve productivity.

Structural Competitiveness and Strategic Trajectory of India's Seed Export Sector

DR. S. RAJENDRA PRASAD

Ex Vice Chancellor, University of Agricultural Sciences, Bengaluru

Dr. S. Rajendra Prasad after completing his Ph D in Seed Technology with distinction, joined the University of Agricultural Sciences, Bangalore and worked in various capacity starting from Research Assistant to Vice Chancellor. He has steered the National Seed Project for 27 years with distinction, serving as a Seed Research Officer, Special Officer (Seeds) and Director, ICAR Indian Institute of Seed Science for 5 years. Dr Prasad is recognized as having made UASB one of the top agricultural universities in the nation and for making substantial advancements in the fields of education, research, and outreach.

He developed the farmer scientists participatory seed production program based on seed village concept and implemented it in Mau, Gazipur, Balia, and Azamgarh Districts and **11 districts** in Karnataka benefiting **90732** farmers. Raised substantial funds to establish model Seed Processing, Seed Farms while serving as Director (ICAR), Mau, Uttar Pradesh. He established Reginal Research Centre ICAR-IISS, two ISTA labs, three new Breeder seed production centers and five Seed Technology centers across the country. Developing seed production techniques, including Aeroponics and Hydroponics, DNA marker technologies for seed purity testing, seed improvement, and storage protocols for field and vegetable crops are among the major accomplishments. He has developed > 35 technologies in seed production, processing and seed treatment and has 3 patents.

His contributions to storage techniques and purity testing have helped increase the output of high-quality seeds.

Dr. Prasad has authored 13 books and over 190 research publications for prestigious journals, and he has served as a major advisor to 14 M.Sc. as well as 9 Ph.D. students, and he has been the Principal Investigator of 18 extramural research projects with a budget outlay of Rs 3585 lakhs. He served as a Chairman and member of various statuary bodies/ authorities. He visited Philippines, Taiwan, China, Netherlands, Germany, France, Belgium, Malaysia, Nepal, Singapore, USA, Spain, Switzerland, Australia and Thailand. Dr. Prasad has received three international fellowships/ awards for his breadth of contributions and 10 National and State awards.

Significant Awards/Recognition (Important one)

- **Dr Amir Singh Memorial Lifetime Achievement Award by Indian Society of Seed Technology, New Dehli on December 13, 2023**
- **Dr. Kalayya Krishnamurthy National Award** for Best Agricultural Research by UAS, Bengaluru during 2012
- **Most Influential Seed Technologist** in The Asia Pacific Public Seed Sector by **APSA Award**, 2022
- **Fellow of Indian Society of Seed Technology,** New Delhi and **Fellow** of Karnataka Science and Technology Academy, Govt. of Karnataka, Bangalore
- **'AIASA Harit Ratna Award-2018'** for outstanding contribution in Agriculture and in empowerment of youth in agriculture on an India by All India Agricultural Students Association (AIASA), New Delhi
- **Best Vice-Chancellor Award – 2021** by All India Agricultural Students Association (AIASA), New Delhi
- **Netherlands Government Fellowship** by IAC, Wageningen, The Netherlands International during 1996, **NFL Fellowship** by University of Philippines, Los Banos Philippines International during 1988 and **International Agricultural Centre Fellowship** by DOAE-Seed Division, Bangkok, Thailand International during 2001

India's seed export story is no longer a niche trade statistic; it is fast becoming one of the clearest expressions of India's scientific strength, economic ambition, and role in global food security. This article traces how India has moved from being a seed-importing nation to an emerging global hub for high-value seed exports, and what it must do next to convert this momentum into lasting leadership.

Seeds in the new bioeconomy

Over the past two decades, seeds have transformed from simple planting material into sophisticated carriers of genetics, technology, and intellectual property. Modern varieties are built using conventional hybridization, marker-assisted selection, genomic selection, CRISPR-based genome editing, and climate-resilient trait stacking, turning seeds into some of the most valuable inputs in the agricultural economy.

This technological shift has reshaped the global seed market, which is projected to cross USD 105 billion by 2031, driven predominantly by hybrid seeds that already command a dominant share of revenue. For countries like India, this is not just an export opportunity but a strategic lever that touches economic growth, food security, and geopolitical influence. Seed sovereignty today means the ability to generate cutting-edge germplasm, protect it through robust IP frameworks, and deploy it both domestically and across borders.

India's rise as a seed export hub

Empirical evidence from recent years underscores how rapidly India's seed export profile has strengthened. In 2024, India's seed exports were valued at around USD 800 million, with an impressive 758,000 global shipments—making India the world leader in export volumes. Fruit and vegetable seeds form a particularly dynamic segment, with exports of 13,605 metric tonnes valued at about ₹1,222.54 crore in 2024–25, and Q1 FY2025 alone recording shipments worth ₹396 crore.

What makes this rise more remarkable is the diversity of destinations. Indian seeds today reach highly regulated markets such as the United States, the Netherlands (as a gateway to the European Union), and Japan, while also serving fast-growing markets in Asia, the Middle East, and Africa. Penetration into strict regulatory regimes signals that Indian exporters are consistently meeting global benchmarks on genetic purity, germination, phytosanitary safety, and traceability.

At a product level, India has built niche strengths in high-value horticultural hybrids like tomato, chilli, capsicum, cucurbits, okra, and brinjal alongside hybrid rice, maize, millets, pulses, and oilseeds like sesame, sunflower, and castor. These are not generic commodities; they are tailored solutions for protected cultivation, organized retail, processing industries, and export-oriented production systems across several continents.

Structural strengths behind India's competitiveness

India's export competitiveness is not accidental; it rests on a set of deep structural advantages. The first is agro-climatic diversity with 15 agro-climatic zones, sharp gradients in rainfall and temperature, and wide altitudinal variation together enable year-round seed production and counter-season multiplication for temperate markets. This allows Indian producers to maintain parental lines, accelerate breeding cycles, and serve as a "global nursery" for companies that cannot produce seeds during their own off-seasons.

Cost efficiency is a second pillar. Hybrid seed production depends heavily on skilled manual operations like detasseling in maize, hand emasculation in vegetables, careful isolation, roguing, and selective harvesting and India's relative wage structure translates into production costs that are often 20–30% lower than global averages, without sacrificing quality. This cost advantage is reinforced by scale economics, mature supply chains, and modern seed processing infrastructure spread across key production clusters.

A third structural strength lies in germplasm richness and technological integration. With more than 150,000 accessions, extensive collections of crop wild relatives, and thousands of landraces, India commands a genetic treasure house that feeds into public and private breeding programmes. Increasing use of CRISPR-Cas9, high-throughput phenotyping, genomic selection, trait stacking, and speed breeding is steadily pushing Indian seed research towards the global technological frontier.

Institutions, regulations, and global integration

Behind every successful export consignment stands a complex ecosystem of institutions and standards. On the international side, Indian laboratories accredited by the International Seed Testing Association (ISTA) and participation in OECD seed schemes ensure that Indian lots are tested, certified, and recognized across borders. This reduces technical barriers to trade, speeds up customs clearance, and builds buyer confidence through standardized protocols and orange certificates.

Intellectual property protection is equally central. Accession to the UPOV framework and strengthening of Plant Breeders' Rights enable Indian companies and public institutions to protect varieties in key markets, negotiate licenses, and deter unauthorized multiplication. At home, APEDA acts as a nodal export promotion body, providing registration, market intelligence, financial assistance, and buyer–seller platforms, while industry associations like the National Seed Association of India coordinate advocacy, capacity-building, and knowledge sharing.

The domestic regulatory architecture covering seed quality standards, traceability norms, and phytosanitary requirements has become more exacting over time. Minimum thresholds for varietal purity, germination, and seed health, combined with mandatory phytosanitary certification aligned with international standards, have been crucial in underpinning India's reputation for reliability. Proposed reforms under the Draft Seed Bill 2026—such as fast-track registration for export-destined varieties, unified digital phytosanitary certification, and export-linked incentives seek to explicitly position seeds as a strategic export sector.

Quality, logistics, and technology at the farm gate and beyond

Seed quality is not defined by genetics alone, but by how well those genetics are preserved from breeder plots to farmers' fields across borders. Moisture control, cold-chain storage, and careful handling are critical to maintaining germination vigour especially for high-value vegetable seeds that are highly sensitive to temperature and humidity fluctuations. Temperature-controlled warehouses, reefer containers, and real-time monitoring have become standard tools for serious exporters. Complementing logistics, NABL-accredited laboratories test moisture, germination, genetic and physical purity, and seed health, often using molecular markers like SSR and SNPs to verify hybrid purity, thereby strengthening confidence in Indian brands and reducing trade disputes. At the same time, emerging digital technologies such as blockchain-based traceability are enabling secure, end-to-end documentation from breeder seed to commercial lot, minimizing border rejections, preventing counterfeiting, and making quality claims verifiable in real time ultimately embedding trust into the data trail that accompanies every seed bag.

Seeds as instruments of development and diplomacy

What makes India's seed exports distinctive is that they often function as catalysts for transformation in importing countries, especially across Asia and Africa. Indian hybrid rice in Nigeria, for instance, has delivered yield gains of around 20% over local varieties, enabling two successful crops in the first year and translating into higher farmer incomes and improved local rice availability. High-oleic sunflower seeds exported to Bangladesh have helped upgrade edible oil quality and support that country's efforts toward self-sufficiency.

Similarly, drought-tolerant chickpea varieties introduced in Kenya have contributed to stabilizing yields under erratic rainfall, reinforcing household protein security while improving farm profitability. In all these cases, seeds are not just a traded

good; they are vehicles for agronomic innovation, climate resilience, and nutritional enhancement exported in compact form. This gives India a unique avenue for South–South cooperation and agricultural diplomacy, deepening strategic ties through technology-led partnerships.

Challenges at the frontier of growth

While India's seed export sector has made notable progress, it continues to face several structural challenges. Delays in Pest Risk Analyses (PRAs) in key destination markets can stall high-value trade opportunities, highlighting the need for stronger scientific engagement and faster regulatory coordination. Domestically, overlapping approval processes across multiple authorities can increase transaction costs and slow the release of export-oriented varieties. Although quality infrastructure has advanced in leading clusters, gaps remain in geographic reach and seasonal capacity particularly for ISTA and OECD accredited laboratories. Enforcing intellectual property rights in overseas markets with limited regulatory oversight also remains a concern, exposing breeders to risks of unauthorized multiplication and mislabelling. Climate change further intensifies these pressures by altering pest dynamics, disrupting production cycles, and stressing seed crops in traditional production zones.

On top of these are competitive pressures from established exporters like the Netherlands, USA, and France, and emerging players such as China, Thailand, and Vietnam. Sustaining an edge will therefore depend on differentiation through technology, climate-resilient germplasm, cost-quality balance, and strategic positioning as a trusted partner to developing countries.

The road ahead: from volume leader to technology leader

India now stands at an inflection point where it must transition from being predominantly a volume-based exporter to becoming a technology-intensive leader in the global seed industry. This requires a deliberate push towards next-generation products genome-edited cultivars, biofortified staples, climate-smart hybrids, and varieties tailored for precision and digital agriculture. Integrating AI-driven breeding, digital phenotyping, and advanced genotyping into mainstream commercial pipelines will be critical to staying ahead of the curve.

Geographically, Africa, Southeast Asia, the Middle East, and Latin America represent the most promising frontiers for expansion, each combining rising demand, climate stress, and varying degrees of local breeding capacity gaps. Product innovation must align with these realities: drought and heat tolerance for water-stressed regions,

salinity resilience for coastal belts, improved shelf life and processing quality for organized retail and industry, and nutrient-dense varieties for combating hidden hunger.

Institutionally, India can scale up invest in high-end breeding and phenotyping infrastructure, expand international-quality testing networks, and deepen human capital through advanced educational programmes and international collaborations. Policy coherence across agriculture, trade, science, and IP regimes and consistent support through export incentives, research subsidies, and risk-mitigation instruments can provide the enabling environment for long-term leadership.

In this emerging landscape, the seeds India exports are far more than packets of genetic material. They embody scientific innovation, carry the promise of better harvests to distant farmers, and signal India's aspiration to be a responsible, technology-rich partner in building a more food-secure and climate-resilient world

The role of National/Regional Associations in Exploring Global Opportunities for the Seed Sector to Achieve Sustainable Growth

MS FRANCINE SAYOC

Executive Director, APSA

Ms Francine Sayoc is Executive Director of the Asia and Pacific Seed Alliance (APSA), where she leads the Secretariat in advancing the development of the seed sector in the Asia-Pacific region through regulatory and policy advocacy, knowledge exchange, capacity building, and industry collaboration.

She works closely with seed companies, seed associations, regulators, research institutions, and global partners to address challenges and create opportunities for seed innovation, market access, and trade.

Previously, Francine worked with the International Seed Federation (2019-2024) as Communications Manager, based in Switzerland.

Prior to that, she was Group Communications Manager of East-West Seed (2011-2019), a vegetable seed company based in Asia serving smallholder farmers in the tropics. Earlier, she served as Media and Communications Director (2004-2011) for a member of the Philippine Senate.

Francine has a background in Journalism, and a Master's degree in International Studies. Her career spans government, the private sector, and nonprofit associations in Asia and Europe.

Abstract:

As the APAC seed sector navigates rapid technological change, regulatory fragmentation, and shifting business needs, national and regional seed associations play an increasingly strategic role in enabling sustainable growth. This presentation explores how associations such as the Asia & Pacific Seed Alliance (APSA) act as a *business accelerator* by creating opportunities for trade and innovation; as an *industry advocate* by shaping enabling policy and regulatory environments; as a *knowledge hub* for capacity building and professional development; and as a *community of peers* that fosters trust, collaboration, and ethical standards across the seed sector.

Artificial Intelligence for Agricultural Development and Farmers' Prosperity with Special Reference to Seed Supply Chain

DR KAVYA DASHORA

Associate Professor, Centre for Rural Development and Technology, Yardi School of Artificial Intelligence, IIT, Delhi

Dr. Kavya Dashora is a distinguished Plant Pathologist with specialization in Plant Pathology and Tissue Culture. Her academic career comprises of her work and contribution at **ICAR, Government, Commonwealth and UN** in various capacities and contributed to **Teaching, Research, Development and Innovation**. Presently, Prof Dashora is now working as Associate Professor in Nanotechnology and Artificial Intelligence at ***Indian Institute of Technology, Delhi***. Her key area of research focuses on ***translational research of Nanotechnology and Artificial Intelligence in Agri-food sector.*** She has contributed to more than 12 countries, graduated 4 PhD scholars and has applied patents for 5 novel products innovated by her. She is also reviewer and on editorial board of very reputed Journals with impact factor ranging from IF15- IF 5. She is also an official mentor for STEM programme both at IIT Delhi (India) and IIT Delhi (Abudhabi).

Work Experience

Her career path led her to the UN-Commonwealth Agricultural System where she made impactful regional contributions for crop pest management, food security, women empowerment, intergovernmental networking. In this role, she played a

pivotal role in agri-food system development, empowering women in agriculture, and spearheading large-scale research programs and missions for global food trade in ***least-developed (LDCs), developing, and developed countries***.

Dr. Dashora is presently working as ***Associate Professor at Centre for Rural Development and Technology and Associate Faculty at Yardi School of Artificial Intelligence***. Her goal is to bridge the gap between Indian farmers and cutting-edge research and technology, utilizing technologies like ***Quantum Tech, Blockchain, AI, Computer Vision, and Image Processing for food safety and security, productivity, and achieving SDG goals.***

Her innovations in food technology, including vegan egg and chicken from plant-based proteins, address protein malnourishment issues, reduce the environment burden of animal farming, bio methanation, ecosystem conservation, soil reclamation by mass legume cultivation, etc.

Dr Dashora is preparing first ever ***National Digital Libraries*** for crop pests & pathogens and food flavours for restoring traditional Indian flavours using ***Artificial Intelligence and Deep Learning tools***. She conducts a lot of workshops for young academicians and research scholars introducing them to modern Artificial intelligence, Machine learning and Deep learning in different academic institutions. Dr. Dashora's dedication extends to scientific expert committees of ***DBT, DST, BIRAC, Industry, Niti Ayog, Ayush,*** and ***Board of Academic Studies, NIFTEM (K***); proposal and policy evaluation committees, curriculum design, and policy development in India's scientific and industrial sectors, and she serves on international boards and committees, actively contributing to agri-food companies' growth.

Her ***publication record*** includes around ***80 papers*** in high-impact journals (IF 16-IF 5), numerous book chapters, and technical reports. A sought-after ***keynote speaker***, she has presented at national and international conferences and prestigious scientific institutions.

Currently, Dr. Dashora ***mentor national startups*** in agri-food system technologies. Her exceptional contributions have earned her ***numerous national and international awards***, including recognition from **IIT, CABI, UNDP, PETA, Scientific societies,** and other esteemed institutions.

Key areas of specialisation

Her key areas of specialisation are translation of nanotechnology and nanotoxicity and artificial intelligence in plant protection, early disease forecasting, pattern recognition, ecosystem restoration, food security, smart proteins, in agri-food systems, valorisation of biomass and bioprocess technologies.

Awards and Honors

- **Felicitation** of mentoring women in science (**2023**)
- **First prize** in Innovation for SDG to address food security in **innovation4SDG** by **UNDP** (**2020)**
- **Best Women Scientist** award by **SBRS (2020**)
- **Innovation in Food Award by PETA** (**2019**)
- **Commonwealth Agriculture Above and Beyond award** by **British High Commission** (**2010)**
- **Prof K.P.V. Menon award** for best poster paper (**2008)**

Artificial intelligence in agriculture is often framed through visible technologies such as drones, robotics, and satellite driven yield dashboards. Yet the economic and biological foundation of farmer prosperity lies much earlier in the production cycle, within the seed supply chain. Globally, quality seed alone is estimated to contribute 15 to 25 percent of yield gains across major crops when compared with farm saved or low quality seed systems. The Food and Agriculture Organization has repeatedly emphasized that improved seed systems are among the highest return interventions in agricultural development, particularly for smallholders. In India, the Seed Replacement Rate for major cereals has improved over the past decade, yet remains uneven across crops and states, with certain regions still relying heavily on farm saved seed. Studies estimate that substandard or spurious seed circulation can lead to yield losses ranging from 10 to 30 percent depending on crop and environment. When translated into economic terms across India's cropped area of more than 140 million hectares, even a conservative 5 percent productivity loss represents billions of dollars in foregone output annually. These are not abstract inefficiencies; they represent direct income erosion at the farmer level.

The seed supply chain is therefore not merely a distribution channel. It is the first risk allocation mechanism in agriculture. The global commercial seed market

exceeds 60 billion dollars in annual value, with Asia accounting for a significant and growing share. India alone has one of the largest seed industries in the world, with thousands of producers, processors, and distributors operating across public and private sectors. Yet fragmentation remains high. Forecasting mismatches, storage losses, counterfeit infiltration, and limited traceability continue to weaken the system. During peak sowing seasons, regional stockouts of specific varieties are not uncommon, forcing farmers to switch varieties at the last minute. Such forced substitutions may reduce yield potential by 10 to 15 percent in stress prone environments. Artificial intelligence becomes transformative in this context because it enables integration of biological, climatic, logistical, and market signals across the seed supply chain into predictive, anticipatory decision systems.

The seed supply chain is a biological industrial continuum beginning with plant breeding and varietal release. Breeder seed is multiplied into foundation seed, which is further expanded into certified seed through registered growers under regulatory oversight. After harvest, seed lots undergo cleaning, grading, drying, laboratory testing for germination and purity, packaging, warehousing, transport, wholesale distribution, retailing, and finally sowing. At each stage, both value and vulnerability accumulate. Germination rates may decline by 1 to 3 percent per month under suboptimal storage conditions of high temperature and humidity. In tropical environments, improperly stored seed can lose up to 15 percent viability within six months. Counterfeit seed, which in some developing regions has been estimated to account for 20 to 30 percent of informal market share, undermines farmer trust and distorts pricing. Artificial intelligence addresses these structural inefficiencies by embedding predictive analytics and anomaly detection directly into operational nodes of the seed supply chain.

Data architecture forms the backbone of AI enabled transformation. At the farmer and plot level, geospatial mapping of land parcels, cropping history, irrigation access, and soil attributes create contextual baselines. Environmental layers including rainfall deviation indices, temperature extremes, soil moisture estimates derived from satellite imagery, and pest surveillance data provide dynamic ecological signals. Production and inventory layers capture lot genealogy, certification status, germination test results, moisture content, packaging date, warehouse location, and movement history. Finally, outcome data such as field level germination success, early vegetative vigor indices, and yield realization close the feedback loop. When interoperable within secure governance frameworks, these data streams allow artificial intelligence models to move beyond descriptive analytics toward predictive and prescriptive intelligence within the seed supply chain.

Demand forecasting illustrates this transformation. Conventional forecasting methods often rely on prior year sales trends and projected acreage, ignoring nonlinear influences such as climate variability and market price fluctuations. Machine learning models such as XGBoost and LightGBM capture complex interactions between rainfall deviations, commodity price movements, historical acreage shifts, and policy signals. Deep learning time series architectures such as Long Short Term Memory networks and Temporal Fusion Transformers incorporate multi season climatic volatility. Comparative evaluations in agri supply chains have shown that advanced machine learning forecasting models can reduce mean absolute percentage error from above 20 percent in traditional models to below 10 percent in well calibrated systems. Even a 5 percent improvement in forecasting accuracy across a national seed market worth several billion dollars translates into substantial reductions in unsold inventory and emergency procurement. For farmers, improved forecasting reduces last minute variety substitution and ensures timely availability during narrow sowing windows, directly protecting income.

Varietal recommendation is another high leverage intervention. Across India's agroecological diversity, microclimatic variation within short distances can significantly influence varietal performance. Artificial intelligence models integrating plot level geospatial data, soil characteristics, historical yield records, and real time weather forecasts enable contextual matching between varietal traits and local conditions. Contextual bandit algorithms dynamically balance exploration of emerging varieties with exploitation of established performers. Causal inference techniques reduce bias arising from confounding factors such as differential input access. Field deployments of AI assisted varietal recommendation systems have demonstrated yield improvements in the range of 8 to 18 percent when compared with generic advisory approaches. In rainfed systems, where yield variability is high, aligning varietal duration and stress tolerance with forecast rainfall patterns can reduce crop failure risk by more than 20 percent. The seed supply chain thus becomes not merely a distribution mechanism but a precision biological allocation system.

Seed quality assurance benefits significantly from computer vision and spectral analytics. Manual grading systems are often limited to inspecting a few hundred samples per day per facility. Convolutional Neural Networks trained on annotated seed image datasets have achieved classification accuracies exceeding 95 percent in detecting physical defects such as insect damage, discoloration, and admixture. Hyperspectral imaging combined with regression models can estimate internal

moisture content and detect hidden deterioration with high predictive performance. By doubling throughput and reducing subjectivity, AI enabled quality testing minimizes the risk of substandard seed entering distribution channels. Considering that even a 5 percent decline in germination across large acreage can translate into millions of dollars in lost productivity, the economic impact of quality stabilization within the seed supply chain is substantial.

Traceability remains one of the most challenging dimensions of seed governance. Artificial intelligence approaches that conceptualize the seed supply chain as a graph network of interconnected actors enable detection of anomalous routing patterns and suspicious clustering of complaints. Graph Neural Networks and anomaly detection algorithms generate risk scores that guide targeted inspections. Pilot programs in agri input supply chains have reported reductions in counterfeit circulation of up to 25 to 30 percent when data driven monitoring replaces random inspection. For farmers, this enhances confidence in purchased inputs and reduces exposure to fraudulent products.

Storage optimization integrates biological decay modeling into logistics. IoT sensors embedded in warehouses stream continuous temperature and humidity data. Survival analysis models estimate germination decline curves under varying environmental conditions. Reinforcement learning algorithms optimize dispatch sequences to minimize viability loss during peak demand. Even a 2 to 3 percent improvement in average germination retention across national storage networks can translate into significant aggregate yield gains when scaled across millions of hectares. By embedding predictive storage intelligence within the seed supply chain, silent biological degradation is converted into manageable operational risk.

Governance and ethical safeguards are indispensable. Farmer data must be protected under clear consent frameworks. Explainable AI techniques enhance transparency and accountability. Continuous field validation ensures models remain grounded in biological reality. Capacity building programs are essential to train extension officers, inspectors, and warehouse managers in interpreting AI outputs critically rather than accepting them as opaque prescriptions. Institutional strengthening ensures that artificial intelligence enhances rather than displaces scientific judgment.

The macroeconomic implications of strengthening the seed supply chain through artificial intelligence are significant. Agriculture contributes substantially to employment and rural livelihoods in many developing economies. Even modest

productivity stabilization of 5 to 10 percent across major crops can influence national food security, inflation stability, and trade balances. For financial institutions, improved predictability in crop establishment reduces lending risk, potentially expanding credit access to smallholders. For seed enterprises, improved forecasting and reduced inventory losses enhance profitability and innovation capacity. For policymakers, intelligent deployment of stress tolerant varieties aligned with climate projections strengthens adaptation strategies in the face of increasing temperature extremes and rainfall variability.

In conclusion, artificial intelligence applied to the seed supply chain is not a peripheral digital upgrade. It is a structural intervention at the first mile of agricultural production. When quality seed adoption increases, when forecasting reduces stockouts, when varietal recommendation aligns with ecological reality, when counterfeit circulation declines, and when storage losses are minimized, the cumulative economic effect is profound. Global evidence indicates that integrated digital input systems can improve net farm returns by 10 to 25 percent while reducing variability and risk exposure. In systems where millions of smallholders operate at thin margins, reducing uncertainty may be as important as increasing yield. An intelligent seed supply chain therefore represents one of the most cost effective and scalable pathways toward inclusive and sustainable agricultural prosperity. Artificial intelligence does not replace the biology of seed; it amplifies it. By transforming fragmented data streams into anticipatory governance, it converts the seed supply chain from a reactive distribution network into a resilient, transparent, and farmer centric system capable of sustaining productivity in an era of climatic and economic volatility.

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