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SUSTAiN-2026

Sustainable Transformation in Agriculture and Nutrition

5th - 6th February 2026

Meeting Proceedings

Climate Resilience

Pest Management

Nutrition Security

Knowledge Partners

UAS - GKVK
Bengaluru

ICAR - NBAIR
Bengaluru

ICAR - IIRR
Hyderabad

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INAUGURAL SESSION

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SUSTAINABLE TRANSFORMATION IN AGRICULTURE AND NUTRITION SUMMIT (SUSTAiN) 2026

India feeds over a billion people while facing critical challenges, including climate change, declining soil health, nutritional deficiencies, and the growing demand for food security. Addressing these interconnected challenges requires more than incremental fixes; it demands a sustained, science-driven, and collaborative reimagining of how food is grown, protected, and consumed. With this conviction, the Tata Institute for Genetics and Society (TIGS) launched SUSTAiN (Sustainable Transformation in Agriculture and Nutrition) in collaboration with the National Centre for Biological Sciences (NCBS). TIGS was established with the purpose of harnessing cutting-edge science and technology in genetics and genomics to solve India's most pressing societal challenges, from preventing infectious diseases and improving access to diagnostics for rare genetic disorders to achieving food and nutrition security through sustainable agriculture. SUSTAiN is a direct expression of this mission. Designed as an evolving annual forum, it seeks to bring together scientists, policymakers, and regulatory stakeholders under one roof to move beyond academic discourse and toward actionable, field-level solutions. The initiative was strengthened by the participation of leading knowledge partners, including the University of Agricultural Sciences (UAS), GKVK, Bengaluru; ICAR–National Bureau of Agricultural Insect Resources (ICAR-NBAIR), Bengaluru; and ICAR–Indian Institute of Rice Research (ICAR-IIRR), Hyderabad. SUSTAiN 2026 was structured around three core themes - climate resilience, pest management practices, and nutrition security - aimed at addressing critical challenges in sustainable agriculture, while simultaneously manoeuvring meaningful and lasting transformations.

The first edition of SUSTAiN was held on 5th and 6th February 2026, with Prof. L S Shashidhara framing the conference as a meeting that sits at the heart of what the Bangalore Life Science Cluster (BLiSC) was built to do. BLiSC, which brings together NCBS, TIGS, Institute for Stem Cell Science and Regenerative Medicine (inStem), and Centre for Cellular And Molecular Platforms (C-CAMP) within the campus of the University of Agricultural Sciences, GKVK, was designed for this kind of convergence: where disciplines meet, where science engages with society, and where research is held accountable to real-world outcomes. Prof. Shashidhara drew attention to the cluster's guiding "One Health" philosophy, which recognises that the health of the environment, agricultural systems, and human populations is deeply intertwined and lasting progress in any one of these areas depends on understanding its relationship with the others. He was equally insistent that nutrition be treated as a first-order concern rather than an afterthought in agricultural planning, reflecting a broader understanding that what food systems produce is inseparable from what people ultimately eat and how healthy they remain.

Dr. S V Suresha brought a perspective that was both historical and unflinching. Tracing India's agricultural journey from the 1950s, he argued that the single-minded pursuit of caloric sufficiency, understandable in a newly independent nation, had gradually come at the cost of nutritional diversity, and the consequences of that trade-off are now visible in both public health and the fragility of farming systems. He particularly pointed about the field's own language: agriculture is perpetually described as being "at a crossroads", yet the conversations that follow rarely move beyond diagnosis. Where must this transition lead, and what concrete steps will take us there? These, he suggested, are questions the field has been too comfortable leaving unanswered.

The environmental toll of the current model further sharpened his argument. Agriculture's significant contribution to greenhouse gas emissions is often overlooked in climate conversations, while the overuse of chemical inputs has steadily eroded the soil that farming depends upon. Most tellingly, despite this intensive dependence on pesticides and fertilisers, crop losses remain substantial, a paradox that points to a structural problem demanding structural solutions. For Dr. Suresha, climate-resilient agriculture must stop being an aspirational phrase and start being engineered as a practical reality, one that requires research designed to scale and transform, and genuine multidisciplinary collaborations.

Dr. Rakesh Mishra anchored SUSTAiN within TIGS's institutional mission, applying cutting-edge genetics and genomics to real-world challenges, with crop improvement for climate resilience, pest management, and nutrition security at the core. He was clear that the questions SUSTAiN is asking cannot be answered by scientists alone; solutions that are scientifically sound but economically unviable or socially unacceptable will not travel from the laboratory to the field. Bringing researchers, policymakers, and regulatory stakeholders into sustained dialogue is the real initiative and he welcomed their active participation to develop SUSTAiN into a meaningful platform for addressing these challenges.

Group photo of participants

Prof. L S Shashidhara

Dr. S V Suresha

SESSION 1 : CLIMATE RESILIENT AGRICULTURE

SESSION CHAIR

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Dr. B K Sarma

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Dr. Satendra Kumar M

Senior Scientist,
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Dr. Mamrutha H M

Senior Scientist,
ICAR-NISST,
Bengaluru.

Dr. Maitrayee DasGupta

Honorary Adjunct Professor,
University Of Calcutta,
Kolkata.

CLIMATE RESILIENT AGRICULTURE

This session aimed to highlight scientific and technological approaches for strengthening agricultural resilience under changing climatic conditions. The discussions focused on biotechnological and integrated strategies to improve crop productivity, resource use efficiency, and stress tolerance across major food crops. The session brought together insights from crop genetics, genome editing, plant-microbe interactions, epigenetics, and breeding innovations, emphasizing evidence-based solutions for sustainable and climate-resilient agricultural systems.

Biotechnological Approaches for Climate-Resilient Agriculture: Dr. Ramesh V Sonti

Dr. Ramesh V Sonti began by highlighting the urgency of climate change, noting that global mean temperatures have already increased by approximately 1.1°C above pre-industrial levels and are approaching the 1.5°C threshold outlined in the Paris Agreement. He emphasized the associated challenges of biodiversity loss, environmental pollution, and the need to ensure food security for a growing global population while reducing inputs such as water, fertilizers, and pesticides.

Dr. Sonti discussed long-term efforts in rice improvement, with specific emphasis on the development of bacterial blight-resistant Samba Mahsuri through marker-assisted selection. He highlighted the success of Improved Samba Mahsuri, which exhibits 96% recurrent parent genome, resistance to multiple pathogenic strains of *Xanthomonas*, and wide cultivation across several Indian states. He further elaborated on various varieties derived from Improved Samba Mahsuri to address multiple stresses. The presentation covered challenges such as diseases, soil nutrient deficiency, lodging, and yield stability under flood, drought, and salinity conditions.

Dr. Sonti also introduced a DBT-supported collaborative project on Direct Seeded Rice (DSR), involving multiple national institutions. The project aims to incorporate traits such as anaerobic germination, enhanced seedling vigour, herbicide tolerance, lodging resistance, and improved nutrient uptake into Samba Mahsuri. Genome editing approaches were presented as enabling tools to facilitate the transition from transplanted to direct-seeded rice cultivation systems, thereby reducing water consumption and methane emissions associated with rice cultivation.

In addition, Dr. Sonti presented work on microbiome-based approaches for improving large cardamom cultivation in Sikkim. This work focuses on the identification and application of beneficial microbial consortia with plant growth-promoting and biocontrol traits to mitigate climate and disease-related stresses.

The presentation concluded with brief remarks on future directions, including the use of transgenic approaches, wild progenitors for accelerated domestication, and the effective utilization of extensive gene bank resources for crop improvement.

Fixing Nitrogen Fixation to Fix Agricultural Resilience: Dr. Maitrayee DasGupta

Dr. Maitrayee DasGupta began by placing the discussion in the context of the Green Revolution, highlighting India's continued and excessive dependence on nitrogen fertilizers since the 1990s, a trend that contrasts with reduced global dependence. She pointed out that this dependence contributes to environmental pollution and increased ammonia emissions. She emphasized the significance of India's Long-Term Fertilizer Experiments (LTFE), a nearly 70-year initiative conducted across multiple centres - which have generated critical insights into soil nutrient dynamics and long-term agricultural sustainability.

Dr. DasGupta discussed holistic nitrogen management approaches encompassing plants, soil, and agricultural practices, with particular emphasis on biological nitrogen fixation. She explained the role of prokaryotic nitrogen fixation and its extension to plants through associative and symbiotic interactions, including rhizobium-legume symbiosis.

Dr. DasGupta further elaborated on global efforts to engineer self-fertilizing crops, particularly non-leguminous crops such as rice, drawing on conserved evolutionary mechanisms including the common symbiosis signalling pathway (CSSP). She highlighted recent technical advances in this area, including receptor engineering, modifications in symbiotic signaling components, and transcriptional regulation involved in infection and nodule development. She also shared insights from her laboratory's recent findings on the structural and molecular mechanisms facilitating symbiosis.

Towards the end of the presentation, she discussed future strategies involving diverse microbial partners, wild cultivars, and nutrient-limited conditions to enhance symbiotic efficiency. Dr. DasGupta concluded by emphasizing that large-scale, coordinated global efforts are underway to develop self-fertilizing crops for sustainable and resilient agriculture**.**

Reprogramming Cytokinin Metabolism via Genome Editing to Improve Rice Productivity: Dr. Satendra Kumar M

Explaining about his work on targeting the cytokinin oxidase 2 gene (*OsCKX2/Gn1A*) Dr. Satendra Kumar M emphasized how it enhanced yield without compromising grain quality, positioning this approach as a key contributor to a potential "second green

revolution" in rice. Dr. Kumar discussed the role of cytokinins in regulating plant growth and yield, emphasizing the need to maintain optimal hormonal balance to avoid yield-related trade-offs.

He highlighted that among the eleven cytokinin oxidase genes in rice, *OsCKX2* plays a major role in controlling panicle grain number. Mutations in this gene reduce enzyme activity, increasing cytokinin levels and grain numbers per panicle.

Later, Dr. Kumar described the development of the Kamala variety through multiplex genome editing in exons 3 and 4 of *OsCKX2* in the Samba Mahsuri genetic background, generating multiple allelic variants. The selected Kamala allele resulted in a moderate increase in cytokinin levels, thereby maintaining protein stability and avoiding negative trade-offs. The edited line exhibited a significant increase in grain number per panicle and an overall yield advantage compared to the parent variety.

Dr. Kumar further highlighted the agronomic advantages of Kamala, including early flowering, complete panicle emergence, stronger culms, improved root architecture, and enhanced tolerance to low nitrogen and drought conditions. He emphasized the sustainability benefits of early maturity, noting its potential to reduce water, fertilizer, and labour inputs.

He concluded that Kamala, is India's first regulatory exempted genome-edited rice variety and emphasized the need for continued support for genome editing approaches to accelerate the development of superior crop varieties.

Harnessing Microbe-Induced Plant Epigenetics for Sustainable Management of Biotic and Abiotic Stresses: Dr. B K Sarma

Dr. B. K. Sarma highlighted that nearly 9 million hectares of agricultural land in India are affected by salinity and projected that up to 50% of arable land may be affected by 2050. He reported that moderate salinity results in 20-40% yield losses, while severe salinity can cause yield losses of up to 80–90%, posing a significant threat to food security.

Dr. Sarma discussed the adverse effects of salinity on nitrogen use efficiency (NUE) and emphasized the economic burden associated with nitrogen fertilizer subsidies in India. He explained that Fusarium wilt causes crop losses ranging from 10–100% in chickpea and that combined salinity and *Fusarium* stress resulted in nearly 88% plant mortality, exceeding the impact of individual stresses. He also noted that chickpea germination is inhibited under high salinity, whereas *Fusarium* can grow and sporulate effectively under saline conditions, thereby favouring disease development.

He presented experimental findings showing enhanced *Fusarium* growth under dual

stress and the role of *Trichoderma* as a biocontrol agent in improving plant growth, nodule health, nitrogen and protein content, and nitrogen use efficiency under stress conditions.

At the molecular level, he discussed the involvement of basic Helix-Loop-Helix (bHLH) transcription factors, particularly MIC-domain-containing bHLH genes, in stress tolerance. He further explained protein-protein interactions and epigenetic modifications, including *Trichoderma*-induced promoter demethylation, which contributes to enhanced defence responses.

In conclusion, Dr. Sarma emphasized that Trichoderma enhances tolerance to combined biotic and abiotic stresses through gene regulation, epigenetic modifications, and activation of plant defence pathways. He advocated for the development of area-specific, customized microbial inoculants rather than universal formulations, to ensure sustainable crop management under diverse soil and environmental conditions.

Integrated Approaches for Developing Climate-Resilient Wheat: Dr. Mamrutha H M

Dr Mamrutha H M introduced the Indian Institute of Wheat and Barley Research (IIWBR) as the nodal institute for wheat research in India under the ICAR system. She highlighted its role in varietal development through the All India Coordinated Research Projects and its collaborations with international organizations such as International Maize and Wheat Improvement Center (CIMMYT) and International Center for Agricultural Research in the Dry Areas (ICARDA).

Dr. Mamrutha highlighted recent trends in wheat production, noting that India has surpassed its Vision 2050 target well ahead of schedule, achieving approximately 117.5 million tonnes of wheat production despite variable climatic conditions across major wheat-growing zones. She attributed this achievement to the continuous development and release of climate-resilient wheat varieties through extensive multi-location testing across 99 screening centres nationwide.

She elaborated on key breeding strategies, including multi-location trials for heat and drought tolerance that generate critical indices for varietal evaluation and release. She also emphasized the role of precision phenotyping using controlled facilities, such as rain-out shelters and high-temperature, salinity, and waterlogging screening setups, to complement field-based evaluations.

Trait-based breeding approaches focusing on physiological traits such as leaf waxiness, drooping leaf architecture, stomatal behaviour, and photosynthetic efficiency were highlighted, including outcomes from international collaborative projects. Dr. Mamrutha also discussed the integration of advanced technologies, including endophyte-based approaches to improve seedling vigor, biological

nitrification inhibition to enhance nitrogen uptake efficiency, and genome editing tools to fine-tune key regulatory genes while minimizing trade-offs.

In her concluding remarks, Dr. Mamrutha emphasized the importance of interdisciplinary collaboration across ICAR institutes, revisiting screening locations in response to shifting stress patterns, and developing region- and district-specific wheat production packages. She acknowledged the contributions of her colleagues, students, and funding agencies supporting research on climate-resilient wheat.

Q&A Session Summary

The Question-and-Answer session covered microbiology, plant–microbe interactions, the role of *Trichoderma* in agriculture, nitrogen fixation, genome editing approaches for crop resilience in rice, wheat, and sorghum, microbiome engineering, and plant stress responses.

Participants discussed the *Trichoderma*-mediated enhancement of nitrogen use efficiency under saline and high-nitrogen conditions. Metagenomic studies indicating increased ammonia-oxidizing bacteria were noted, along with the need for quantitative validation through dose-response studies rather than relying solely on qualitative observations.

Discussions on gene editing emphasized the importance of prior understanding of plant biology, gene expression timing, and wild-type behaviour. It was noted that CRISPR-based approaches enable multi-gene editing, such as five or six genes in Indian mustard, while allowing targeted modification of tissue-specific, and actively expressed gene copies.

Rice-related discussions acknowledged improvements such as enhanced stem girth, increased diameter, improved mechanical strength, and resistance to wind and rain in varieties like Kamala. Participants identified gaps in resource-use efficiency in rice, particularly in water-use efficiency, and suggested the need for collaborative research efforts. Edited rice lines were reported to perform better under direct - seeded aerobic conditions despite stomatal trade-offs, with further stress validation planned.

Wheat-related discussions focused on maintaining pollen viability in tolerant genotypes and addressing the effects of high night-time temperatures during grain filling, which are reported to significantly reduce yields under simulated conditions.

Strategies for multi-copy gene knockouts in polyploid crops such as Ragi emphasized the importance of precise, tissue-specific targeting rather than editing all gene copies. Chickpea resilience breeding efforts were discussed, with emphasis on targeting elite mega-varieties using speed breeding and marker-assisted selection,

complemented by classical breeding and microbial approaches for sustainable production.

Alternate Wetting and Drying (AWD) in rice was discussed as a strategy for reducing water use and emissions. However, yield penalties of 30-40% were reported, and trait stacking was suggested as a potential approach to mitigate losses.

Protein enhancement strategies were discussed with a focus on plant-microbe signalling interfaces to strengthen nodulation and improve nutritional quality. Overall, the discussions underscored the need for integrated, quantitatively validated, and climate-resilient approaches to crop improvement.

Dr. P V Shivaprasad

Dr. Mamrutha H M

From left: Dr. Mamrutha H M, Dr. Satendra Kumar M, Dr. P V Shivaprasad, Dr. Ramesh V Sonti, Dr. Maitrayee DasGupta, Dr. B K Sarma

SESSION 2: SUSTAINABLE PEST MANAGEMENT

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Dr. R Asokan

Consultant Scientist,
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Dr. Kamala Jayanthi

ICAR National Professor,
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Dr. Rohini Sreevathsa

Principal Scientist,
ICAR-NIPB,
New Delhi.

SUSTAINABLE PEST MANAGEMENT

Sustainable Pest Management in India: Current Status, Future Prospects and Regulatory Framework: Dr. S N Sushil

Dr. S N Sushil provided an overview of the plant protection in India, highlighting the economic impact of pests, including pathogens, weeds, and rodents, collectively causing an estimated 10-30% crop loss amounting to nearly ₹2.25 lakh crore annually. Despite the Government of India's sustained efforts to promote Integrated Pest Management (IPM) through policy initiatives since 1985, he highlighted the rising trend in pesticide consumption since the 1950s, reaching almost 500 g/ha by 2023-24. He mentioned the establishment of key national interventions such as Central IPM Centres and State Bio-control Laboratories, the development of IPM packages for major crops, and the phased withdrawal of hazardous pesticides. Outlining the regulatory framework under the Insecticides Act, 1968, he stressed about the roles of the Central Insecticides Board and the Registration Committee in ensuring the safe registration, quality control, labelling, and judicious use of pesticides, supported by a nationwide laboratory network and awareness campaigns.

Dr. Sushil also addressed biosecurity and plant quarantine measures, noting India's significant economic losses were due to invasive alien species. He also emphasized the extensive quarantine infrastructure that controls around 1,400 agricultural pests at multiple points of entry. Reports of pest invasions between 2023 and 2025 were highlighted alongside successful, classical biological control interventions led by ICAR-NBAIR, which have been shown to generate substantial economic benefits. Dr. Sushil concluded the talk with an overview of locust management in India, describing the role of the Locust Warning Organisation, establishing monitoring thresholds, and integrating control strategies involving approved chemical insecticides and bio-pesticides such as *Metarhizium anisopliae*.

The Growing Threat of Insecticide Resistance in Crop Pests: Bridging Science, Policy and Practice: Dr. K Murali Mohan

Dr. K Murali Mohan presented on the growing threat of insecticide resistance and the need to bridge science, policy, and practice in its management. The presentation defined insecticide resistance as a heritable change in pest sensitivity leading to repeated failure of pest control. He highlighted indiscriminate insecticide use, repeated application of chemicals with the same mode of action, and overreliance on chemical control as the key drivers of resistance development. The global and economic impacts of insecticide resistance were emphasized, with resistant and invasive pests causing losses exceeding US $70 billion annually. Instances of increased spray frequencies and severe crop losses in India, including neonicotinoid

resistance in whitefly leading to major cotton losses in Punjab were highlighted as examples of these losses.

Dr. Mohan outlined the current status of resistance worldwide, reporting over 19,600 cases across insect orders, particularly in Lepidoptera, Coleoptera, and Diptera, with a high incidence of resistance to organochlorines, organophosphates, pyrethroids, and carbamates. Case studies highlighted insecticide resistance in major pests such as diamondback moth, whitefly, and pink bollworm. This observation was supported by local data from UAS Bengaluru which reported high resistance levels in pink bollworm to multiple insecticides and Bt toxins. The role of incomplete *Bt* trait purity and feeding on segregated seeds in hybrid cotton as mechanisms driving *Bt* resistance was discussed. It was also noted that hybrid *Bt* cotton seeds naturally contain about 5% non-*Bt* seeds due to limits in achieving complete purity, suggesting that India's "Refuge in Bag" strategy may not always be necessary. The talk concluded with recommendations regarding robust resistance monitoring, development of effective Insecticide Resistance Management strategies, data-driven policies, farmer education, adoption of non-chemical measures, and judicious insecticide use.

Application of CRISPR for Insect Pest Management: Dr. R Asokan

The session featured a comprehensive presentation by Dr. R Asokan on the application of CRISPR technologies for insect pest management. The presentation began with an overview of genome editing research at IIHR, tracing the evolution of CRISPR from bacterial adaptive immunity to a powerful genome-editing tool, highlighting key milestones such as the discovery of CRISPR loci, crRNA-tracrRNA systems, PAM recognition, and the development of single guide RNA–based Cas9 editing. The molecular mechanism of CRISPR/Cas9-mediated DNA cleavage, including PAM binding, guide RNA interaction, and double-strand break induction followed by error-prone non-homologous end joining, was explained as the basis of targeted genome editing in eukaryotes.

Dr. Asokan discussed advances beyond Cas9, including Cas12a, Cas13a, Cas3, base editors, prime editors, and twin prime editing, emphasizing their potential to enable precise editing without double-strand breaks. Applications in insect pest management were illustrated through editing of key genes involved in sex determination, spermatogenesis, olfaction, reproduction, and behaviour in major pests such as *Spodoptera frugiperda, Spodoptera litura, Plutella xylostella, Maruca vitrata, Pectinophora gossypiella, Bactrocera dorsalis, Zeugodacus cucurbitae*, and *Bemisia tabaci*. The concept of precision-guided Sterile Insect Technique (pgSIT) was highlighted as a promising, non-transgenic, area-wide pest management approach with advantages over conventional SIT. Experimental strategies, including embryonic microinjection, receptor-mediated ovary transduction of cargo (ReMOT), and RNP-

based delivery, were discussed, along with successful gene-editing outcomes such as intersex formation and disruption of spermatogenesis in *B. dorsalis*.

The presentation also covered CRISPR-based diagnostics using Cas12a and Cas13a for rapid virus detection, plant and animal genome editing approaches, and current limitations related to regulation. The session concluded by emphasizing that responsible deployment of genome editing technologies in agriculture requires careful balancing of scientific benefits, biosafety considerations, and societal acceptance.

Plant-insect Chemical Dialogues: Strengthening IPM for Sustainable Pest Management: Dr. Kamala Jayanthi Pagadala Damodaram

Dr. Kamala Jayanthi Pagadala Damodaram presented the role of semiochemicals in developing sustainable Integrated Pest Management (IPM) strategies, with particular emphasis on fruit flies. The talk highlighted India's strong agricultural productivity while drawing attention to significant crop losses (25–30%) caused by pests due to intensive monocropping and climate change, underscoring the need for sustainable IPM approaches. The FAO-defined IPM framework was discussed, emphasizing reduced risks to human health and the environment, supported by global studies demonstrating increased yields, reduced pesticide use, and superior benefit–cost ratios compared to conventional practices. Semiochemicals were presented as effective, economical, and environmentally safe IPM tools that manipulate insect behaviour in a species-specific manner.

Research on the oriental fruit fly (*Bactrocera dorsalis*) showcased the limitations of male-specific methyl eugenol traps and highlighted the potential of host-derived kairomones, such as γ-octalactone from mango and jackfruit, as female attractants and oviposition stimulants, offering prospects for unisex lures. The presentation also emphasized the role of host–microbe interactions in insect behaviour and outlined future directions focusing on female-targeted trapping, advanced chemical ecology approaches, and the development and commercialization of novel semiochemical-based products.

How Redox Homeostasis Shapes Insect Resistance in Pigeon Pea Wild Relatives: The *Helicoverpa armigera* - *Cajanus platycarpus* interaction as a paradigm: Dr. Rohini Sreevathsa

Dr. Rohini Sreevathsa began the talk by discussing the role of redox homeostasis in shaping insect resistance in pigeon pea wild relatives. The talk highlighted the importance of pigeon pea (*Cajanus cajan*) as a drought-tolerant, protein-rich legume and addressed the significant yield gap in India, where actual productivity remains far below its potential due to biotic and abiotic stresses. The polyphagous pod borer,

Helicoverpa armigera, was identified as the most severe constraint to pigeon pea productivity, capable of causing devastating yield losses. While transgenic *Bt* approaches exist, the presentation emphasized the exploitation of resistant wild relatives as a sustainable management strategy. Wild species, particularly *Cajanus platycarpus*, were showcased as valuable reservoirs of genetic diversity exhibiting resistance to pod borer, Fusarium wilt, nematodes, and salinity.

Dr. Sreevathsa detailed the molecular basis of this resistance, highlighting a multi-tiered defence system involving physical, chemical, and cellular mechanisms, with redox homeostasis playing a central role. The regulation of reactive oxygen species through antioxidant systems was shown to be critical for activating effective defence signalling without causing self-damage. Methionine sulfoxide reductases, notably *CpMSRA2* and *CpMSRB1*, were identified as key genes protecting proteins from oxidative stress during herbivory. The defence response was described as a synergistic salicylic acid and jasmonic acid-mediated pathway, with CpMSRB1 interacting with chorismate mutase to sustain phenylpropanoid metabolism and phenolic compound production, which is strongly associated with reduced pod damage. The speaker concluded the presentation by demonstrating that tight regulation of redox balance underpins effective insect resistance in pigeon pea wild relatives.

Q&A Session Summary

The Question-and-Answer session highlighted the intersection of molecular innovation, resistance management, regulatory reform, and farmer-centric implementation in implementing sustainable pest and crop management systems. Discussions on stress-inducible promoters and genome editing showed promising progress in molecular tools such as CRISPR, RNAi, and AI-assisted gene prioritization. Drought-inducible promoters showed validated stress-responsive expression, indicating potential for multi-stress tolerance. However, ecological safety, regulatory clarity, and robust genomic datasets remain essential for responsible deployment. Gene drives and advanced genome editing approaches face regulatory and technical barriers, while crop editing currently appears more feasible.

A major theme of discussion was pesticide overuse and the development of resistance, with weak dealer regulation, misleading trade names, permanent product registrations, and reliance on informal advisory systems being identified as the primary drivers. The need for structured Insecticide Resistance Management (IRM), nationwide resistance surveillance, and rotation of mode of action was emphasized. Pesticide resistance was recognized as not merely a biological issue but also a systemic governance challenge requiring coordinated national action.

The session also examined barriers to biopesticide adoption and biological control, including inconsistent product quality, weak certification systems, supply chain limitations, and limited farmer awareness. Strengthening regulatory oversight, improving quality assurance, and enhancing extension networks such as Krishi Vigyan Kendras (KVKs), NGOs, and advisory systems were identified as critical steps for scaling sustainable alternatives.

Regulatory frameworks emerged as a cross-cutting concern, particularly regarding dsRNA products, genome editing, and deregistration of ineffective pesticides. Policy trends indicate a gradual shift toward biological and green technologies, but institutional strengthening is necessary to support this transition.

Finally, farmer sensitization and research dissemination were identified as foundational pillars to support and enhance all other efforts. Continuous education, clear labelling, improved advisory systems, and proactive extension efforts are essential to promote responsible pesticide use, adoption of integrated management approaches, and long-term sustainability.

Overall, the session emphasized that sustainable agricultural transformation requires an integrated approach combining molecular innovation, resistance surveillance, regulatory reform, market restructuring, and strong farmer engagement systems.

Dr. R Asokan

Dr. S N Sushil

From left: Dr. Rohini Sreevathsa, Dr. R Asokan, Dr. S N Sushil, Dr. T Venkatesan, Dr. Kamala Jayanthi, Dr. Murali Mohan K

SESSION 3: SUSTAINABLE NUTRITION SECURITY

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Dr. Saurabh Pandey

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Magstik,
New Delhi.

SUSTAINABLE NUTRITION SECURITY

Dr. R M Sundaram began the session by reiterating that SUSTAiN 2026, as a national forum, has assembled researchers, policymakers, startups, and industry leaders to promote crop enhancement and the agriculture-nutrition transition. He emphasized the need to shift the focus from calorie-based food security to nutrition-sensitive agriculture, with a special emphasis on micronutrient density, quality proteins, climate resilience, and minimizing losses in the value chain of production, processing, and distribution. While discussing the triple burden of malnutrition: undernutrition, micronutrient deficiencies, and overnutrition, Dr. Sundaram emphasized the need for resource efficiency based on the "more nutrition per drop, per hectare, per unit carbon" approach. He stressed the need for a convergence of plant breeders, biofortification researchers, genomics researchers, food technologists, nutrition experts, policymakers, and entrepreneurs to make nutrition accessible and affordable for all.

Biofortification of Cereals: Towards the Nation's Nutrition Security: Dr. C N Neeraja

Dr. C N Neeraja began her talk by addressing the nutritional security challenges that India continues to face despite the success of the Green Revolution in food production and the presence of extensive public distribution systems. She emphasized that micronutrient and protein deficiencies remain a global issue, significantly contributing to disability-adjusted life years (DALYs). The Comprehensive National Nutrition Survey, conducted by the Indian Council of Medical Research (ICMR), has revealed the widespread prevalence of stunting, underweight, anaemia, and deficiencies of zinc, vitamin A, and B vitamins, particularly among children, women, and vegetarian populations.

Dr. Neeraja described biofortification as the genetic enhancement of staple crops to increase their nutrient content, presenting it as a sustainable and cost-effective alternative to supplementation and fortification programs, such as the use of fortified rice kernels (FRK). She stated that other methods, like agronomic practices, are limited to the experimental stage, while genetic modification faces regulatory challenges, as seen in the case of Golden Rice. However, success has been achieved through conventional breeding, which involves screening of germplasm, strategic breeding, and the efforts of the All India Coordinated Research Projects (AICRP) of ICAR, supported by the infrastructure and initial breeding stocks provided by HarvestPlus.

She highlighted significant progress in cereals, with the development of over 180 varieties. These include 12 high-zinc rice varieties achieving up to 24 ppm zinc (compared with a 16-ppm baseline), high-protein rice, various wheat varieties combining iron, zinc, and protein, quality protein maize enriched with provitamin A,

and pearl millet meeting mandatory release levels of iron (>42 ppm) and zinc (>32 ppm). The new varieties have yields, quality, and disease resistance comparable to the existing standards. Efficacy trials have confirmed the effectiveness of these varieties in increasing bioavailability, supporting child growth, providing commercially available low glycemic index rice, and enhancing poultry growth through biofortified maize.

Dr. Neeraja further emphasized that the adoption activities include field demonstrations, tribal development plans, Farmer-Producer Organisations (FPOs), and state-level activities such as Odisha's participatory breeding. The challenges identified were yield-nutrient dilution effects, soil variability, antinutrient phytates, lack of molecular markers for rice nutrient traits, inadequate farmer incentives due to the invisible nature of nutrient attributes, miller preferences, and unaddressed gaps in the convergence of health-nutrition-agriculture.

Dr. Neeraja concluded her presentation on a positive note, stating that these varieties are ready for scaling up through Krishi Vigyan Kendras (KVKs), extension programs, and the soon-to-be-launched National Nutrition Mission, which plans to prioritise biofortified cereals. She also stated that with the recognition from the Prime Minister and support from ICAR's CRP-Biofortification group, aggressive scaling up through the Public Distribution System (PDS), mid-day meal programs, and the Integrated Child Development Services (ICDS) could bring about revolutionary improvements in nutritional outcomes.

Bioengineering Pathways for Iron Partitioning Using Integrated Functional Approaches: Dr. Ajay K Pandey

Dr. Ajay K Pandey began the discussion by describing bioengineering approaches for the iron distribution in wheat. He emphasized the problem of micronutrient deficiency and the need for an integrated functional approach that addresses both increasing iron content and enhancing its bioavailability. He highlighted a key problem in the cereal crops, i.e., only 2-8% of ingested iron is bioavailable. He explained the dual nature of iron- ferrous iron, which is more bioavailable but toxic in excess amounts in anaerobic environments, and ferric iron, which is more prevalent in aerobic soils and must be taken up in chelated form. Excess iron causes toxicity, while deficiency leads to chlorosis, which affects photosynthesis, growth, and resistance to pathogens.

Plant species have unique iron acquisition strategies. In dicots (Arabidopsis, tomato, etc.), Strategy I involves root H+-ATPase-mediated proton secretion to reduce ferric iron, which is then taken up as ferrous iron by the IRT1 transporter. In grasses like wheat, Strategy II involves the secretion of phytosiderophores that chelate ferric iron, which is then taken up by yellow stripe-like transporters. Rice plants utilize both

strategies in a condition-dependent manner, while hexaploid wheat, with a genome consisting of the A, B, and D sub-genomes, requires multi-genome targeting, complicating biotechnological applications.

Dr. Pandey introduced the comprehensive datasets generated from the transcriptome analysis of iron-starved wheat variety C306 seedlings, which covered early signalling, symptomatic, and late stages. Early signalling was dominated by the A and D genomes in roots and shoots, which later changed to the A and B genomes. Laser-capture microdissection revealed that the root tip is the iron-sensing "mini-core" region, and cell-type deconvolution of approximately 5,000 differentially expressed genes (DEGs) showed that pericycle cells are the major contributors. Interestingly, the multicopper oxidase TaMCO3 gene family was identified as a key candidate. Functional validation using yeast complementation, GFP localisation, and hexaploid overexpression revealed their membrane-bound function in xylem loading, leading to increased iron content in roots and shoots under iron deficiency.

He also presented data on genome editing of the HRZ1 ubiquitin ligase, a negative regulator whose iron-binding HHE domain was disrupted by CRISPR, leading to decreased transcription factor binding and increased mobilisation. Modules consisting of GRF4-GIF1 demonstrated an increase in transformation efficiency from 0.5-0.7% to 8-10%, producing 30-40% edited lines with endosperm iron concentrations of 45-48 ppm and optimized iron-phytate ratios. Simultaneously, the endosperm-specific overexpression of vacuolar iron transporters using high-molecular-weight glutenin promoters was confirmed through yeast assays, immunostaining, STC29 intestinal cell ferritin expression, and Western blots supporting bioavailability.

Dr. Pandey concluded that integrating transcriptomics with cell-type resolution and precise genome editing can overcome bottlenecks related to soil uptake, long-distance transport, and grain loading, thereby positioning bioengineered wheat to improve nutritional security.

Control of Rice Grain Size and Nutrition by a C2H2 Zinc Finger Repressor: Dr. Pinky Agarwal

Dr. Pinky Agarwal began her presentation by discussing the molecular control of rice grain size and nutrition through REP1, a C2H2 zinc finger transcriptional repressor crucial in increasing yield and improving quality to address global food security challenges.

Dr. Agarwal then explained the biology of rice, including a small embryo and starchy endosperm consisting of amylopectin-branched glucose units and amylose-linear units. Varieties with high amylose, such as long-grain Basmati, have a non-glutinous

texture with translucency, low glycemic index (GI), and high resistant starch that ensures slow digestion, making it suitable for diabetics. In contrast, amylopectin-rich rice has a glutinous, chalky endosperm with low resistant starch and high GI, which can cause spikes in glucose. The world population is projected to reach 10 billion by 2050, but the area under rice cultivation is expected to remain constant. This emerging demand-supply gap needs improvement in both yield and quality. Rice provides up to 70% per capita protein energy in Southeast Asia; therefore, enhancing protein and amylose is economically viable for the poor.

REP1, one of the 189 rice C2H2 zinc finger (ZF) factors with two ZnF domains and DLNs, was studied by Agarwal, who observed its high accumulation during the grain maturation stages S4 and S5. The high level of expression was validated through transcriptome database comparisons for small grain varieties.

Complete N-terminus knockout (KO) was lethal, demonstrating the essentiality of REP1, whereas, as expected, C-terminus knockout and knockdown (KD) transgenic plants survived. Overexpression (OE) resulted in an “open beak” phenotype with smaller grain length, width, and weight, while KD/KO showed increases in these traits. The investigation of husk also supported that REP1 negatively regulates size by expanding cells only. OE displayed chalky cores, reduced amylose, spherical and loosely packed grains, and decreased biosynthesis enzymes, whereas KD/KO grains were transparent and contained high amounts of amylose. The enzyme content of total starch decreased in all lines. Protein content was elevated in KD/KO, while it was reduced in OE lines, affecting SSP bands. REP1 was shown to repress the promoters of glutelin (GLU1) and albumin (ALB1) at zinc finger domains both in vitro and in planta. Additionally, genome data revealed REP1 overexpression in small grains during S4 and S5 of grain development.

Dr. Agarwal concluded that "*REP1*" is a negative regulator of grain traits because its knockdown results in large size, protein content, and amylose levels. She also stated that her group is studying "miRNAs," "E3 ligases," "HDACs," "NACs," and other C2H2 factors for comprehensive crop improvement.

Genomics-assisted Breeding for Healthier Rice: Dr. Haritha Bollinedi

Dr. Haritha Bollinedi began her presentation by outlining genomics-assisted breeding strategies for healthier rice varieties, targeting India's dual burden of micronutrient malnutrition and non-communicable diseases, including a third-place ranking for obesity with 74 million diabetics. She underscored malnutrition's economic toll, costing India 4% of GDP and US$3.5 trillion worldwide annually, framing it as both a health and developmental crisis.

Dr. Bollinedi outlined a comprehensive, multi-pronged approach to enhancing grain quality, which includes endosperm iron & zinc biofortification. HarvestPlus aims for 28 ppm zinc and 12 ppm iron, compared to 15-16 ppm zinc & 5 ppm iron in popular varieties. Additional improvements focus on boosting antioxidants, reducing phytic acid, lowering the glycemic index (GI), and increasing bran storability. For zinc biofortification, the landrace Karuppunel, which consistently exhibits 40 ppm zinc in polished rice across locations, served as the donor.

Integrated approaches combining Genome-Wide Association Study (GWAS), biparental mapping, and Quantitative Trait Locus (QTL)-seq identified common QTLs introgressed into both Basmati and non-Basmati backgrounds. Genotyping-by-sequencing (GBS) of 316 RILs from Karuppunel crosses generated 2.1 million SNPs, which were filtered down to 15,000 and mapped to 21 zinc-related QTLs explaining 0.5% to 15% of the phenotypic variance. Advanced backcross lines demonstrated agronomic superiority; however, integrating yield, quality, and nutrient traits remains a significant challenge.

In the case of diabetic rice, an optimized in vitro enzymatic approach was used to screen 1,000 varieties, resulting in GI values ranging from 46 to 110. High-amylose rice exhibited the lowest GI value; however, consumer preferences indicate a need for intermediate amylose content, between 22% and 24%, to ensure acceptable cooking and eating quality. Low GI values were observed across all amylose content types, demonstrating the feasibility of producing rice varieties suitable for diabetic diets. Additionally, near-infrared spectroscopy prediction models showed promising results, with R^2=0.7 for screening purposes, and efforts to improve these models through wet lab analysis continue.

Triacylglyceride degradation by lipase and lipoxygenase enzymes acting on aleurone/embryo substrates produces free fatty acids that are unsuitable for oil extraction. Explaining India's leading rice production, which generates substantial bran waste and is hindered by rapid post-milling rancidity, Dr. Bollinedi explained three strategies to counter rancidity: developing enzyme-deficient lines, reducing polyunsaturated fatty acids (PUFA) content (ranging from 14% to 36%), or increasing antioxidants such as gamma-oryzanol (predominantly 24-methylene cycloartanyl ferulate). Biochemical screening identified 10 Indian accessions with a novel *LOX3* C-deletion (exon 2), distinct from the G-to-A mutation in all aromatic Basmati types found in Thai Dawdan. Independent evolution was confirmed in the 3K genome panel using a functional marker, while GWAS mapped 19 gamma-oryzanol-associated loci, explaining 48% of the phenotypic variance.

In brown rice, issues related to phytic acid-bound iron and zinc, as well as poor cooking quality, were addressed in the Shapasand × Pusa Basmati 1121 cross. QTL-seq identified significant loci on chromosomes 1, 5, and 7. Germinated brown rice exhibited improved texture and increased GABA content. Dr. Bollinedi concluded that

these approaches, like GWAS, QTL mapping, and marker-assisted selection, work synergistically to enhance nutrition, bioavailability, GI response, and overall quality simultaneously, positioning genomics as the cornerstone of sustainable rice improvement.

Scaling Low-GI Rice from Research to Retail: Dr. Saurabh Pandey

Dr. Saurabh Pandey discussed the strategies for the commercialization of low-glycemic rice, addressing the gaps between research and retail in eastern Uttar Pradesh, where institutional voids create challenges that surpass those encountered in metropolitan hubs like Hyderabad or Bengaluru.

Focusing on India's vast diabetic and pre-diabetic population, Dr. Pandey promoted ICAR-Centre for Cellular and Molecular Biology (CCMB) ISM Low GI Rice, enabling staple food adaptation without requiring lifestyle changes. Partnerships were established with farmers, TIGS for research collaboration, and educational institutions, utilizing PhD students to disseminate knowledge about Trichoderma seed treatment. Three rice varieties are being scaled up: Sehat Bhog, GI-tagged aromatic rice Kalanamak, and red rice Tinni. Outreach efforts facilitated the marketing of “sugar-free rice," marking and milling paddy for patient prescriptions, and integration with healthcare systems. Continuous support fostered trust by providing direct access to farmers beyond seasonal cycles.

ISM variety in eastern UP had fungal risks, timing conflicts with potato cropping cycles, and yield limitations, highlighting the need for improved varieties, as well as enhanced financial literacy and intensive farming practices. Scaling up efforts involves organizing procurement in South India to ensure supply resilience, engaging regional distributors to reduce logistics costs, conducting trials for DRR varieties, and establishing demonstration sites to facilitate comparative evaluations.

Drawing on the Swiss model of his own startup, Databaum, which integrates satellite, weather, and government data into AI across 16 grape-growing cantons to create the largest disease dataset in Europe, Dr. Pandey highlighted a patent-pending disease prediction system that reduces pesticide use by 30% to 45%. Community databases share weather data freely, while demonstration sites promote app-based scientist advisories, bringing stakeholders together in a transparent manner. Dr. Pandey concluded that the success of low-GI initiatives requires collaboration, adaptation, trust, and data democratization.

Q&A Session Summary

The Q&A session of the Sustainable Nutrition Security event showcased a dynamic interaction among agricultural biotechnology experts, breeders, and the attendees. The discussion primarily focused on challenges and solutions in crop biofortification, particularly in rice, but also included oilseed crops, wheat, and several others.

Breeding Challenges

The discussion began with concerns about yield penalties and nutrient dilution in biofortification breeding programs, where Dr. Neeraja emphasized breeding high-nutrient donor varieties, such as Karuppunel, and developing segregating populations through crosses to effectively combine yield and nutrient traits. Dr. Sundaram supported this approach by likening breeding to a "numbers game" and encouraging more crosses to increase the likelihood of success. Meanwhile, Dr. Haritha highlighted the polygenic control of traits like zinc content in crops and recommended genomic selection to combine superior recombinants without compromising yield or quality.

Nutrient Limits and Bioavailability

One of the key themes was establishing limits for minerals such as iron and zinc to prevent toxicity while maximizing bioavailability. This approach highlights the advantage of biofortified crops over chemical ones, aligning with Dr. Sundaram's policy of evidence-based research. Regarding iron in rice and wheat, targets were discussed to achieve 75-80 ppm of iron in wheat to achieve the RDA of 42-55%, and Dr. Haritha stated the difficulties in attaining the goal of setting the level of zinc in rice at 28 ppm, aiming to meet only 30% of the RDA without any toxicity concerns at present. Soaking and germination were suggested as methods to reduce phytic acid and thereby enhance iron bioavailability, along with brown rice to source bran iron to compensate for losses during processing, with the potential to address these losses through the genome editing of transporter genes.

Oilseeds and Quality Traits

Enhancements in oilseeds were discussed, with speakers highlighting high oleic acid groundnut; soybeans containing low levels of antinutrients; soybeans; and mustard varieties with low erucic acid and glucosinolate content. Research on reducing glucosinolates through the knockout of mustard transporter genes was also presented. Regarding rice quality traits, the introduction of the *LOX3* null allele was welcomed for increasing shelf life by inhibiting grain-specific enzyme activity, with minimal phenotypic side effects, and compensating for reduced PUFA by an increase in healthier MUFAs. To maintain rice quality with a low GI, limits were proposed for amylose content (below 24%) and gel texture, which should be soft.

Tech and Farmer Adoption

Digital technologies have raised significant concerns regarding data privacy. Dr. Saurabh Pandey presented a three-tiered storage system designed to securely store data while enabling AI-based predictions for selecting crop varieties and diseases, utilizing drone and farmer images, and facilitating collaborations in phenotypic prediction. Dr. Neeraja emphasized the indispensability of farmer education through pamphlets and routine practices, such as the application of zinc sulfate. Across multiple trials, soil adaptability was observed; biofortified varieties demonstrated resistance to pests, although birds showed a preference for nutrient-rich landraces.

Policy Takeaways

There was strong advocacy for the adoption of second-generation biofortified varieties that combine nutritional benefits with tolerance traits, such as disease resistance, since farmers were reluctant to adopt them without clear advantages and incentives. Additionally, Dr. Sundaram recommended implementing assured purchase prices—for example, Rs. 500 per quintal in Odisha—and establishing mainstreaming thresholds, such as 20 ppm in rice trials, to increase adoption to over 4–5 million hectares. Start-ups play a crucial role in this process through bottom-up advocacy. Finally, the chair emphasized the convergence model encompassing agriculture, nutrition, health, robust seed systems, and continuous research.

Dr. R M Sundaram

Dr. C N Neeraja

From left: Dr. Saurabh Pandey, Dr. Pinky Agarwal, Dr. R M Sundaram, Dr. C N Neeraja, Dr. Haritha Bollinedi, Dr. Ajay K Pandey

PANEL DISCUSSION

MODERATOR

Dr. R Uma Shaanker

(Retd.) Professor,
UAS-GKVK,
Bengaluru.

Dr. R M Sundaram

Director,
ICAR-IIRR,
Hyderabad.

Dr. Veena S Anil

Head, Dept. of Plant Biotechnology,
UAS-GKVK, Bengaluru.

Dr. Prachi Pandit

Consultant,
Shiv Nadar Foundation,
New Delhi.

Dr. T Venkatesan

Head, Division of Genomic Resources,
ICAR-NBAIR,
Bengaluru.

Dr. Sresty Tavva

Principal Scientist,
TIGS,
Bengaluru.

Dr. Vairamani Ramanathan

Head, R&D, Seeds & Biotech Division, Rallis India Ltd.,
Bengaluru.

PANEL DISCUSSION

The concluding session of the event featured a panel discussion chaired by Dr. R Uma Shaanker. The dialogue reflected on the three core themes of the event: climate-resilient agriculture, sustainable pest management, and sustainable nutritional security. Following brief introductions outlining their respective areas of expertise, the panelists engaged in a moderated discussion led by Dr. Shaanker, whose questions prompted insightful reflections, cross-disciplinary perspectives, and forward-looking deliberations.

Nutrition, Behaviour Change & Food Systems: Dr. Prachi Pandit

Dr. Prachi Pandit emphasized that nutrition challenges are not solely due to nutrient deficiencies but are fundamentally driven by issues of access, exposure, and behavior. She noted that people make food choices based on convenience, familiarity, and context rather than nutritional value, particularly among vulnerable populations with competing priorities.

Dr. Pandit highlighted that nutrition interventions often fail because they do not translate effectively into real-life settings, especially at the household and kitchen level. She stressed the need to bridge the gap between research and consumption by ensuring that nutrient-rich foods are easy to prepare, culturally acceptable, and appealing in taste and appearance. She advocated for stronger collaboration between scientists, behavior change experts, and social marketing professionals to ensure that solutions become natural choices rather than forced interventions.

Dr. Pandit also emphasized adopting a life-cycle approach to nutrition, tailoring interventions for different groups such as adolescents, pregnant women, and lactating mothers, and aligning them with public distribution systems. She further pointed out that large-scale nutrition programs often face low uptake due to poor product design, including issues related to taste, appearance, and acceptability. She stressed the importance of improving these aspects to compete with commercially available food products.

In conclusion, she called for greater focus on studying successful regional models and scaling them appropriately, while urging researchers to move beyond traditional approaches and develop practical, behavior-sensitive solutions for improving nutrition outcomes.

Integrated Pest Management in India: Breaking the Pesticide Nexus and Overcoming Adoption Bottlenecks: Dr. T Venkatesan

Dr. T Venkatesan spoke about the challenge of breaking the strong dependence on chemical pesticides and low adoption of Integrated Pest Management (IPM).

He noted IPM use has increased only slightly in the past 30 years from 1% to about 3.2% indicating progress has been slow despite continued institutional efforts. He explained that IPM includes several components such as host plant resistance, cultural practices, timely sowing, seed and seedling treatments. Trichoderma, biological control agents, and pheromone or pyramid traps are the commonly practiced methods in IPM. However, most of these solutions are available mainly within research institutions and are not easily accessible to farmers. In contrast, chemical pesticides are readily available in village markets, making them the easier choice. He stressed that if IPM needs to succeed at the field level, bioagents must be made locally available.

Dr. Venkatesan also highlighted the economic and structural challenges. Although about 65 biopesticides and semiochemicals have been developed and licensed to nearly 100 companies, companies need profits to survive. Large-scale production of macrobial and microbial agents requires advanced planning, proper storage, and quality control. Hence, he stressed the need for the industries to overcome these challenges during upscaling. He emphasized that better coordination among scientists, extension workers, and farmers, along with faster registration and improved subsidies, is crucial for wider adoption and sustained field impact. Reducing pesticide residues and the chemical footprint on food requires systematic efforts, which calls for sustained policy support and farmer training that collectively enable IPM practices to be practical and reliable.

Climate-Resilient & Biofortified Rice Systems: Dr. R M Sundaram

As Director of the ICAR-Indian Institute of Rice Research (ICAR-IIRR), Dr. R M Sundaram emphasized the development of mission-oriented, multidisciplinary rice breeding for sustainability and nutrition. He pointed out the need for a stronger public–private partnerships which should have started long ago. He highlighted the importance of private sector as a progress partner rather than a competitor. Public institutions continue to play a critical role in foundational and strategic research, while recognizing the private sector as an adversary in product development, scaling, and market delivery. Dr. Sundaram emphasized that a major shift is now underway toward market-driven and stakeholder-oriented research. Instead of developing technologies in silos, institutions are increasingly aligning research priorities with the needs of farmers, millers, input suppliers, and consumers. .

Under his leadership, the institute has developed mission-driven rice varieties, including improved versions of Samba Mahsuri with resistance to bacterial blight and blast, better tolerance to salinity, and even low glycemic index traits.

He also discussed dry direct-seeded rice (DSR) as a strategy to reduce methane emissions, stressing the requirement of ecosystem redesign including mechanization and trait-specific breeding rather than simple seed broadcasting. He also emphasized DRR Dhan 75, a high-yielding, medium-slender rice variety with decent tolerance to many diseases and pests, and a moderately high zinc content in the polished form. Overall, Dr. Sundaram emphasizes that agricultural sustainability must be collaborative, practical, and focused on real-world impact so that innovations are accessible, widely adopted, and truly beneficial.

Industry Perspective on Sustainable Seed Innovation: Dr. Vairamani Ramanathan

From an industry perspective, Dr. Vairamani Ramanathan addressed the balance between innovation and practicality. He emphasized that time-to-market and performance reliability are critical in agricultural systems. He explained that industry often prioritizes "low-hanging solutions" for rapid deployment while maintaining long-term innovation pipelines for complex challenges. He highlighted that farmers cannot adopt solutions solely for sustainability; instead, sustainability must be embedded within technologies that also improve yield, reduce costs, or enhance profitability. An example discussed was a methane-reducing microbial solution for rice cultivation that initially struggled to gain traction when framed purely as a climate intervention. Once its benefits were reframed in terms of yield enhancement, improved grain weight, and shortened crop duration, its practical value became clearer. The key takeaway was that sustainability must be integrated as an intrinsic benefit within economically viable agricultural technologies rather than presented as an additional burden to farmers.

Harnessing the Plant Microbiome: From Microbial Consortia to AI-Driven Precision Agriculture: Dr. Veena S Anil

Dr. Veena S Anil highlighted the transformative potential of plant microbiome research, describing microbiomes as naturally evolved systems that enhance plant fitness, stress tolerance, and resilience. She emphasized on leveraging these plant-microbe interactions as it could significantly reduce dependence on chemical inputs. Approaches such as compost-based formulations, microbial consortia, and synthetic microbiomes were discussed, with stress on developing tailored consortia specific to crop, soil, and climatic contexts rather than generic formulations. She introduced the audience to precision agriculture by using a tailored microbiome to enhance desirable traits in the crop.

Dr. Anil introduced the concept of microbiome-assisted breeding, where plant genotypes may be selected not only for intrinsic agronomic traits but also for their capacity to recruit beneficial microbial communities.

Furthermore, she underscored the importance of integrating microbiome research with AI and machine learning models to enable precision agriculture and data-driven decision-making. Overall, microbiome-based strategies were positioned as central to the next generation of sustainable and resilient agricultural systems.

Genome Editing & Translational Crop Biotechnology: Dr. Sresty Tavva

Dr. Sresty Tavva discussed the evolution of crop improvement strategies, beginning with traditional mutation breeding and moving towards precise genetic tools. He emphasized for greater precision and efficiency, modern breeding must leverage advances in genetics and molecular biology.

He underscored the importance of marker-assisted breeding to accurately track and combine desirable traits, rather than attempting to work on multiple traits in isolation. He noted that editing one or two genes is often insufficient, highlighting the complexity of polygenic traits such as pest management, yield, and stress tolerance. In such cases, broader approaches, including transgenic strategies, may be necessary.

Dr. Tavva emphasized that their work is driven by societal impact rather than profit, although licensing may be required to support seed production and distribution. He noted that trait selection is guided by close interaction with breeders who understand field-level challenges and farmer needs.

Focusing on rice, particularly biotic stress traits, he highlighted the need for durable, broad-spectrum resistance due to the rapid evolution of pathogens. To address this, his team adopts a multiplex genome editing approach, targeting multiple genes to improve the longevity of resistance.

Dr. Tavva concluded that the most effective path forward lies in an integrated strategy that combines biological control, genome editing, and marker-assisted breeding. He advocated for using these complementary technologies together to develop sustainable, scalable, and durable agricultural solutions.

Q&A Session Summary

The session concluded with an engaging interaction between the panelists and the audience, reflecting both enthusiasm and concern regarding the practical translation of scientific innovations.

Participants raised questions on regulatory bottlenecks, scalability of biological solutions, and the affordability of sustainable technologies for smallholder farmers. There was particular interest in understanding how emerging tools, such as gene editing, microbiome-based interventions, and climate-resilient breeding could move more rapidly from research institutions to field-level adoption. Panelists acknowledged that while scientific advancements are progressing steadily, institutional coordination, policy alignment, and last-mile delivery systems remain critical challenges.

The discussion also highlighted the importance of capacity building and stakeholder engagement. Audience members emphasized the need for stronger extension systems, farmer awareness programs, and collaborative platforms that bring together researchers, industry, policymakers, and community organizations. In response, the panel reiterated that sustainable agriculture and nutrition security require a systems-level approach, integrating innovation with economics, behaviour, regulation, and infrastructure. The exchange concluded on a constructive note, with a shared recognition that meaningful impact will depend not only on scientific breakthroughs but also on inclusive partnerships and sustained institutional commitment.

Dr. R Uma Shaanker

From left: Dr. R Asokan, Dr. Kamal Kumar Malukani, Dr. Rakesh Mishra, Dr. R Uma Shaanker, Dr. Sresty Tavva, Dr. Veena S Anil, Dr. Vairamani Ramanathan, Dr. R M Sundaram, Dr. T Venkatesan, Dr. Prachi Pandit

CONCLUDING REMARKS

Dr. Rakesh Mishra's concluding remarks distilled the spirit of SUSTAiN 2026 into a clear-eyed assessment of where Indian agriculture stands, what two days of deliberation had surfaced, and what the initiative must become if it is to matter beyond the room.

The most consequential observation he drew from the discussions was not about what science lacks; it was about what it fails to reach. Effective solutions to many of agriculture's persistent challenges already exist, yet they remain stranded between the research ecosystem and the farmer's field. The reasons are varied: some interventions are grounded in traditional knowledge and still await rigorous scientific validation, while others have been thoroughly validated but are unknown to the very communities that need them most. In either case, the bottleneck is translation. Dr. Mishra made clear that closing this gap requires a fundamentally different kind of engagement: one that treats farmers, policymakers, and government officials as active participants in shaping the desired scientific output. Their absence from this first edition was noted as a gap that future editions of SUSTAiN must deliberately address.

He also identified a quieter but equally damaging failure of communication in how agricultural technologies reach the public. Regulatory pathways for innovations such as genome editing are advancing, and the science underpinning them is robust, yet public anxiety about safety continues to constrain adoption. This, he argued, is not a scientific problem but a communication one. When approval processes are opaque, and safety evidence is not proactively shared, hesitation fills the void. The same logic applies to pesticide use: in regions where resistance is high, farmers continue to apply chemicals far beyond recommended levels, not out of negligence, but because the guidelines that could inform better practice simply have not reached them. The costs, borne by their health, their finances, and the land they depend on, are avoidable.

Looking ahead, Dr. Mishra reaffirmed that SUSTAiN is designed to be a living platform, one that returns each year to measure what has moved, hold the community accountable to its recommendations, and progressively widen the circle of stakeholders at the table. Thanking the experts, thought leaders and all the participants of SUSTAiN-2026, he emphasized that the role of TIGS within this platform, is not to generate intellectual property for its own sake, but to develop science that is financially accessible and socially workable, solutions that can actually be used by the people they are intended to serve.

Aligning with this sentiment, this proceedings document is an attempt to capture the substantive learnings from each session of the inaugural SUSTAiN meeting, ensuring that the essence of the discussions can be carried forward as the foundation for subsequent editions.

Dr. Rakesh Mishra

Snippets from best poster awards

KEY TAKEAWAYS

- **Sustainability must align with farmer profitability.**

Climate-resilient and environmentally sound technologies will scale only if they enhance yield, reduce risk, or improve farmer income.

- **Public-private partnerships are essential for impact.**

Early structured collaboration between research institutions and industry is essential to accelerate translation, commercialization, and large-scale deployment.

- **System-level approaches are necessary for climate mitigation.**

Interventions such as Direct Seeded Rice require integrated solutions involving breeding, mechanization, agronomy, and institutional support.

- **Gene editing is a complementary tool, not a standalone solution.**

It offers precise, targeted trait improvement, particularly when integrated with conventional breeding and supported by clear regulatory pathways.

- **IPM adoption is constrained by systemic barriers.**

Limited availability, regulatory delays, quality control challenges, and insufficient farmer awareness continue to hinder large-scale uptake of biological pest management solutions.

- **Microbiome research holds transformative potential.**

Harnessing plant-microbe interactions could significantly reduce chemical inputs while improving resilience and productivity.

- **Nutrition challenges extend beyond nutrient science.**

Behavioural, cultural, economic, and delivery factors must be integrated into nutrition interventions to ensure real-world impact.

- **Delivery systems and stakeholder engagement are as important as innovation.**

Sustainable outcomes depend on strong extension systems, policy support, interdisciplinary collaboration, and inclusive partnerships.

- **Mission-driven, multidisciplinary teams are the future of agricultural research.**

Breaking disciplinary silos enhances the relevance, speed, and scalability of scientific solutions.

ANNEXURE

At SUSTAiN 2026, a total of 98 posters were presentation. The posters represented a diverse research community and were across three thematic categories, to reflect the breadth of ongoing work in sustainable agriculture, pest management, and nutrition security. These categories were: Climate Resilient Agriculture, Sustainable Pest Management, Sustainable Nutrition Security. It also featured posters from NCBS and TIGS.

Theme 1: Climate Resilient Agriculture

Sl.No	Name	Poster title
1	Aishwarya S	Characterization of regional rice cultivars for combined drought and heat stress response
2	Vinay M. Gangana Gowdra	Optimizing soybean performance to episodic waterlogging through nutrient intervention
3	Ritesh Ghosh	Mechanostimulation: a promising strategy for sustainable agriculture
4	Senthamil E	Foliar supplementation of nitrogen fertilizers and growth regulators to improve resilience against waterlogging stress in maize
5	Dr. Harshata Pal	Development of salt stress resilience through seed inoculation by microbial bio stimulants unveiled altered metabolic and molecular functions in plant cell
6	Miti Tali	Marker Trait Associations for Low Light Tolerance in Rice (*Oryza sativa L.*) under Field Induced Shading Conditions
7	Sriprada G	Integrating Soil Health and Genomic Insights to Enhance Climate resilience in *Brassica Juncea*
8	Aryasree R	Expression analysis of pathogenesis-related and other defense-associated genes in *Brassica rapa* following infection by *Alternaria brassicicola*

9	Gourav Sabharwal	Quantification of maize crop evapotranspiration and mapping using surface energy balance algorithm for land model and medium resolution satellite data
10	Mohammed Wajid I	Prediction of Greenhouse Gas emission in maize crop as influenced by different nutrients levels
11	Divyashree M M	Weather variability and Land Resource Inventory (LRI) based interventions for enhancing climate resilience in Cotton, Chilli and Groundnut
12	Hari Kumar E	Evaluation of Mechanized Cultivation under Drip Fertigation as a Climate-Smart Strategy: Impacts on Sugarcane Productivity and Sustainability
13	Nandhini B	Climate Change and the Emerging Risk of Phytophthora Blight in Pigeonpea: A CLIMEX-Based Assessment
14	Gokulakrishnan M	Multi-omics Insights into Bruchid (*Callosobruchus sp.*) Resistance in Chickpea (*Cicer arietinum L.*)
15	Nikitha J	Whole Genome Sequencing Elucidates Submergence Tolerance Alleles and QTL Associations in the Climate Adaptive Rice Landrace, Thavalakannan
16	Nivedita Shettigar	Assessing maize resistance to Fall armyworm using partial replication
17	Bhavani. P	Molecular and morphological characterization of browntop millet (*Urochloa ramosa L.*) germplasm
18	Dayanandanaik S	Building climate resilient agriculture for a sustainable future: impacts, challenges
19	Anujaa B	Resilient Farming for Coastal Zones : A Multi-Component Integrated Farming System with Ericulture as major component
20	Nandini K S	Rab11 gene acts as a negative regulator of combined drought and heat stress tolerance in rice
21	Nisarga V Gangavati	Functional analysis of *OsChla/b* overexpressing rice under combined drought–heat Stress
22	Papri Nag	Isolation of *Paraburkholderia bengalensis sp. nov.* and *Microbacterium bengalense sp. nov.* and their impact on N-cycling in rice rhizosphere

23	Deeya Saha	Network-based Computational framework to explore regulatory mechanisms underlying gene expression patterns in broad spectrum resistance against drought and blast disease of rice
24	Anjali Kalburgi	Screening and identification of Phosphate solubilizing bacteria (PSB) for enhanced nutrient bioavailability
25	Chethankumar M	Silicon supplement reduces the impact of climate change and enhances tolerance to pink stem borer infestation in wheat
26	Greeshma Varghese	Nanocarrier mediated dsRNA-for Managing Viral Diseases in King Chilli
27	Nikita Biradar	Genetic variability studies in segregatin generations and screening for mymv resistance using rga primers in greengram (*vigna radiata (l.) Wilczek*)
28	Padmasri Ghosh	Physiological and Metabolic Responses of Rice Seedlings to Arsenite(As^{3+}) Stress under Manganese(Mn) and Copper(Cu) Excess
29	Soham Rana	Climate-resilient technologies for a sustainable transition in soil microbial health
30	Amrita Saxena	The Role of SWEET Genes in Broad-Spectrum Stress Resistance in Rice
31	Himani Meena	Mapping Research Landscapes in Climate-Smart Digital Agriculture: A Comparative Bibliometric Study of Global and Indian Trends
32	Madhurjit Singh Rathore	Evaluating Pearl Millet Germplasm for Morphological and Biochemical Parameters: Characterization of pearl millet
33	Prima Bagui	Optimization of Fibre Flax Quality under Moisture Stress Conditions in Rice Fallow Regions
34	Tharani N	Sustainable Seed Priming with Bamboo Leaf Ash Derived Silica Nanoparticles for Enhancing Moisture Stress Tolerance in Maize
34	Aiman Zehra	Chitosan Nanocomposite Films Embedded with Thyme Oil, $CaCl_2$, Nanoclay, and ZnO for Fresh Strawberry Shelf Life Extension
36	Ananth Krishna Narayanan	Production of high-value terpenoids in yeast through synthetic biology

37	Arjun V K	Deciphering regulatory network of essential oil biosynthesis in *Pogostemon cablin* (Blanco) Benth
38	Bopanna S L	Elucidation of the aroma biosynthesis in Agarwood (*Aquilaria malaccensis*)
39	Sruthi Mohan	Exploration of essential oil biosynthesis in commercially important aromatic plant Davana (*Artemisia pallens*)
40	Khyathi Majji	CRISPR-Cas9 Mediated Enhancement of Stress Tolerance in Rice

Theme 2: Sustainable Pest Management

Sl.No	Name	Poster title
1	Dr. Gopalakrishnan R	Molecular Profiling of Insecticidal and Plant Growth–Promoting Activity in Native Bacillus thuringiensis Effective Against Fall Armyworm (*Spodoptera frugiperda*)
2	Vignesh S	Genomic Insights into *Bacillus thuringiensis* Strain T419: A Novel Biocontrol Agent for Lepidopteran Pest Resistance Management
3	Thrunavukkarasu Selvamuthukumaran	From Volatile Botanicals to Persistent Protection: Engineering Sustainable Controlled-Release Nanoporous Biopolymer Sponges of *Acorus calamus L.* Essential Oil for Long-Term, Residue-Free Management of Pulse Beetle (*Callosobruchus maculatus Fab.*)
4	Praveenkumar C	Electrophysiological and Behavioural Responses of Invasive Thrips, Thrips parvispinus (Karny) to Essential Oils and Key Volatile Compounds
5	Selvam Saravanan	Integrating electrophysiology, behavioral response, and docking studies to decipher odorant-binding protein function in the brinjal shoot and fruit borer, *Leucinodes orbonalis Guenee*
6	Mithilaa Selvaraj	Highly sensitive electrochemical detection of paraoxon ethyl in Apple sample based on GNP/Chit/AuNP modified glassy carbon electrode.
7	Darlin Prakash R	AI Integrated IoT system for Real Time Detection of Stored Product pests
8	Gaargie Modhale	DNA Barcoding for Rapid Identification of Major Crop Pest Species
9	Shashikala T	A simple CRISPR/Cas13a based approach for rapid, amplification-free detection of groundnut bud necrosis virus (GBNV)
10	Amirtha P	Host Plant–Mediated Alterations in Spinning and Folding Behaviour of Rice Leaffolder (*Cnaphalocrocis medinalis Guenee*) on Selected Traditional Rice Genotypes

11	G.Yogapriya	Adjusting planting dates as an ecological engineering tool cultural manipulation through planting dates for sustainable pest suppression in rice
12	Aswini V	Integrating host plant resistance and ecosystem dynamics for sustainable pest management in different jasmine species
13	Deepanjana Saha	Natural Pest Control in Farmlands: The Role of Vertebrate Predators
14	Mohanprabu D	Elucidation of chemical and visual cues that attract flower thrips to Jasmine flowers
15	S Navadeep Chidamabaram	Biology and Evaluation of Botanicals against Rugose Spiralling Whitefly (*Aleurodicus rugioperculatus*) on Guava
16	Desika Jayasaravanan	Identification of Maize (*Zea mays L.*) Hybrids for Fall Armyworm (*Spodoptera frugiperda J. E. Smith*) Resistance under Artificial Infestation
17	Anusha S	Influence of cropping diversity on insect pests of groundnut
18	G Komala	TiO_2-loaded botanical nanoemulsion from Simarouba glauca bark: A sustainable nano-enabled strategy for managing fall armyworm in maize
19	Sneka	Overcoming the Climate-Driven Sucking Pest Barrier: Efficacy of Nano-Encapsulated *Acorus calamus* Essential Oil against *Phenacoccus solenopsis* and *Aphis craccivora*
20	Nalimala Veeramanikanta Reddy	Silencing of microtubule associated gene *Tektin1* in *Zeugodacus cucurbitae* (Diptera: Tephritidae)
21	Ratnakala	Induced systemic resistance in maize: wRT-PCR based evaluation of defense genes activation by entomopathogenic bacteria against *spodoptera frugiperda*
22	Dr. Sourav Sarkar	Optimizing Predator–Parasitoid Compatibility for Sustainable Biological Control of Tomato leaf miner Phthorimaea (*Tuta*) *absoluta* (Meyrick)
23	Akshay Kumar	CRISPR mediated sterility in *Plutella xylostella* (L.) and *Spodoptera frugiperda* (J.E. Smith) for Genetic Pest Management

Theme 3: Sustainable Nutrition Security

Sl.No	Name	Poster title
1	Chandana B	Assessment of seed health and quality in chilli (*Capsicum annumm L.*) genotypes.
2	K Sri Sai Venkat	Multi-trait Selection using MGIDI of High-Yielding Biofortified Rice Lines
3	Mihika Bidikar	Potential of plant growth promoting rhizobacteria to enhance sugar content in sugarcane
4	Rhitorbi Sengupta	Effect of Green synthesised bimetallic CuO-ZnO Nanoparticles on yield and fruit quality improvement in Tomato (*Solanum lycopersicum L.*)
5	Tanisha Chhetri	Effect of Seed Biopriming using biocontrol agents on the physiological status of normal and organic seeds of fenugreek
6	Divya C	Embedding Biofortification in Agricultural Food Systems to Counter Hidden Hunger and Support Rural Nutrition Security
7	Kavya S	Screening of foxtail millet (*Setaria italica (L.) P. Beauv.*) accessions for their nutritional, yield and other related traits
8	Likitha Ag	Breaking Crossability Barriers in Tulsi for BioactiveRich Nutraceutical Cultivars
9	Mohan Raj V	Scanning Seeds for Sustainability: Portable X-ray Florescence as a Game-Changer in Biofortified Crop Breeding
10	Shaik Vahab	Expression of Zinc Transporter Genes in the Flag Leaf Correlates with Zinc Accumulation in Brown and Polished Rice Grains
11	Anushka Shukla	Development of Moringa oleifera Soup Powder from Leaves, Flowers, and Pods: Biochemical Characterization and ISSR-Based Molecular Diversity Analysis for Sustainable Agriculture and Food Security
12	Shreya K R	Reimagining Nutrition: How Functional Foods Can Transform India's Journey to Sustainable Development

13	Dr. Rashmi K.V.	Valorization of Underutilized legume and Millets through Fermentation for Sustainable Nutrition Security
14	Mrutyunjaya Parhi	An Integrated Enzymatic, Metabolomic, and Mineral Profiling Approach to Elucidate the Biochemical Rationale of Rancidity in Stored Pearl Millet
15	Yuvarajan S	Enhancing Nutrition Security through Seaweed Liquid Extracts: Effects on Biochemical and Quality Parameters of Rice (*Oryza sativa L.*)
16	Eniyavan P	Analysis of Phenolic Diversity in Coloured Maize (*Zea mays L.*) for Sustainable Nutritional Security
17	Indhu S M	NGS-driven functional marker development for low-phytate maize breeding
18	Praveena M	Whole genome sequencing reveals unique anthocyanin pathway variants in the medicinal rice landrace Navara
19	Sugyan Preet	Exploring the interaction between amylose biosynthesis and sirtuins in *Oryza sativa* under drought for sustainable agriculture

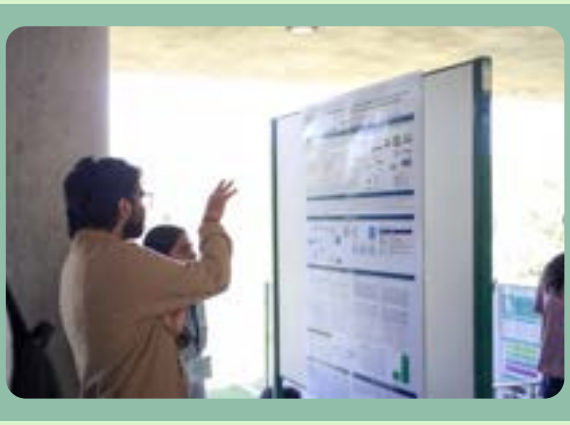
Posters from NCBS

Sl.No	Name	Poster title
1	Aravind M	Distinct development-associated roles of rice histone variant H2A.X in suppressing deposition of active H3K4me3 marks and in restricting H2A.W incorporation
2	Archana A	RdDM initiation complex is a suppressor of aberrant sRNA production across plants
3	Kuntal Patra	An adapted fitness protein encoding carbonic anhydrase is used for virulence by the vascular wilt fungal pathogen *Fusarium oxysporum*
4	Riju Dey	Understanding the role of an embryo-specific chromatin remodeler in maintaining small RNA biogenesis and DNA methylation
6	Steffi Raju	Copper sensitive SPL9 transcription factor regulates domestication associated miRNAs and phenotypes

Posters from TIGS

Sl.No	Name	Poster title
1	Syam Sura	Development and optimization of tissue culture and transformation protocols for finger millet varieties
2	Vandana Suresh	Automation of INDIGO and ICE webservers: A high throughput analysis of Sanger sequence data to detect allelic variations created by CRISPR/Cas9-mediated genome editing of crop plants
3	Moniusha Jayasekar	Precision genome editing to enhance broad-spectrum resistance against rice blast disease
4	Chandra Girish	CRISPR/Cas9-mediated genome editing of the effector binding site in the *SWEET11* promoter to enhance resistance against bacterial leaf blight in elite rice cultivars
5	Manoj R Y	Targeted modification of host susceptible genes for developing broad-spectrum resistance to rice blast disease
6	Ramanjaneya Reddy Vennapusa	Generation of homogenous hermaphrodite pointed gourd (Parwal) lines and their agronomic evaluation under field conditions
7	Dr. Ashok K	Silencing the Enemy: RNA Interference as a Precision Tool for Sustainable Insect Pest Management
8	Dr. Dileep N T	Insecticide Resistance in Field Populations of Fall Armyworm (*Spodoptera frugiperda*) in India
9	Chandana Mulagala	Establishing a High-throughput Nutrition Assessment Platform for Developing Rice Varieties with Enhanced Nutritional Values
10	Ganavi B N	Effect of processing methods on the nutritional composition of rice
11	Callistus Nathan Monteiro	Evaluation of rice BAAP Accessions for grain iron and zinc content and identification of potentially associated QTLs through GWAS

SNAPSHOTS FROM POSTER PRESENTATION



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