ICRISAT
INTERNATIONAL CROPS RESEARCH INSTITUTE FOR THE SEMI-ARID TROPICS

भाकृअनुप
ICAR

taas
Progress Through Science

IRRI

ICARDA
Science for resilient livelihoods in dry areas

National Workshop on

Bridging the Yield Gaps to Enhance Foodgrain Production: A Way Forward

26 August 2021

Proceedings and Recommendations

Trust for Advancement of Agricultural Sciences (TAAS)

Avenue II, IARI, Pusa Campus, New Delhi – 110012
Website: *www.taas.in*

Indian Council of Agricultural Research (ICAR)

Krishi Bhawan, Dr Rajendra Prasad Road, New Delhi - 110001
Website: www.icar.org.in

International Crops Research Institute for the Semi-Arid Tropics (ICRISAT)

Delhi Office, NASC Campus, DPS Marg, New Delhi 110012
Website: www.icrisat.org

International Rice Research Institute (IRRI)

Indian Liaison Office, NASC Campus, DPS Marg, New Delhi 110012
Website: www.irri.org

International Center for Agricultural Research in the Dry Areas (ICARDA)

South Asia and China Program, NASC Campus, DPS Marg, New Delhi 110012
Website: www.icarda.org

National Workshop on

Bridging the Yield Gaps to Enhance Foodgrain Production: A Way Forward

26 August 2021

Proceedings and Recommendations

Organizers

Trust for Advancement of Agricultural Sciences
Indian Council of Agricultural Research
International Crops Research Institute for the Semi-Arid Tropics
International Rice Research Institute
International Center for Agricultural Research in the Dry Areas

Citation : Paroda, Raj, Bhag Mal and Srivastava, Umesh. 2021. *National Workshop on Bridging the Yield Gaps to Enhance Foodgrain Production: A Way Forward – Proceedings and Recommendations.* Trust for Advancement of Agricultural Sciences (TAAS), Avenue II, Pusa Campus, New Delhi. viii+48 p

Published by : **Secretary**
Trust for Advancement of Agricultural Sciences (TAAS)
New Delhi

For copies and further information, please write to :

Secretary
Trust for Advancement of Agricultural Sciences (TAAS)
Avenue II, Pusa Campus, New Delhi - 110012
Ph.: +91-11-25843243; +91-813011137
E-mail: taasiari@gmail.com; Website: www.taas.in

Printed *:* December, 2021

Contents

Acronyms and Abbreviations

ADG	Assistant Director General
AI	Artificial intelligence
AICRPs	All India Coordinated Crop Improvement Projects
AVT	Advanced Varietal Trials
BGREI	Bring Green Revolution to Eastern India
BI	Bioversity International
BISA	Borlaug Institute for South Asia
BLSB	Banded Leaf and Sheath Blight
BMS	Breeding Management System
BNI	Biological Nitrification Inhibition
CA	Conservation Agriculture
CAGR	Compound Annual Growth Rate
CAZRI	Central Arid Zone Research Institute
CC	Climate Change
CGIAR	Consultative Group of International Agricultural Research
COVID-19	Corona Virus Disease=19
CRISPR	Clustered Regularly Interspaced Short Palindromic Repeats
CSA	Climate-smart Agriculture
CSR	Corporate Social Responsibility
CVRC	Central Variety Release Committee
DDG	Deputy Director General
DH	Doubled Haploid
DoAC& FW	Department of Agriculture and Cooperation and Farmers Welfare
DRDO	Defence Research and Development Organization
DSR	District Survey Report
DSSAT	Decision Support System for Agro-technology Transfer

FAO	Food and Agriculture Organization
FAOSTAT	Food and Agriculture Organization Statistics
FAW	Fall Army Worm
FICCI	Federation of Indian Chambers of Commerce and Industry
FLD	Front Line Demonstration
FPC	Farmer Producing Companies
FPO	Farmer Producers Organizations
FSII	Federation of Seed Industry of India
G × E × M	Genotype × Environment × Management
GAB	Genomics-assisted breeding
GAP	Good Agricultural Practices
GAP	Good agricultural Practices
GDP	Gross Domestic Product
GEAC	Genetic Engineering Approval Committee
GEBVs	Genome Estimated Breeding Values
GM	Genetically Modified
GR	Green Revolution
GS	Genomic Selection
GYGA	Global Yield Gap Atlas
HBB	Haplotype-based Breeding
HCN	Hydrogen Cyanide
HPRC	Hybrid Parent Research Consortium
HYVs	High Yielding Varieties
ICAR	Indian Council of Agricultural Research
ICARDA	International Center for Agricultural Research in the Dry Areas
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
ICT	Information Communication Technology
IDM	Integrated Disease Management
IIMR	Indian Institute of Maize Research; Indian Institute of Millets Research
IIPR	Indian Institute of Pulses Research

IIWBR	Indian Institute of Wheat and Barley Research
IIWM	Indian Institute of Water Management
INM	Integrated Nutrient Management
IoT	Internet of things (IoT)
IPM	Integrated Pest Management
IRRI	International Rice Research Institute
KVK	Krishi Vigyan Kendra
MAS	Marker assisted selection
MoA&FW	Ministry of Agriculture and Farmers' Welfare
MoUs	Memorandum of Undertakings
MSME	Micro, Small and Medium Enterprises
MSP	Minimum Support Price
NAAS	National Academy of Agricultural Sciences
NARS	National agricultural Research Systems
NBA	National Biodiversity Authority
NBPGR	National Buraeu of Plant Genetic Resources
NBSS&LUP	National Bureau of Soil survey and Land Use Planning
NDVI	Normalized Difference Vegetation Index
NFSM	National Food Security Mission
NGO	Non Government Organization
NRM	Natural Resource Management
NRRI	National Rice Research Institute
OCS	Optimal Contributions Selection
OUAT	Odisha University of Agriculture and Technology
PC	Project Coordinator
PJTSAU	Professor Jayashankar Telangana State Agricultural University
PPP	Public-private partnership
PPV&FRA	Protection of Plant Varieties and Farmers Rights Authority
QPM	Quality Protein Maize
QTL	Quantitative Traits Loci

R&D	Research and Development
SAUs	State Agricultural Universities
SDGs	Sustainable Development Goals
SDM	Sorghum Downy Mildew
SDN	Site-Directed Nuclease Technology
SKNAU	Shri Karan Narendra University of Agriculture and Technology
SRR	Seed Replacement Ratio
SWOT	Strengths, Weaknesses, Opportunities, and Threats
TAAS	Trust for Advancement of Agricultural Sciences
TFP	Total Factor Productivity
ToT	Transfer of Technology
UN	United Nations
USD	United States Dollars
WOFOST	World Food Studies
YMV	Yellow Mosaic Virus

National Workshop on

Bridging the Yield Gaps to Enhance Foodgrain Production: A Way Forward

BACKGROUND

The world's population will reach 9.8 billion by 2050, which will be about 34 per cent higher than at present. Out of 794.6 million undernourished people globally, 779.9 million live in developing countries (UN, 2017). It is estimated that globally, we will require 70 per cent more food (FAO, 2009) considering the present dietary pattern, income and consumption scenario. India's current population of 1.39 billion is likely to reach 1.51 billion by 2030. A fundamental question arises as to whether India will remain self-sufficient in foodgrain production. The challenge, therefore, to produce more from decreasing per capita arable land and irrigation water, besides increasing abiotic and biotic stresses, is indeed formidable. In the past over the past six decades, due to Green Revolution (GR), India's foodgrain production has increased about six times (currently 308.65 mt) as against more than four times increase in human population. India would need around 355 mt by 2030 (FICCI, 2019), i.e., around 50 mt more, which means about 5.0 mt per annum additional foodgrain production. It would require an increase in productivity by bridging the existing yield gaps. In fact, the crop productivity of foodgrains varies from state to state. Since arable land has remained static, the only option is to increase productivity per unit of land and expand vertically. Also, the factor productivity needs to be enhanced, while reducing the production cost to be globally competitive.

Major challenge currently is of economic and ecological access to food, so critical to ensure zero hunger and no poverty (being important SDGs) by 2030. Important constraints to bridge the yield gaps are: i) agro-climatic and eco-regional variations, ii) deteriorating soil health, and iii) climate induced variability. Also, pests, diseases, and weeds are major constraints due to prevalence of tropical and sub-tropical environment. Nutrient imbalance is another important constraint. It is also important to ascertain whether the yield gaps are due to technology constraints or due to biophysical factors. Also, there are socioeconomic constraints such as lack of credit, lack of knowledge and poor agricultural extension services.

A few other important constraints are: i) yield plateauing in high productivity areas, ii)imbalanced use of fertilizers, iii) non availability of labour, iv) lack of knowledge regarding location-specific improved production packages, v) low input management and vi) relatively low area coverage under high yielding varieties and hybrids. The sustainable productivity challenges include trends in agricultural productivity, sustainability of agriculture; agricultural innovation system, trends in R&D funding, private on-farm investment, foreign direct investment (FDI), and policies and institutions. These, if not addressed urgently, are bound to adversely affect our future food and livelihood security.

Since there is practically no scope for horizontal expansion, vertical expansion through increased productivity appears to be the only way forward needing an agro-ecoregion-wise, state-wise and crop-wise strategy. The possible options to bridge the yield gaps could be through: greater use of quality seeds of improved varieties, use of hybrid technology, adoption of GM crops, promoting conservation agriculture, precision farming to increase water and nutrient use efficiency, expanding horizontally food crops in non-traditional areas, use of potentially disruptive technologies such as internet of things (IoT), artificial intelligence (AI), and the adoption of climate-smart agricultural practices. Also, strengthening of public-private partnership (PPP) through enabling government policies and incentives shall enhance further foodgrain production. Some recent innovations for increasing productively are: genomics-assisted breeding (GAB) including marker assisted selection (MAS) for trait specific genes, genetically modified (GM) crops, genome/gene-editing, etc. Presently, around 200 mha of 'biotech crops' are being grown worldwide. GAB has already delivered many varieties for several traits in India. Further, promoting GM maize, soybean and canola could help considerably in increasing crop productivity and income of farmers in India. Gene editing (CRISPR/Cas9) technique is now a potential tool which can help in speedy and targeted modification of genes to provide both biotic and abiotic tolerance. Hence, there is fully justified need of both R&D support and policies to scale these innovations. Further, the yield gap can be minimized by making the inputs available to the farmers in sufficient quantity, good quality and at right time. The major constraints responsible for yield gap such as late sowing/ transplanting, higher price of seed, non-availability of required fertilizer at sowing time, lack of credit and infestation of pests and diseases need to be addressed for enhancing both productivity and production.

THE NATIONAL WORKSHOP

In order to discuss the current constraints, options for bridging the yield gaps, and suggest strategies to increase both production and productivity of foodgrains in

India to meet future demands, the Trust for Advancement in Agricultural Sciences (TAAS), New Delhi, a neutral 'Think Tank' and the Indian Council of Agricultural Research (ICAR) in collaboration with International Rice Research Institute (IRRI), International Crops Research Institute for Semi-Arid Tropics (ICRISAT), and International Center for Agricultural Research in the Dry Areas (ICARDA) has organized a "National Workshop on Bridging the Yield Gaps to Enhance Foodgrain Production: A Way Forward" in virtual mode on 26 August, 2021. A total of 119 diverse stakeholders from the Central and State Governments, CG Centers, scientific institutions, private seed industry and farmers participated. The main objectives of the workshop were:i) to discuss and target specific crop wise areas to bridge the yield gaps, ii) identify specific constraints and possible options for increasing productivity crop wise/eco-region wise for enhancing food grain production, and iii) to identify specific constraints and suggest a clear strategy to increase both production and productivity of foodgrains.

INAUGURAL SESSION

The National Workshop was chaired by Padma Bhushan **Dr RS Paroda,** Chairman, TAAS and Former Secretary, DARE and DG, ICAR. Dr Paroda welcomed Dr T Mohapatra, Secretary DARE and DG, ICAR, distinguished invitees and other participants. He emphasized that the workshop aimed to discuss and target specific crop-wise areas to bridge the yield gaps, identify possible technical options for increasing productivity crop wise and eco-region wise for enhancing foodgrain production, and also to identify specific constraints and define a clear strategy thereof.

In his opening remarks, Dr Paroda expressed that it is very critical when we discuss and deliberate issues related to bridging yield gaps in food crops. At present, India is one of the three largest exporting countries in the world, and India has become the 5th largest economy (nominal GDP) in the world. During FY 2019-20, India exported basmati rice worth US$ 3.88 billion, non-basmati rice worth US$ 1.84 billion and other processed foods worth US$ 2.71 billion. To increase farmers' income and harness export potential and also make India a leading player in agriculture sector, the Government of India launched a comprehensive agriculture export policy.

Currently, one of the most important challenges to achieve food security is the intensification of food production. Although, most research efforts in agriculture focus on crop production, these do not take into account the instability of yield over time or the variability and reliability of crop production over the years. Therefore, to produce 'more from less for more' i.e., from decreasing per capita arable land and irrigation water, besides increasing abiotic and biotic stresses, is indeed formidable. We have to harness suitable technology to reduce costs and increase yields. For that, there is need to use new tools such as marker assisted selection (MAS), gene-editing (CRISPR/ Cas9) technology, quantification of G × E × M interactions to identify the best combinations of G and M for target crop production environments. He also asserted to go for vertical improvement, eco-regional approach, and globally competitive specific strategies, crop-wise focus, to generate location-based approaches for diverse farming situations under various socioeconomic conditions, domestic needs, market infrastructure, input supply, efficient use of farm inputs which contribute to a strong rural economy, etc. Further, among several important issues, two priority area, namely, enhancing total factor productivity (TFP) growth and promoting climate-smart agriculture (CSA) deserve special mention. Regarding TFP, despite doubling and trebling the average yield of rice and wheat, average yields of most cereals, pulses and oilseeds are low, and there are serious gaps in actual, realizable and potential yields. There is ample scope for improving India’s TFP through increasing input use efficiency and productivity as TFP increases when outputs rise and inputs remain constant or even decrease. As regards CSA with its triple wins of enhanced productivity, resilience and mitigation, with ‘save and grow’ should be rooted in climate-smart villages. For all these concerns, farmers need to be sensitized judiciously.

GoI’s endeavour towards National Food Security Mission (NFSM) has been instrumental in enhancing food production a great deal but in the present context and after COVID-19, it has to be re-visited for giving crop-wise /region-wise focus to bridge the yield gaps in different commodity crops. It has been reported that yield gaps, estimated as the difference between national average yields and well managed demonstrations with current recommendations, were equivalent to 27 per cent yield increase for wheat, 35 per cent for mustard, 45 per cent for potato, and 32 per cent for lentil. Hence, in the intensive cropping patterns, there is scope for increasing crop yield through applying balanced fertilizer dose. There is need to revisit relevant policies/frame new policies to meet the current requirements. Also, GoI should consider giving clearance to gene-editing technology and lift the moratorium on GM crops.

Dr RB Singh, Former President, NAAS, New Delhi stated that our agriculture is at the cross-roads and the time is ripe to re-invent it. With India expected to become a USD 5 trillion economy by 2024-25 and also doubling farmers’ income by 2022-23, the agriculture sector needs to play an even more important role in the coming years. As we are aware, India accounts nearly 47.38 per cent of the cultivated land and 86.25 per cent smallholder and marginal farmers with over 50 per cent sub-marginal farmers possessing less than 0.5 ha land. Despite their higher per unit productivity, the extremely small and fragmented holdings are economically non-viable, and swelling the ranks of hungry and poor. The biodiverse and predominantly crop-livestock mixed-farming in India is the key to ensure resilience to climate change (CC) and sustainability of smallholder farming agro-ecologies. Climate change affects farming in a number of ways, including through changes in average temperatures, rainfall, and climate extremes (e.g., heat waves), changes in pests and diseases, changes in atmospheric carbon dioxide and ground-level ozone concentrations, changes in the nutritional quality of some foods and changes in sea level. He further emphasised that seed replacement ratio (SRR) plays a crucial role in increasing the yields in self-pollinated crops where the farmer saves seed for use in the next year. The SRR has been going up steadily but it needs to be speeded-up. If the yield gaps between states have to be reduced, a few actions need to be taken, for example, large scale education of farmers in the states with lower yields and improving their capacity to absorb new technologies, timely supply of good quality inputs through a public/private partnership program, and providing institutional support to the farmers in terms of access to credit, access to markets, scientific extension and similar matters. Other possible options to bridge the yield gaps could be through use of hybrid technology, adoption of GM crops, cultivation of GM soybean, promotion of Zn and iron rich millets, promoting conservation agriculture, and precision farming to increase water and nutrient use efficiency. He opined for high priority to use genomics, gene-editing to solve problems of biotic and abiotic stresses, climate change; science communication, vibrant innovative extension system, better education policy, developing fortified varieties, strengthening of public-private partnership (PPP), and funding from corporate using corporate social responsibility (CSR) through enabling government policies and incentives shall further enhance foodgain production.

Policy support, production strategies, public investment in infrastructure, and research and extension for crop and livestock can significantly help in increasing the agricultural productivity, food production and its availability. The strategy of “More for less for more” needs to be adopted vigorously. The major constraints responsible for yield gap such as late sowing/ transplanting, higher price of seed, non-availability of required fertilizer at sowing time, lack of credit and infestation of pests and diseases need to be addressed for enhancing both productivity and production.

Dr. Jacqueline Hughes, DG, ICRISAT, Patancheru stated that today’s diet of most people around the world is dominated by the Big Three - rice, wheat, and maize-which account for about 50 per cent of the world’s consumption of calories. According to FAO, about 95 per cent of the world’s food needs are provided for by just 30 species of plants. With the rise of industrialized agriculture, the crop diversity on our plates has reduced and only the crops amenable to large-scale industrialized farming have come to dominate our diets. She further stated that farming is a complex and high-risk activity; the risk is higher in smallholder rain-fed systems. There is no single answer as farming is profitable for a variety of reasons and unprofitable for just as many reasons. Better pest and disease management, soil fertility and good agronomic practices, increased resilience to climate change, availability of quality seed of improved varieties, better access to markets, addressing workforce shortages through mechanization, improved post-harvest practices and processing options, strengthened value chains and a supportive policy environment can make farming profitable. She remarked that closing the gap between current and potential yields is one means of increasing agricultural production to feed the globally increasing population. Therefore, investigation of the geographic patterns, trends and causes as well as quantification of crop yield gaps is essential to identify where yields might be increased. Looking towards yield gaps is very important for food and nutritional security and biological, physical and multiple factors affecting crop yields need to be addressed.

She further emphasized that improving access to agronomic practices (such as fertilizer and high-yielding seed) and developing agricultural policies and strategies could increase the crop yields and narrow down the yield gaps. There is need to minimize waste, increase productivity and provide better management. Farmers are the key to the issue and they need to be incentivised, new technologies to be adopted, and partnerships are to be strengthened. Intensification and/or expansion of agriculture are the two main options available to meet the growing crop demands. The sustainability of such agricultural intensification largely depends on the way management strategies for bridging yield gaps are chosen and implemented. A precise spatial knowledge of potential yield and actual yield is crucial to assessing an increase in grain yield and is relevant to national food security. Bridging yield gaps to attain potential yields may be a viable option to increase the global crop production. Most countries will reach food self-sufficiency or improve their current food self-sufficiency levels if potential crop production levels are achieved.

Dr T. Mohapatra, Secretary, DARE and DG, ICAR emphasized that the topic ‘bridging yield gaps’ chosen for this workshop is very crucial and the ICAR is always looking for good recommendations so that it can re-orient/plan its research programs accordingly. Thus, the discussion is very relevant. He repeatedly said that we have achieved over 300 mt of food production today which is 6-times increase from the day of our independence. He emphasised that while we have been improving crop yields over the years, even then we have 30-50 per cent yield gaps in different crops. He asserted that crop yield gap is a global phenomenon. A crop growth/weather modelling plays a significant role in system approach which has been developed extensively over several years and a diverse range of crop models are now available. Effective crop modelling represents a better way of synthesizing knowledge about different components of a system, summarizing data and transferring better research results to users. We have to find out factors and need to work on them aggressively. Therefore, realization through crop modelling on achievable yields is a necessity. He also advocated using new technologies, such as gene-editing technology (CRISPR/Cas9) where lot of potential exists but we have to finally see that the government allows going ahead for using this technology when other countries in the world are using it successfully. He informed that the ICAR has already allocated Rs 1,000 crore for this technology.

Quantifying food production capacity on every hectare of current farmland in a consistent and transparent manner is needed to take firm decisions on policy, research, development and investment that aim to affect future crop yield and land use planning and to inform on-ground action by local farmers through their knowledge networks. There is need for accurate agronomic and current yield data together with calibrated and validated crop models. The analysis of rate of increase in productivity of major cereal crops clearly shows that there is consistent increase in productivity. The rate of increase in productivity of maize and pearl millet has been several times higher than that realized during GR era. Rice productivity witnessed a continuous increase throughout. In fact, India has been witnessing a silent evergreen revolution in major cereals. Wide variations observed in inter-state and inter-district productivity, for example, in case of wheat, in Punjab, it is 5 t/ha, Chhattisgarh 1.3 t/ha whereas its potential yield is 7-8 t/ha. The productivity of rice and wheat in the trans-Gangetic region has been more than 3 t/ha and 4 t/ha, respectively as against 2-2.5 t/ha in lower and mid-Gangetic plains (eastern Uttar Pradesh, Odisha and Bihar). Also, the pace of development of rice hybrids in India has slowed down considerably in the public sector, and hence efforts by the private sector need to be encouraged and incentivized. We actually need to target low-productivity states/districts to bridge yield gaps and enhance productivity. The productivity of crops in Punjab and Haryana, which have largely exploited available ground water resources, is to be raised now with less water and for that suitable varieties need to be developed.

The future of India's agriculture economy lies in crop diversification. The continued practice of wheat and paddy crop production pattern since the Green Revolution has adversely impacted the natural resources. India needs to promote growing of less water consuming crops like oil seeds, cotton, pulses and maize.

Growing of paddy led to depleting water table, soil fertility and stubble burning in the states of Haryana, Punjab and Uttar Pradesh. The incentives provided by the government have not yielded the desired results. Government provides high MSP rates for paddy and wheat which leads to many farmers growing the same. The reason for lack of crop diversification in India is the financial overpower of the traditional crop over the new crops. We know wheat production target of 100 mt by 2020 has already been achieved, the productivity increase further would demand judicious efforts. In fact, India has the potential to emerge as number one wheat producing country in the world in next one decade. He also mentioned about epigenetic manipulation because epigenetic changes help determine whether genes are turned on or off, they influence the production of proteins in cells. This regulation helps ensure that each cell produces only proteins that are necessary for its function. We should try to explore the relationship between the genome and the chemical compounds that modify it. In particular, we should work as to what epigenetic modifications and errors have on gene function, protein production, and human health. Further he emphasised on use of useful germplasm to enhance productivity.

THEMATIC PRESENTATIONS

The Session on Thematic Presentations was co-chaired by **Dr PL Gautam**, Former Chairperson, PPV&FRA and **Dr TR Sharma,** DDG (Crop Sciences), ICAR. The five thematic presentations made in the Session included Strategy for Bridging Yield Gaps in Rice, Wheat, Maize, Sorghum and Pearl Millet, and Pulses.

Dr Dipankar Maiti, Director, ICAR-NRRI, Cuttack in his presentation informed that 90 per cent of global rice is produced and consumed in Asia. In India, rice is grown by 67 million farm families (56% of farmers) with annual value of US$ 53 billion (17% of crop value). It is livelihood to 150 million rural poor (40% of poor) and feeds 0.8 billion people (65% of population). Its current production is 116.6 mt. Projected demand of rice in India will be 200 mt by 2050. The drivers of rice R&D includes increasing income, yield stagnation, water shortage, climate change, malnutrition, environmental pollution, value addition and value chain, discovery to delivery, digital agriculture, and capacity building.

Yield gap in different states of India varies from 45 to 80 per cent. Average yield in China is 6.6 t per ha whereas in India, it is 3.4 t per ha. There are several constraints in rice farming which include: i) poor recommended inputs use capacity by small and marginal farmers in eastern states; ii) erratic rainfall with poor soils and use of local varieties in Madhya Pradesh, Odisha and some parts of Uttar Pradesh; iii) flash flood, water logging due to poor drainage in Assam, West Bengal, North Bihar and eastern Uttar Pradesh; iv) low and imbalanced use of fertilizers in Northeastern and Eastern states; v) poor adoption of production technology mostly uplands and lowlands; vi) saline and alkali soils in West Bengal, Odisha, Andhra Pradesh, Tamil Nadu, Kerala, Karnataka, Maharashtra, Gujarat, Western Uttar Pradesh, Punjab, and Haryana; and vii) acute labour and energy shortage in Northern states and other areas To overcome these constraints, farmers should adopt good agricultural practices (GAPs). Farmers are to be brought under cooperative umbrella of farmer producing organizations (FPOs) and farmer producing companies (FPCs), GoI's Central Sector Scheme targets to develop 10,000 FPOs; popularize small implements; attract rural youths towards agri-enterpreneurship including service centres for agri-appliances in local areas, promote farming system models developed separately for all categories of farmers; custom hiring for farm implements by developing group entrepreneurship; and value addition at local level to maximize profit; develop varieties suitable for erratic rainfall, and flash flood and water logging; location/ecology specific multi-stress (biotic and abiotic) tolerant varieties; promotion of climate resilient production technology; improve seed replacement rate (SRR) with better coordination among state department, NSC, research institutes; encourage seed village concept as a model (4S4R model of NRRI), mass-media campaign for greater awareness among the farmers regarding hybrid and high yielding varieties; promotion of hybrid varieties in niche ecologies; and varieties for coastal saline and alkaline ecology.

For varietal development, there is need for intensive use of modern tools and techniques, viz., biotechnology techniques such as marker-assisted selection, transgenic and gene-editing (CRISPR/Cas9) approaches that involve genetic modification; empirical breeding strategies have to be integrated with genomic assisted breeding (GAB) to have more precision and higher genetic gain; use of double haploid technologies as part of breeding tools to shorten the breeding cycle and make it more sustainable and removing constraints of hybrid production using androgenic protocol of double haploid (DH) technology; development of super rice (>10t/ha); multi-stress tolerant varieties specific for each ecology; improvement of short-grain, aromatic local landraces and registration of landraces for branding; and biofortified varieties with high yield and good grain quality.

Dr GP Singh, Director, ICAR-IIWBR, Karnal while making his presentation emphasized on: i) enhancing seed and varietal replacement rate – especially targeting eastern India; ii) promoting 'seed village' concept for higher and better quality seed production; iii) enhancing the quality seed production and distribution through certified seed agencies and to reduce the spurious seed in the seed chain; iv) pro-active partnership with the Department of Agriculture and Cooperation and Farmers' Welfare (DoAC & FW), State Agriculture Department and National Food Security Mission (NFSM) on seed production and seed distribution; v) mass dissemination of high yielding recent varieties (cluster demonstrations) through strengthening of institutional linkages between the ICAR) and SAUs, The DoAC & FW and State Agriculture Departments to bridge the yield gap between realized and potential yield levels; vi) strengthening public-private partnership (PPP) in seed production for faster technology outreach, for example DBW 187 variety notified by the Central Variety Release Committee (CVRC) during 2019 became the number one seed indented variety within 3 years; vii) travelling seminars involving stakeholders for creating awareness on recent varieties particularly in areas with high yield gaps (North Eastern Plains Zone); and viii) organizing 'Campaign/Field Days' on economic impact of recent wheat varieties at the farmers' field to show the relative profitability with other competing crops by bridging yield gaps.

For bridging yield gap, focused attention is required on: i) input use efficiency (water, nitrogen, and radiation), increased photosynthetic capacity, and disease resistant varieties through conventional breeding; ii) varieties with optimized partitioning to grain yield while maintaining lodging resistance; iii) breeding for tailor made plants with optimum traits combination for wider adaptability; iv) wheat improvement through utilization of wheat genome sequence information; v) accelerated genetic gain: integration of speed breeding with genomic selection (GS) could enhance the efficiency and pace of varietal development programs; vi) precision phenotyping - translating basic research to applied through utilization of actual quantitative traits loci (QTLs) in varietal improvement programs; vii) novel trait introgression- speed breeding for rapid trait introgression of race-specific genes and QTLs for disease resistance into elite lines; viii) GS to be used for rapid recycling of parents through genome estimated breeding values (GEBVs); ix) population improvement through targeted pre-breeding for the development of product profiles for specific production environments; x) identification of useful traits for screening at early stages of selection (e.g. normalized difference vegetation index (NDVI), canopy temperature, biomass, radiation use efficiency (RUE, roots); and xi) exploratory research-biological nitrification inhibition (BNI) technology for a nature based solution to enhance the nitrogen supply in wheat.

Dr Sujay Rakshit, Director, ICAR-IIMR, Ludhiana highlighted on status of maize in the country. India stands 4th in area after China, USA, Brazil and 7th in production after USA, China, Brazil, Argentina, Ukraine and Indonesia in the World. The compound annual growth rate (CAGR) of maize area (1.94%) and production (3.55%) are very impressive as compared to other cereals like rice (0.27% in area and 1.23% in production) and wheat (0.02% in area and 1.43% in production) during 2018-2019. Further, the CAGR of yield during the period for maize (1.58%) is the highest as compared to rice (0.96%) and wheat (1.40%). In India, the maize area, production and yield has witnessed unprecedented growth during the past two decades. During 2015-19, the maize area, production and yield has shown tremendous growth which is 0.83 per cent in area, 7.09 per cent in production and 6.21 per cent in yield; the growth rate of area, production and yield of maize is the highest among other major cereals like rice, wheat, pearl millet and sorghum during 2015-19. The average maize yield of in Tamil Nadu, Andhra Pradesh, West Bengal and Telangana states is above than the national average of 3.1 t/ha. However, in states like Karnataka, Bihar, Madhya Pradesh, Himachal Pradesh, Uttar Pradesh, Gujarat, Maharashtra, and Rajasthan having major area under maize, the average maize yield is below the national average.

There are 87 districts in the country with more than national average maize yield, whereas rest of 351 districts have below the national average maize yield. Thus, it is important to identify the critical districts with substantial area which have low productivity, so that focused efforts can be made to enhance the yield through better technologies and an efficient extension system for bridging the yield gap in maize.

Germplasm diversification should be major focus to bridge the yield gaps with emphasis on the following: i) genetic diversification through introgression of exotic and wild alleles in tropical background to develop maize single cross hybrids (SCHs) with yield potential of ≥ 9-10.0 t/ha in *kharif* and >12.0 t/ha in *rabi*; ii) recycling of lines with tolerance to various abiotic and biotic stresses; iii) systematic characterization and heterotic grouping of diverse germplasm; iv) need to integrate use of double haploidy (DH), genomic selection (GS) and precision phenotyping against abiotic and biotic stresses tolerance; v) combined tolerance to major abiotic stresses (drought + heat; drought + water logging) and resistance to common biotic stresses; and vi) need to give special attention to develop a diverse germplasm for specialty corns, viz., sweet corn, baby corn, popcorns, quality protein maize (QPM), silage and fodder maize. Towards natural resource management (NRM), the focus should be on: i) popularization of maize-wheat/mustard-mung bean cropping system for better system and energy productivity in rice-based cropping system; ii) effective weed and nutrient management through right kind of intercultural operations and application of post-emergence herbicides; and iii) seed-to-seed mechanization of the maize cultivation for maximum crop productivity. Disease and pest management including post-harvest management needs to be focused and effective to reduce losses due to aflatoxin and rice weevil for which the availability of dryers with silos is a key component and needs to be paid attention.

The tasks in hand to bridge the yield gaps in maize are: i) enhancing rate of genetic gains; ii) germplasm diversification and broadening of genetic base – wild and temperate sources; iii) developing hybrid oriented germplasm and recycling of inbreds – proper classification and grouping; iv) using new tools and techniques – DH, GS and genome editing; v) climate resilient hybrids for rainfed ecologies – abiotic stress management (drought +/- heat; drought +/- water-logging; high temperature); vi) sustainable management of diseases such as banded leaf and sheath blight (BLSB), sorghum downy mildew (SDM), stalk rot, etc. and insects such as fall army worm (FAW) and borers}; vii) improvement of nutritional traits – QPM + Vitamin A, low phytate, high methionine, Fe, Zn; viii) partnership for germplasm exchange – equitable partnership with micro, small and medium enterprises (MSME) seed companies; ix) enhancing resource use efficiency – adoption of improved packages of practices for optimum plant population and efficient weeds management; x) mechanization and conservation agriculture: timeliness of operation and soil health; xi) enhancing the production in new ecologies – water stressed regions and upland rice; and xii) policy support in maize value chain-district centric approach. The key in the whole process is upscaling hybrid adoption complemented with better crop management including seed availability.

Dr VA Tonapi, Director, ICAR-IIMR, Hyderabad stated that India produces >17.0 mt millets (80% of Asia's and 20% of global production) whereas global average yield is 1, 229 kg/ha and India's 1,239 kg/ha. Area decreased across crops over the years till 2018-19 and is more stable since the last two years whereas production increased during first 4 years, but reduced during 2018-19; again, increased during 2019-20 and 2020-21 due to productivity gain in all millets. Area under millets decreased (56%) and shifted to other crops because of procurement provision and enhancement in irrigated area. But productivity has significantly increased (228%) due to adoption of new high yielding varieties and hybrids. Up to 1965-70, millets were contributing to the tune of 20 per cent to the total foodgrain basket, now they contribute to 6 per cent of food basket. Post GR, now food is dominated by rice and wheat and the resources are declining. There is need to promote climate resilience millets and mainstream them to food plate of all for ushering in food and nutrition security. The largest yield gap is in Rajasthan which may be due to poor soil fertility and wide rainfall fluctuations. However, overall wider yield gaps show a significant scope for yield improvement of sorghum during *kharif* season with the adoption of improved cultivars and technologies through a well-planned strategy in identified areas. The application of protective irrigation at flag leaf and grain filling stage could boost the productivity of sorghum. To bridge the yield gaps of sorghum and pearl millet, important points for consideration are: i) grain yields generally fluctuate between 25-50 per cent of potential yields, ii) best farmers' yields tend to underestimate the potential yields, ii) simple crop simulation models provide a more accurate estimation of potential yield, iv) soil fertility and weed management are the predominant causes of yield gaps, v) great potential exists for closing the yield gap by improving agronomic practices, vi) integrated watershed-based approach encompassing harvesting of excess rainfall for supplemental irrigation, vii) growing high yielding crop cultivars, viii) integrated nutrient management (INM), integrated pest management (IPM) and integrated disease management (IDM) would be essentially required, ix) value addition of products and their multiple uses are necessary to make them more remunerative for the farmers.

To bridge the yield gap in millets, there is need to make available quality seeds of hybrids and varieties, enhancing seed and varietal replacement and strengthening community seed systems; vertical expansion-increased productivity through trait led genomics; all season sorghum cultivars, short duration hybrids with erect leaf ideotypes for high density planting and product diversification in pearl millet for demand led infusion; horizontal expansion in non- traditional states; incentivising cultivation; need for better agronomy, good agricultural practices (GAP) and watershed development; and diversified agriculture and diversified food plates for food and nutrition security addressing SDG 1 and SDG 2. Efforts need to be made for accelerating awareness programs about the nutritional and health benefits of the millets among the consumers. The value chain strengthening is also needed with emphasis on value addition and development of value-added products from millets. Concerted efforts need to be made for linking millet farmers to the market. For boosting production and productivity, the required policy support from the government in the form of incentivising cultivation of millets need to be in place.

Dr NP Singh, Director, ICAR-IIPR, Kanpur made a presentation on pulses and highlighted that pulses are the backbone of Indian agriculture due to their significant role in human and animal nutrition, soil ameliorative properties, environmental sustainability and economic viability. India is the largest producer, processor, importer and consumer of pulses in the world. With >12 major and minor pulses cultivated over 27-28 mha, the country witnessed an all-time high production during 2020-21 producing 25.72 mt of pulses with an average productivity of about 950 kg/ha. Looking not far behind, we were hovering around 14-15 mt till 2010 and around 17-18 mt till 2014-15. Since 2014-15, an increase of >8.5 mt (>50%) was witnessed in an overall production of pulses, the highest being in mung bean (106%), followed by chickpea (64%), pigeonpea (52%), lentil (39%) and urd bean (21%). This unprecedented growth not only ensured self-sufficiency in pulses in the country and their increased availability to the masses, but also reduced the import burden and consequently saving a significant amount of foreign exchange. However, this required a systematic planning and execution of a 3-dimensional strategy in the last decade which included: i) area expansion to add 2-3 million additional area under pulses by way of introducing pulses into newer niches, and rice and wheat fallows, promotion of mung bean during summer season and intercropping of pulses with sugarcane, soyabean, cotton, millets, etc.; ii) productivity enhancement or vertical expansion of pulses, by way of adopting improved varieties, timely availability of quality seeds through establishment of seed hubs, improved inter-cultural operations; iii) reducing post-harvest losses and value chain strengthening. As a result of planned and concerted efforts, several breakthrough achievements were recorded in the research front including reduction in crop duration: mung bean (75 to 55 days), lentil (140 to 120 days), chickpea (135 to 110 days); increase in seed size (100-seed weight) of *kabuli* chickpea from 35 to 55 g; development of yellow mosaic virus (YMV) resistant, non-shattering and synchronous varieties in mung bean and urd bean; development of high input responsive, wilt resistant varieties in chickpea and early maturing and machine harvestable varieties in pigeonpea for multiple cropping; development of green seeded variety in field pea and biofortified varieties in lentil and chickpea. Hybrids were successfully developed and adopted in pigeonpea besides development of cultivars in the backgrounds of most successful chickpea varieties of past years through marker assisted breeding. Despite these historical developments, there is no room for complacency as we would be requiring 32 mt of pulses by the end of 2030 and 39 mt by the end of 2050, thereby requiring additional 6-7 mt of pulse grains in the next 8-10 years while sustaining the present production figures. A critical yield gap analysis has clearly indicated a great void between the yield potential and realized yield in pulses. For example, on the basis of full package technology demonstrations data, it has been observed that there is a yield gap of >37 per cent in case of lentil, >35 per cent in case of chickpea and field pea, >31 per cent in case of *rajmash*, >28 per cent in case of urd bean, and >23 per cent in case of mung bean. Furthermore, the situation is much more alarming in a few states as compared to the other states. For example, in Maharashtra the yield gap in chickpea and pigeonpea has been found to be >90 per cent whereas in case of Chhattisgarh, the situation is still worse where the yield gap is >130 per cent in pigeonpea and 50 per cent in chickpea. If the yield potential of the improved varieties is further increased by at least 30 per cent and the current yield gap is bridged to about 50 per cent, India will not only become completely self-sufficient, but also pulse exporting country.

Strategies to bridge yield gap in different pulses include: i) accelerating genetic gains in pulses by developing superior new varieties through aggressive breeding by way of speed breeding, precision phenotyping, doubled haploidy (DH), increasing efficiency of selection through marker assisted selection (MAS), genomic selection (GS), digitalization of breeding records, efficient breeding management system (BMS), transgenic technology, genome editing, pre-breeding and distant hybridization, ii) strengthening seed system to meet future demands; iii) strengthening mechanization and post-harvest technology research- through strategic partnership and collaborations; and iv) value chain development and PPP. In addition, the following strategies need to be adopted to bridge the yield gap in pulses: i) faster and efficient technology dissemination and its adoption by the farmers; ii) main streaming of new high yielding varieties with multiple stress resistance, iii) matching agro-technologies for higher yield in pulses (new agro-chemicals, post emergence herbicides, micro-irrigation and resource conservation technologies); iv) promotion of mung bean as a spring and summer crop; v) introduction of pulses (early pigeonpea) in soybean-wheat and cotton-wheat cropping system; vi) pulses as intercrop in cropping systems under rainfed/dryland systems; and vii) promotion of pulses (lentil, chickpea and field pea) in eastern India and urd bean and mung bean in southern India under rice fallows.

For productivity enhancement of pulses, we need to work towards improving seed replacement rate (SRR) through advance state-wise planning for rolling seed plan; production of sufficient quantity of breeder seeds and their conversion into foundation and certified seed; maintenance of seed buffer; public-private partnership and farmers' participatory seed production. Providing life-saving irrigation in pulse growing districts by adopting micro-irrigation through sprinklers or drip and rainwater harvesting will also help in assured production. Besides, ensuring timely availability of critical inputs like biofertilizers, sulphur, zinc, gypsum, boron, biopesticides, etc. at field level and impetus to mechanization of pulses especially for essential agricultural operations like tillage, planting, harvesting, inter-cultivation, threshing, processing, etc. through cooperatives or custom hiring will go a long way in bridging yield gaps. More investment is needed in R&D particularly in frontier areas like genomics, artificial intelligence, nanotechnology, etc. In addition to the on-going efforts towards productivity enhancement, there is need to resort to the identified futuristic technologies towards significantly enhancing the yield potential of the new cultivars: These will include designing targeted crop plants for higher productivity, restructuring their plant types for mechanical harvesting, developing super early and super-nodulating varieties and fullest exploitation of heterosis and development of "super hybrids" in crops like pigeonpea. Development of artificial seed and embryo encapsulation in high volume crops will help in reducing high volumes of seed loss. Besides, integration of bioinformatics, genomics and systems biology, gene prospecting and allele mining for target traits and development of fortified varieties will expedite the development of more nutritious and more productive varieties of pulses.

PANEL DISCUSSION

The panel discussion on 'Strategy for Bridging Yield Gaps' was moderated by **Dr RS Paroda**, Chairman, TAAS along with **Dr RB Singh,** Former President, NAAS. While introducing the theme of panel discussion, Dr Paroda emphasised the need for applying appropriate technologies to reduce yield gaps and realise the full genetic potential of crop varieties. He recalled the growth of single cross maize hybrids in India and its impact on maize productivity which rose from 2 tons/ha to 4 t/ha and now 7 t/ha at some places. He also stressed on the need for greater R&D efforts in both public and private sector towards increasing maize productivity and expansion of area under single cross maize hybrids. Eight eminent experts participated in the panel discussion.

Dr SK Vasal, Former Distinguished Scientist and World Food Laureate, CIMMYT, Mexico, was of the view that plant breeders must adopt strategies that yield greater gains with fewer resources. This would require development of multidisciplinary teams with multipurpose objectives. Complex problems can be solved through skilful application of technologies. Similarly, constraints caused by reduced funding can be overcome by operating joint projects involving both public and private sector organizations and also following appropriate breeding methods that save resources, time and space. He specifically highlighted that:

- The genetic fundamentals of the crop should be clear to the breeding teams. For example, for efficient exploitation of hybrid technology in maize, consideration of the source of germplasm and its grouping into specific heterotic groups is important.
- A strong inbred source germplasm is essential for hybrid breeding in maize. Detailed profiling of inbred lines and their alleles is important to make their full and efficient use in breeding programs.
- It is important to maintain purity of male and female parent lines by avoiding contamination during growing stage or during seed maintenance.
- Complex problems can sometimes be solved through simple and skilful selection and technology intervention. For example, lines with good plant standability will be less susceptible to lodging, better amenable to mechanical harvesting and have better resistance to stalk rot pathogens.
- There is a need for identifying better testers in maize for which special efforts must be made.

- Breeding programs must ideally be carried out in public-private participatory mode which will synergise development of new varieties as also their popularization among farmers and other stakeholders.

Dr HS Gupta, Former DG, BISA, New Delhi stated that there exists significant yield gaps in all the crops in India. Therefore, it's imperative to find out ways and means to bridge the yield gaps. In order to bridge the yield gaps, he suggested two-pronged strategy: (i) short- term that deals with measures up to 2030; and (ii) long-term that deals with the measures up to 2050. He highlighted the following important points:

- The priority should be laid on revamping transfer of technology (ToT) which continues to be a major constraint in realizing full potential of improved technologies developed by the national agricultural research systems (NARS). Agricultural extension has not been able to take full advantage of information communication technology (ICT) in ToT. We also need to deploy innovative methods of extension with the help of NGOs and post offices. In addition, input supply at the farmers' doorstep should also be ensured through FPOs. The NARS has developed technologies that would be able to meet the foodgrains requirement of the country if efficient and effective ToT is put in place. In addition, a special push needs to be given to soybean production and consumption to reduce protein malnutrition and to biofortified crops for overcoming micronutrient deficiency.
- In long-term, agricultural R&D efforts should be accelerated for using new technologies capable of giving a quantum jump in per unit productivity. The country has witnessed the impact of genetically engineered cotton on yields and productivity. Therefore, the hesitancy in adopting new technologies and crops developed through such technologies like GM and gene edited crops must be overcome.
- Development of hybrids should be taken up in a big way in most crops especially, rice, maize, pigeonpea, pearl millet and sorghum. It is high time that the ICAR initiates another network program on development of hybrids in field crops in a mission mode.
- There is a need to adopt caution in adopting unproven technologies. The experience of Sri Lanka in going fully organic which has caused severe hit in its agricultural production and resulted in massive increase in agricultural commodity prices should ring alarm bells in states and organizations that are proposing to go down the organic path.

Dr KV Prabhu, Chairperson, PPV&FRA opined that the ICAR needs to change its current mechanism of assessing yield gaps in major crops through front line demonstrations (FLDs) and agronomy trials under the AICRIPs. He made the following suggestions:

- It should adopt the Global Yield Gap Atlas (GYGA) protocols and the yield data be shown on its map. This change is important since the United Nations (UN) has accepted that the final referee for a country's report on SDG2 will be the GYGA establishment. It is, therefore, recommended to shift over to the GYGA protocol-based assessment of yield gaps at the earliest.
- The observed yield gaps of 20-40 per cent in different crops are on the expected lines since the present assessments are based on incidental best yields under particular agronomic inputs with no efforts being made for estimating full genetic potential of a participating variety in the ACIRP trials. The agronomic fixation of fertilizer dose, depth of planting, time of planting trials needs to be made case by case, based on observations of the breeder, and with dynamic location, environment and agronomic hypothesis to be verified.
- A high-level committee comprising DDG (Crop Sciences), DDG (Horticultural Sciences), DDG (Natural Resource Management) and Commissioner Agriculture/ Horticulture should be constituted to decide upon the agronomic trials on varieties being tried in advanced varietal trials (AVT) and GYGA protocols for estimation of the yield gaps in different cropping systems and geographic locations.
- Indian participation in GYGA comprising just two agronomists (one from ICAR-IIWM, Bhubaneswar and one from ICAR-NBSSLUP, Nagpur) is extremely limited considering the country's diversity of crops and agro-climates. As exemplified by the experience of Australia where in rainfed wheat, the strategic changes brought about by following the GYGA protocol-based results have led to increase in production from less than 15 mt to more than 19 mt, and hence there is huge potential of enhancing the productivity at farmers' fields.

Dr AK Singh, Director, ICAR-IARI, New Delhi pointed out that it is possible to bridge yield gaps by 15 to 40 per cent through appropriate interventions. The studies also revealed that 10 per cent farmers achieved up to 20 per cent higher yields than reported in the coordinated field trials which point to the need for improving the maintenance of research trial farms. He highlighted the following important points:

- The determinants of yield gap II (yield gap at top 10% resource rich farmers) are: i) adoption of new varieties, ii) balance in fertilizer use, iii) access to credit, iv) farm mechanization, v) energy use, and vi) investment made by the farmers.
- Some technological interventions that can reduce yield gaps include precision farming, nanotechnology, molecular breeding and other methods that enhance genetic gains.

- Crops diversification has a potential to bring better benefits to the farmers while saving resources. Adoption of soybean in Punjab in place of cereals should be facilitated through policy support including provision of minimum support price (MSP).
- Food safety is becoming an issue by way of the acceptance of Indian grains in foreign markets. Use of good agricultural practices and safe use of pesticides need to be ensured.
- Adoption of public sector hybrids needs to be enhanced through public-private participation (PPP) and policy support for biofortified crops.

Dr. Ram Kaundinya, DG, FSII, New Delhi stated that for increasing crop yields research, development and policy actions are to be strengthened. He added that there is need to go to develop suitable varieties which can be adopted under modern agronomic practices; quality seed production; access to advanced research technologies with regulatory facilitation; uniform national agricultural policies. Also, several hurdles created by the regulatory environment need to be addressed through support for trait providers, acceptance of regulatory approval granted in some selected countries, enabling policies for new gene technologies, and harmonized regulatory regime for transboundary movement of seeds and germplasm. Development of productive public-private partnership in foodgrain seed technology requires: mutual trust building and mutual respect; encourage cross-sharing of germplasm and infrastructure; integrated research programs between the ICAR institutes and private sector organizations; joint market-oriented research and clearly defined and fair framework for sharing of intellectual properties. An institutional mechanism needs to be put in place for licensing open pollinated varieties (OPVs) and hybrids from public institutions to private industry and for sharing research infrastructure between public and private intuitions.

Dr. Arun Joshi, Asia Regional Representative, CIMMYT, New Delhi opined that yield gap in crops is a global issue. In India, it occurs mainly due to large variation in agroclimates, agricultural practices and farmers' capacities, being mostly small holders. Communication gap between the client (farmers) and managers (policy makers, researchers, etc.) contributes to perpetuation of yield gaps. Actually, yield gap issues need comprehensive scientific analysis of the different parameters, possible solutions and their adoption, upscaling and outscaling including the use of modern digital tools. There is a need for adopting appropriate models for yield gap analysis. In Europe, the World Food Studies (WOFOST) simulation model is used which measures plant biomass on daily basis along with recording all other types of data – soil, weather, crop management, etc. Based on a simulation model, best decisions are taken for agro-technology transfer. A model like decision support system for agro-technology transfer (DSSAT) is useful for this purpose. India may take advantage of the Global Yield Gap Atlas (yieldgap.org) to learn from the experiences of other countries. Accordingly, a pilot project may be initiated as a first step to implement the yield gap bridging program. To ensure desired implementation of the program covering all the priority crops, deployment of a dedicated team of experts will be useful.

Dr. Nafees Meah, South Asia Representative, IRRI, New Delhi highlighted that the Green Revolution helped transform India from a food deficit to surplus country and moved millions of people out of poverty. However, despite this achievement a very high incidence of poverty, hunger, and malnutrition persists, particularly in rural areas. India has the world's largest area under rice cultivation and is one of the biggest producers of white rice, accounting for 20 per cent of the global rice production. Rice is the staple of most Indians. India is the world's second largest exporter of rice and production is expected to reach a record high of 121.5 mt in 2021. Despite this progress, due to the steady diversion of agricultural land for non-agricultural uses and relatively intensive water and labor use in rice cultivation compared to other crops, rice cultivation area in India has plateaued at *ca* 44 mha. India's average rice productivity is well below the world average, and there are wide variations in productivity in rice producing states depending on the irrigation water and availability of other resources. Over the next 10-years, it is expected that because of increasing water deficit in Northwest India and South India, there will arise the need for a significant shift of rice production towards Eastern India. Smallholder farmers provide *ca* 75 per cent of the food supply; and they are transitioning from subsistence to commercial agriculture. In case, over the next decade, these smallholder farmers can improve on-farm productivity, increase resource-use efficiency, diversify their crops, gain better market access, and find non-farm employment for their households, then the livelihoods, nutrition, and incomes of millions of smallholder farmers and their families could be improved substantially.

Food systems are at the heart of the 2030 Agenda for Sustainable Development Goals (SDGs). Until now, national agricultural policies have tended to focus on increasing production and, in general, not addressed negative externalities on nutritional health, natural capital, and the protection of biodiversity. What is needed now is a food system transformation to address these issues. This means: i) access to affordable nutritious and healthy food for all; ii) sustainable food production, processing, trade, and retailing; iii) mitigating and adapting to climate change; and iv) improved smallholder farmer livelihoods and resilience by enhancing prosperity of farming and rural communities. Hence, we need to reorient agriculture to enabling healthy diets and a clean environment. To operationalize the food system transformation, we will need to generate the evidence base for sustainable food value chains for appropriate mixed farming systems (e.g., rice, livestock, fish, pulses, oilseeds, etc.) tailored for specific regions and ecologies (e.g. Gangetic delta region). India would need to engage with private sector actors (seed companies, millers, agricultural machinery manufacturers, CSOs, etc.) to scale-up innovations and ensure that the focus is on increasing the overall productivity, aggregate profitability, and efficiency of the food system from farm-to-fork. These must be market demand-led processes that are designed to increase incomes of farmers and bring benefits to the rural economy. As most farmers in South Asia are women and men smallholders, horizontal coordination between producers i.e., through farmer producer organizations, as well as vertical integration in the value chains, needs to be facilitated.

Improving nutritional outcomes should be addressed through the different pathways of nutrition-sensitive production, increased incomes, increased nutrition knowledge, women's empowerment, and strengthening of local markets. Environmental sustainability will need to be ensured by promoting agronomic practices that enhance the provision of ecosystem services and biodiversity and by developing the evidence base on consumers' willingness to pay premiums for environmentally friendly food products. Country would need to enhance the value of rice-based systems through developing value chains for important by-products such as rice bran oil. Finally, India needs to promote policy frameworks that accelerate the expansion and dissemination of improved varieties, new technologies and institutions, and packages of science-based best practices that enable sustainable value chains. A notable development during the COVID-19 pandemic was that e-agriculture, especially the direct e-linkage of farmers to retailers and consumers, boomed organically across the region because of the logistical challenges that were present at the initial stages of the pandemic. To develop this further and to support inclusive agricultural transformation, precision agriculture, and sustainable food-land-water management, we should digitalize the rice-based agri-food value-chains from farm to fork. This will improve information systems, such as the provision of climate services, and strengthen digital innovation ecosystems.

Dr. Rajeev Varshney, Research Program Director- Accelerated Crop Improvement, ICRISAT, Patancheru suggested three broader approaches to bridge yield gaps: i) developing better technologies in faster and cost-efficient manner, ii) strengthening seed system, providing better agronomic management practices and following system approach, and iii) value-addition and linking farmers to markets so that farmers can generate more income. Some R&D areas that need further attention for bridging the yield gaps are suggested below:

- Though pre-breeding approaches have been used in the past and several successes have been achieved, it is time now that with help of sequencing and phenotyping technologies, we should consider utilization of genetic diversity at a large scale.

- Breeders need to consider using new approaches in breeding to breed products for different market segments. We need to have engagement of market research and social scientists in prioritizing breeding varieties specific to market needs.
- Genomics-assisted breeding (GAB) approaches need to be used very proactively in various crops including oilseed crops such as soybean, and mustard and also in pulse crops.
- New GAB approaches (GAB 2.0) like haplotype-based breeding (HBB), optimal contributions selection (OCS), genomic selection (GS) should be included in breeding portfolio. While HBB helps in pyramiding superior haplotypes that are missing in the elite variety, OCS can help us define and identify the best parental combinations based on genomic composition so that we have better alleles and also enhanced genetic diversity. GS helps us to select the lines using breeding values based on whole genome prediction.
- Several countries have harvested fruits of GM and genome edited technology, including in food crops. However, because of a number of reasons, we have not been able to harness this technology other than Bt cotton in India. Similar situation should not happen in the use of GE technology.
- Speed breeding technology can help to advance up to 6 generations in a year. This technology should be used in conventional breeding, genomics-assisted breeding, or even genome editing technologies.
- There is a need to strengthen seed system so that farmers can have quick access to better varieties. Furthermore, better agronomy, encouraging farmers to use digital tools, and help connect farmers to markets are recommended.
- Crop diversification, strengthening of public-private partnership (PPP) through enabling government policies and incentives shall further enhance the foodgrain production.

Dr. Ashutosh Sarker, Regional Coordinator and Food Legume Leader, ICARDA South Asia and China Program, New Delhi stated that progress in crop production derives from advances in breeding and agronomy, including improvements in the spatial and temporal arrangement of crops in farming systems. Presently, crop yields vary across regions even within the same climatic zones. These variations are related to input, market accessibility, purchasing power of smallholder farmers, agricultural work force, and terrain factors, besides water and nutrient management. The sustainability of agricultural intensification largely depends on the management strategies for bridging the yield gaps. The important points for consideration as suggested as below:

- Well defined location-specific package of practices needs to be developed and disseminated considering soil testing, seed rate, seed treatment, plant population, foliar spray, irrigation schedule and methods, use of biofertilizers and on-farm testing and demonstrations at farmers' fields as a technological intervention to reduce the yield gap.
- Transfer of technology in relation to pulses needs to be strengthened in a farmer participatory mode with active involvement of multidisciplinary team of researchers to reduce the extension gap. Extension agencies need to develop and disseminate of location specific package of practices of pulses and need to ensure adequate quality and timely availability of inputs.
- Policy initiatives need to be taken for management of wild animals as they damage the pulse crops. For management of wild animals, government needs to develop special parks in the forest area for the animals like blue bull, wild pig and monkey and special campaign should be in place to catch these animals and put them in the reserved parks.
- There is need to establish custom-hiring centres in the villages to promote mechanization for pulse crop cultivation.
- For availability of quality seeds of high yielding varieties (HYVs) to the farmers, state government in collaboration with research organization needs to develop 'Village Seed Hub' for production of recommended variety seed of location specific area.
- State government in collaboration with *Krishi Vigyan Kendras* need to organize farmers' field schools and special awareness campaigns to acquaint farmers on new innovations including improved production packages. Also, extension interventions are required to facilitate farmers for direct marketing (producer to consumer) to eliminate middlemen/commission agents in the marketing channel.
- A digital technology-enabled approach to farming that observes, measures, and analyses the needs of individual fields and crops. Precision agriculture is a key component of the third wave of modern agricultural revolutions.

Dr OP Yadav, Director, ICAR-CAZRI, Jodhpur mentioned that some issues adversely impacting agricultural productivity enhancement including shrinking resources, more than required production in some crops, long-term challenges of climate and limited scope for horizontal expansion have been highlighted by previous speakers. Case studies of R&D development in pulses, maize and millets provide an example of the potential and problems faced in enhancing productivity and bridging yield gaps. Development of new plant types has brought about a revolution in mung bean production and productivity. In millets, breeding efforts have resulted in very significant increase in productivity resulting in saving of 12 mha of land area. However, this land has been diverted to production of more resource intensive crops likes groundnut, cotton and soybean. Nutri-millets has great potential as far as nutrition is concerned and now there is need for creating demand for millets so that farmers are attracted towards millet cultivation. Mould in *kharif* sorghum and quality in *rabi* sorghum still remain the major constraints in enhancing production. There is need for selection and testing for early maturing types in millets. There is immense potential for expansion of maize cultivation. However, there has been no systematic population improvement program. Heterotic grouping needs to be accelerated and agronomic practices for rainfed maize standardized. There is also a need to revisit recommendation for plant populations to be maintained under rainfed conditions. In wheat, heat and drought tolerance needs to be addressed. Also, biomass enhancement should be given attention to enhance harvest index.

Dr C Tara Sathyavathi, PC (Pearl Millet), Mandor, Jodhpur informed that the major challenges faced in pearl millet include: i) high temperature and low moisture during seedling establishment stage (A_1 zone - i.e., western Rajasthan comprised of Barmer, Jaisalmer, Bikaner, Jodhpur, Nagaur, Sikar, parts of Ganganagar); ii) low soil fertility, iii) biotic stresses – blast, downy mildew, smut, ergot and rust; iv) poor shelf-life of pearl millet flour – rancidity. Suggested strategies to bridge yield gaps include:

- Improving productivity in A_1 zone – i) developing high yielding dual purpose hybrids and varieties suitable for this agroecology especially in the western Rajasthan – hybrids suitable for Barmer and Jaisalmer; ii) material development by ICRISAT should also aim at parental line development (that would generate short duration, high yielding hybrids) and sharing with the Hybrid Parent Research Consortium (HPRC) members, private sector and public institutions; iii) precision phenotyping – a crucial factor in identifying the desirable genotypes.
- PPP – for faster technology dissemination – Private sector has its own R&D and also market penetration is good. MoUs between public and private sector would help in faster penetration on the public bred hybrids into the market.
- Other important criteria for yield enhancement include i) improving the availability of seed to the farmers – seed hubs and PPP mode, ii) pre-breeding activities to incorporate resistance to blast, iii) physiological breeding, iv) enriching genomic resources for modernizing the breeding activities, v) utilization of speed breeding technology for rapid genetic advancement in parental line development in public sector institutions; vi) input use efficiency

through agronomic management; vii) benchmarking of nutritional traits – which was done in pearl millet for the first time in the world in any of the crops; and viii) stringent evaluation and quality data generation in the coordinated trials. Replacing and changing the checks with the recently released hybrids from the AICRP system.

PARTICIPANT'S VIEWPOINTS

Dr PL Gautam, Former Chairperson, PPVFRA and NBA, Government of India desired to develop a Road Map for diverting a crop grown in one area to the new areas seeing the feasibility of adaptation in the new niche. All the major cereal crops are known to have a higher contribution to global warming than alternative crops such as millets which are important for mitigating global food insecurity and hence be given focused attention. There is no doubt that a rapid shift in the cropping pattern and eating habits incorporating millets in today's population is vital as it would lead to a healthy lifestyle.

Dr Deepak Pental, Former Vice Chancellor, Delhi University, Delhi remarked that we experience huge crop losses due to weeds, diseases, and pests which is required to be addressed meticulously. There is need to strengthen research on gene editing which is being widely applied in plants which in turn can revolutionize crop improvement a great deal. There is a, need for a strong R&D on crop relationship. Also, there is need for extension services through actual demonstration for better learning to farmers. There should be separate system in place for technology evaluation. Currently, plant breeders are engaged in developing varieties, and they are also the evaluators, which is not proper. Further, he advised to conserve back-crossed material in NBPGR gene bank for their use in future by all concerned.

Dr V Praveen Rao, Vice Chancellor, PJTSAU, Hyderabad highlighted that the challenges in different crops are different in different ecosystems, hence one technology will not fit for all and we have to work for specific package of technologies for particular location as per requirement. He felt that there is knowledge constraint, and technology constraint among farmers which need to be addressed judiciously.

Dr Bhag Mal, Secretary, TAAS pointed out about inadequate use of germplasm. The germplasm assembled in Indian gene bank and elsewhere need to be evaluated for useful traits. He emphasized that germplasm enhancement and pre-breeding aspects need to be strengthened which include all such activities related to the identification of desirable genes from the wild and weedy relatives and other unadapted materials with specific traits of interest as well as a means to broaden the diversity of improved germplasm.

Padma Shri **Dr Brahma Singh,** Former Director Life Sciences, DRDO, New Delhi opined that yield gaps are there locally, regionally and nationally. There are several ways and means of increasing the yields (reducing the gaps) in addition to the one being discussed. He wondered whether yield gaps should only be improved (as is done), by improving genetic potential of seed to yield more or the approach be different to have better total production of a crop say wheat or rice. One such approach is larger coverage of area by a high yielding commercial variety by making available adequate seeds/inputs of it to willing farmers(unable to get seeds, either non-availability or unaffordable whatever small cost is there and convince the unconcerned ones to sow high yielding commercial variety through promotional practices). There is need for increasing area under commercial high yielding varieties/hybrids to have targeted production besides breeding/developing high yielding varieties/hybrids/Replacement of existing varieties is time and resource intensive which should go on to replace the commercial varieties in due course. There is need to ensure adequate acreage under high yielding commercial varieties/hybrids of grain crops.

Dr TR Sharma, DDG (Crop Sciences), ICAR emphasized that we should use plant germplasm a great deal in genetic improvement of crops. He advocated the strong need of doing pre-breeding across different crops to broaden the genetic base of breeding material. He felt the need of constituting 'Technology Release Committee' on the lines of CVRC and the relevant technologies may also be released along with varieties during AICRP workshops. He also mentioned about need to produce more with fewer resources, food wastage is to be curbed, need to have youth human resource to help farmers directly to infuse in them the latest modern technologies for adoption in order to bridge the yield gaps.

Dr Umesh Srivastava, Former ADG (Horticulture), ICAR and Consultant, TAAS stated that actual yield is determined by the water/nutrient deficiencies or imbalances, poor soil quality, root and/or shoot diseases, insect pests, weed competition, water logging, and lodging. In order to minimize yield gap, different management strategies such as integrated plant nutrient management (IPNM) practices need to be implemented. These strategies also reduce the environmental impact on agriculture by eliminating nutrient overuse, which still could increase maize, wheat and rice yield by approximately 30 per cent. Also, to obtain a sustained growth rate of 8 per cent, India must accelerate its agricultural growth from the existing level of 2 to 4 per cent. Hence, a mission-mode program for faster agricultural growth needs to be initiated on priority. It requires a dynamic approach based on well-planned and coordinated strategies.

Dr JS Sandhu, Vice Chancellor, SKNAU, Jobner-Jaipur mentioned about the need to focus towards low production areas, promoting new technologies, and greater thrust on pre-breeding program. He stressed that cultivation of hybrid maize may be extended 100 per cent all over in a mission mode manner.

Dr PK Agarwal, Vice Chancellor, OUAT, Bhubaneswar stated that better technology needs to be used and encouraged. Also, while developing varieties in various crops, utmost consideration must be given to the needs of farmers.

Dr DK Yadav, ADG (Seeds), ICAR expressed concern over seed system in the country. He apprised that public sector has 35 per cent seed of 87 per cent improved varieties whereas private sector possesses 65 per cent seed of only 13 elite varieties with very robust seed traceability system. He also informed that 70-80 per cent breeders' seed are coming from private sector based on tender system which need to be stopped by the states.

Several other participants also made brief interventions about their views/ experiences. **Dr SS Singh,** Former Director, ICAR-IIWBR informed that in Uttar Pradesh, line sowing of wheat has led to 14 mt more production in two years period. **Dr AK Padhee,** Director (Country Relations), ICRISAT Delhi office said that extension system in the country is crumbling and needs to be addressed on priority. **Dr Sanjeev Gupta,** ADG (OP), ICAR stated that micronutrient deficiency be addressed and accordingly necessary policy decisions need to be taken. **Dr SC Dubey,** ADG (PP&B), ICAR expressed that to bridge the yield gap, only hybrids and multiple diseases and pests resistant varieties need to be encouraged. Also, weed is a serious problem in most of the crops and should be managed on priority.

CONCLUDING SESSION

In his concluding remarks, **Dr TR Sharma** advocated for broadening of the genetic base of breeding material in different crops. He also emphasised on the need to produce more with diminishing resources, and youth need to be motivated to help farmers directly to infuse in them the latest modern technologies for adoption in order to bridge the yield gaps. Also, Government policies should provide conducive environment for research investment, improve productivity, alleviate poverty, ensure systems' sustainability, protect the environment, and provide food security. It is therefore imperative that through appropriate policies, socio-economic adjustments needs to be in terms of input-output pricing, institutional support, and to redress the needs of farmers in order to complement the technological gains.

Dr RB Singh emphasised that in order to obtain a sustained growth rate of 8 per cent, India must accelerate its agricultural growth from the existing level of 2-4 per cent. Hence, a mission-mode program for faster agricultural growth needs to be initiated on priority. He mentioned about adopting cultivation of genetically modified golden rice variety which is claimed to be able to fight vitamin A deficiency. He also emphasized on integrating science social responsibility (SSR) with corporate social responsibility (CSR) through public-private partnership (PPP), value chain approach, crop-based approaches, eco-regional approaches, and ecosystem preservation. Greater attention needs to be given on PGR utilization and pre-breeding, development of hybridsincluding apomictic hybrids, harnessing the power of millets, simulation modelling to predict yield, need-based strategies and research support, adopting vocal for local approach, and work accountability and developing action plan.,

Finally, **Dr RS Paroda** concluded that understanding yield gap is very crucial as it helps in crop yield predictions. Also, information on determinants of yield gap can be used in policy interventions for enhancing crop production. Advances in breeding and agronomy including improvements in the spatial and temporal arrangement of crops in farming systems are major drivers of enhanced production. A mission-mode program for faster agricultural growth based on well-planned and coordinated strategies needs to be initiated on priority. The narrowing of the yield gap requires integrated and holistic approaches including appropriate policy intervention, understanding of farmers' real constraints to high yield, deploying of new technologies, promotion of integrated crop management, adequate supplies of inputs and farm credit, and strengthening of research and extension. He emphasized that enhancing total factor productivity (TFP) growth and promoting climate-smart agriculture (CSA) are the two priority areas which deserve special attention. He advocated the use of new tools such as genome/gene editing technology, quantification of G×E×M interactions, vertical improvement, ecoregional approach, and globally competitive specific strategies, crop-wise focus, to generate location-specific approaches under various socioeconomic conditions. He also advocated that the Government may consider lifting the moratorium on GM crops and giving clearance for the use of gene-editing technology for bridging the yield gaps in foodgrain crops.

Dr Bhag Mal extended vote of thanks to the chairs/co-chairs, speakers, panelists, distinguished invitees and participants.

KEY RECOMMENDATIONS

The key recommendations that emerged from the 'National Workshop on Bridging Yield Gaps to Enhance Foodgrain Production: A Way Forward' are as follows:

I. Strategic Initiatives

1. There is an urgent need to re-visit the projected demand of 345 mt of foodgrains by 2030 considering current diversified food basket, and the future

requirements for both food and feed, keeping in view the demographic changes in different agro-ecologies in India. This analysis will help in developing a robust future strategy for producing foodgrains and other commodities.

2. A 'Strategy Paper' needs to be developed on priority jointly by the ICAR/NAAS/TAAS to ensure future food and feed security *vis-a-vis* the demand for the foodgrains. This should include a clear 'Road Map' to bridge the yield gaps in different foodgrain crops through coordinated efforts by relevant stakeholders.
3. Adopting a differentiated and disaggregated approach, crop-wise and state-wise yield gap analysis should be done to define the year-wise production targets for major foodgrain crops; these should be monitored rigorously for implementation. Also, there is a need to develop a 'Vision Document' for each crop by the respective crop institutes addressing the current status, SWOT analysis, specific needs, and possible strategies to bridge the yield gaps under specific agro-ecologies and the states.
4. A committee comprising DDG (Crop Sciences), DDG (Horticultural Sciences), DDG (Natural Resource Management) and Agriculture/Horticulture Commissioner be constituted urgently to decide on agronomic trials of varieties in advanced varietal trials (AVT) of AICRPs adopting 'Global Yield Gap Atlas (GYGA) Protocol' for the estimation of yield gaps under various geographic locations in different states.

II. Strengthening Research

5. Major thrust is needed on germplasm enhancement and pre-breeding of the foodgrain crops. Assigning germplasm into different heterotic groups is fundamental for exploitation of heterosis and thus be given high priority. Towards this, a consortium among public-private institutions could be created for pre-breeding, targeted effective use of local landraces to increase genetic diversity for important yield-contributing traits, and for the development of heterotic groups in foodgrain crops having option for hybrid breeding, like maize, sorghum, pearl millet, pigeonpea, etc.
6. There is a need to focus on intensive use of biotechnology related techniques such as molecular marker-assisted selection, genomic selection (GS), transgenic and genome editing (CRISPR/Cas9); use of speed breeding, precision phenotyping, integrating empirical breeding strategies with genomics assisted breeding (GAB) for more precision and higher genetic gains; use of doubled haploid (DH) technologies to shorten the breeding cycle and make it more efficient; removing constraints in hybrid production using androgenic protocol of double haploid technology; and developing multiple-stress tolerant

varieties specific for defined ecologies in different crops. Also, greater thrust needs to be given to GAB approaches like haplotype-based breeding (HBB), optimal contributions selection (OCS), genomic selection (GS), etc. wherein HBB helps in pyramiding superior haplotypes that are missing in the elite variety. OCS can help us to define and identify the best parental combinations based on genomic composition so as to have better alleles and also enhanced genetic diversity. GS helps to select the lines using breeding values based on whole genome prediction. Use of functional genomics for trait understanding and improvement is very important, including improvement of complex traits.The prospects of commercialising apomictic hybrids also need to be examined. It is high time to ramp up the use of these new approaches for upscaling productivity in foodgrain crops. Breeders from the state agricultural universities (SAUs) and ICAR centres should be trained in these GAB approaches at advanced ICAR centres like NIPB and CGIAR centres like ICRISAT in India.

7. Intensive and focused breeding efforts are needed to develop high yielding, good quality hybrids in major foodgrain crops to bridge the existing yield gaps at a much faster pace. Therefore, a National Mission Mode Project on hybrid research with an allocation of Rs 1,000 crore is fully justified and should be initiated on priority by ICAR. The Crop Science Division of ICAR/GoI may take the lead without any delay involving key public and private sector institutions/ stakeholders in a consortium mode.

8. To bridge the yield gaps in major foodgrain crops, the following key researchable issues need to be addressed on priority:

   (i) In rice, the projected demand will be 140 million tons (mt) by 2030 as against present production of 122.27 mt. This target can be achieved by bridging the yield gap in different states which varies from 45 to 80 per cent. Average rice yield in India is 3.4 t/ha, which can be easily enhanced to 4.0 t/ha by 2030 through concerted efforts to cover more area under improved varieties by increased seed replacement rate (SRR) and bringing more area under hybrid rice mainly in the eastern states, coupled with the adoption of good agronomic practices (GAP) aiming at high input-use efficiency. For genetic improvement, there is a need to focus on genomic-assisted breeding (GAB) for more enhanced genetic gains; developing super rice (with >10 t/ha yield) for the most favourable ecologies both in the north and south; breeding multiple-stress tolerant varieties specific for different rice ecologies; improvement of short-grain, aromatic local land races and registration of these land races for branding; and development of biofortified varieties with high yield and excellent grain quality. Also, major thrust is needed to develop high quality hybrid rice for the upland rainfed ecology and breeding for high yielding, early maturing *Basmati* rice for direct seeding. Major effort is also needed as a national goal to breed for new high quality hybrid rice suited to more favourable ecologies, especially in the north-western region through strong public-private partnerships. In this context, public institutions would need to revamp their hybrid rice research programs with renewed mandate and achievable targets. Besides, concerted efforts are needed for developing rice varieties for efficient C4 photosynthetic pathway and minimizing CO_2 loss through photorespiration. Breeding for herbicide tolerance specifically in *Basmati* rice, will also be highly beneficial.The recently developed non-transgenic herbicide tolerant *Basmati* rice varieties at IARI, especially suited to DSR region, should reach the farmers as soon as possible.

(ii) The existing yield gap in wheat ranges from 4.85 per cent in Punjab to 59.52 per cent in Manipur. The state-wise productivity varies from the lowest (1.73 q/ha) in Karnataka to the highest (8.22q/ha) in Madhya Pradesh. There is an urgent need for intensified pre-breeding efforts and to develop disease resistant, drought as well as heat tolerant varieties to bridge the yield gap. There is also a need to breed improved varieties with better input-use efficiency, increased photosynthetic capacity, and terminal heat and drought tolerance in major wheat growing regions; hybrid wheat with optimized partitioning of grain, and maintaining disease resistance and lodging/drought tolerance with wider adaptability would be important. This would require strong partnership between the public and private R&D institutions. Strong emphasis needs to be laid on exploring physiological basis for high yield and wide adaptability as present in varieties such as HD 2967; identification of useful traits for screening at early stages of selection (e.g. NDVI, canopy temperature, biomass, roots); and undertaking exploratory research on biological nitrification inhibition (BNI) technology for a nature based solution to enhance the nitrogen supply in wheat. Major push is warranted on pre-breeding materials that can help in selecting improved varieties suitable for specific production environments.

(iii) To bridge the yield gaps in maize, the major focus must now be on: genetic diversification through introgression of exotic including temperate germplasm, in the tropical backgrounds to develop specifically single-cross maize hybrids with yield potential higher than 6.0-8.0 t/ha in the *kharif* season and 12.0 t/ha in the rabi; recycling of lines with tolerance/ resistance to major abiotic and biotic stresses; systematic characterization and heterotic grouping of maize germplasm used in breeding programs; breeding improved maize hybrids using doubled haploid lines; selecting, identifying lines with tolerance to multiple combinations of abiotic and biotic stresses using modern genetic tools; developing and deploying climate resilient hybrids for rainfed agro-ecologies; greater focus on specialty maize, viz., sweet corn, baby corn, popcorn, specialty corns, single-cross and QPM hybrids with nutritional traits (provitamin A, low phytate, high methionine, high Fe and Zn). To achieve these, greater thrust needs to be given on enhancing genetic gains through integration of powerful genetic tools/technologies, including doubled haploidy (DH), precision phenotyping, genomic selection (GS), and decision support tools, besides broadening the genetic base.

(iv) In millets, the yield gaps are mainly because of poor soil fertility and suboptimal rainfall. Significant scope exists for improving millet yields during the *kharif* season with the adoption of improved cultivars and technologies through a well-planned strategy in identified areas. In pearl millet, dual purpose hybrids for the driest A1 zone, with resistance to downy mildew, tolerance to drought/heat, and rich in micronutrients (Fe and Zn). In case of sorghum, varieties/hybrids resistant/tolerant to shoot fly, grain mould, stem borer, and drought/salinity; higher juice recovery, brix, high green fodder digestibility, and high biomass for paper and pulp industry need to be developed. Also, efforts are needed to develop Bt transgenics with stem borer resistance, low HCN, and salinity and drought tolerance. Greater attention needs to be given for developing sorghum hybrids specially for the *rabi* season in Maharashtra, to replace the old but the most predominant variety *Maldandi* having good drought tolerance and excellent grain quality.

(v) India will need 32 mt of pulses by 2030, thus requiring an additional 6-7 mt. The yield gap analysis indicates a gap of >37 per cent in case of lentil, >35 per cent for chickpea and field pea, >31 per cent for Rajmash, >28 per cent for urd bean, and >23 per cent for mung bean. In addition, there is a huge variation in terms of yield gaps across states. There is an urgent need to pursue an aggressive breeding approach to develop short duration and high yielding pulse varieties. Molecular approaches are needed for mapping and introgression of novel gene(s)/ QTL for resistance/tolerance to salinity and drought. In case of pigeonpea, early-maturing (110 days) hybrids are urgently needed to expand the area in the north-western states of Punjab, Haryana, Rajasthan and Gujarat. To achieve this, there is a need to critically look into the technological constraints and develop a robust strategy for urgent implementation by the national breeding centres and ICRISAT. Futuristic strategies around restructuring plant types for mechanical harvesting, developing early maturing and higher nodulating varieties, biofortified varieties, and varieties that can tolerate micro-nutrient deficiency such as sulphur, etc. should be pursued on priority.

III. Development Efforts

9. There is need to adopt a two-pronged strategy to bridge the yield gaps- vertical gap (GAP 1) between genetic potential, attainable/experimental stations/ frontline demonstration yields and actual/average yields at the farmers' fields and horizontal gap (GAP 2) between different geographically differentiated regions/districts/states in different crops. There are wide variations in inter-state/inter-district productivity for instance, inter-state variation in wheat productivity ranges from as low as 1.4 t/ha in Maharashtra to as high as 4.3 t/ha in Punjab. Similarly, in rice, variation ranges from 1.23 t/ha in Bihar to 4.00 t/ha in Punjab. Inter-District variations in productivity are also prominent within the states. It is, therefore, necessary that we target low productivity states/districts with high priority to bridge the existing yield gaps by addressing specific varietal or agronomic or input related constraints affecting productivity. As already highlighted, considerable yield gaps exist between different regions/states/districts in different crops which need to be bridged to enhance production through the use of better varieties and hybrids and improved agronomic package of practices, including scaling of conservation agriculture (CA) especially in rainfed areas. This has a good potential for increasing crop production while saving on costly inputs, thereby increasing farmers' income.

10. Need based economically, socially, ecologically defined crop diversification through potential non-conventional crops in different parts of the country also needs to be promoted. There is considerable potential for area expansion of short-duration varieties of chickpea in Andhra Pradesh, Tamil Nadu and Karnataka; inter-mixed cropping of black gram, green gram, pigeonpea and chickpea in central and peninsular regions; introduction of short-duration pigeonpea in North-western region; and lentils and peas in rice fallows in Bihar, West Bengal and Odisha. Also, there is good scope for promoting mung bean as a summer crop in rice-wheat system in the north; pulses (lentil, chickpea and field pea) in north-eastern India, and urd bean and mung bean in southern coastal India under rice fallows. By enhancing the productivity of pearl millet in Rajasthan, Maharashtra, Karnataka, Andhra Pradesh and Telangana to the level of the national average, an additional production of 2 mt of pearl millet could possibly be achieved. The cultivation of hybrid

rice also needs to be expanded from the current ~3 mha to at least 10 mha in next decade out of 44 mha total rice cultivated area presently. The area under single-cross maize hybrids also needs to be increased from the current 60 per cent to >95 per cent, so as to double maize production in the next one decade. Upland rice in eastern and central India, and boro rice in West Bengal and Bihar needs to be replaced by maize.

11. There are several underutilized pseudo-cereals (grain amaranth, buckwheat, quinoa), legumes (rice bean, faba bean, adzuki bean, winged bean, moth bean), and small millets (finger millet, kodo millet, little millet, foxtail millet, proso millet, barnyard millet, brown top millet), which have tremendous potential. Hence, there is an urgent need to develop high yielding and nutrition rich varieties of these crops. Also, greater attention needs to be paid on transferring valuable traits/genes from related species for enhancing their production, nutritional value and general adaptation.
12. Major thrust is needed on quality seed production of best high yielding varieties and hybrids of crops and to enhance seed replacement rate (SRR) of important foodgrain crops. A focused 5-yearly 'Seed Rolling Plan' comprising a network of efficient seed producers, across both public and private organizations is required. The states must aim to increase the SRR up to 33 per cent for self-pollinated crops and more than 90 per cent under hybrids in case of cross-pollinated crops. A critical review by the states is also needed to urgently replace the old and obsolete varieties with the latest and best varieties/hybrids to enhance productivity and climate resilience. Revolving funds for quality seed production needs to be provided to all the crop-based institutes of ICAR, particularly where hybrids are playing more prominent role.
13. Multidimensional interaction of genotypes (G), environment (E), and management (M) in determining crop yields is attracting focus mainly in view of changing climate over the past few decades, Hence, promoting the use of G x E x M strategy in future will greatly help in adoption of good agronomic practices that are needed to improve the total factor productivity (TFP) which otherwise is declining; this is critical for bridging the yield gaps in the foodgrain crops. The approach should ultimately ensure congruence of productivity, profitability, resilience and mitigation.
14. There is a strong need to re-orient the existing extension system to make it more effective through partnerships with the private sector, civil societies (NGOs, FPOs,) and involvement of youth (including women) as 'Paid Technology Agents and Input Providers'. Through the option of corporate social responsibility (CSR) as well as public-private partnerships

(PPP), each KVK could become a strong Knowledge-cum-Innovation Centre where the private and public research institutions could showcase their specific new technologies and good agronomic practices, train farmers and impart relevant knowledge without dissemination loss to the farmers. FPOs should be vigorously promoted to enhance farmer centric participatory approach along the value chain to strengthen low-input high-return agri-food systems.

15. Focused efforts in a Mission Mode are needed to bring Green Revolution to Eastern India (BGREI). In this context, BGREI program of the Government to address the constraints limiting productivity of “rice-based cropping system” could effectively be implemented and monitored to harness good soil and water potential available in Eastern India. Use of alternate crops like maize, pigeonpea, etc. needs to be explored aggressively along with establishing their efficient market system.
16. Effective coordination is also needed between MoA&FW and ICAR and also between state agriculture departments and SAUs to undertake field demonstrations/ mini kits. Towards this, well-defined location-specific package of practices, including soil testing, seed rate, seed treatment, plant population, irrigation schedule, use of biofertilizers, biopesticides and required inorganic fertilizers, pesticides/herbicides, etc. will have to be adopted. Also, it will be helpful to have large area coverage under high yielding varieties/hybrids by making available their quality seeds at the farmers’ doorstep.

IV. Enabling Policies

17. Policy support by GoI is required for accelerating foodgrains production both crop-wise and ecosystem-wise through increased area coverage under climate-resilient and nutritionally enriched varieties/hybrids including provision of relevant incentives to farmers rather than subsidies for adoption of good agricultural practices (GAP). Also, urgent attention is needed to provide farmers with critical inputs, such as high-quality seed, credit, good agricultural practices to improve productivity, enhancing use of biofortified varieties/hybrids, better minimum support price (MSP) for hybrids, and strong linkage between hybrid rice research, seed production and extension agencies.
18. In order to accelerate the process of plant breeding using disruptive innovation, there is an urgent need for exploiting genome editing using CRISPR/Cas9 with clearance of guidelines by the government through Genetic Engineering Approval Committee (GEAC) suggested for SDN-1 and SDN-2 category, to be

at par with normal breeding methods and to be out of biosafety testing requirements as already done in countries such as USA, Japan and Australia. In fact, immediate clearance of proposed guidelines recommended by DBT in consultation with the ICAR that are scientifically sound and based on an in-depth discussion by the senior experts and the fellows of National Academy of Agricultural Sciences (NAAS), and those who participated in the expert consultation organized by the Trust for Advancement of Agricultural Sciences (TAAS), a 'Think Tank' would provide much needed enabling environment for future genetic improvement in crops.

19. The required enabling policy environment needs to be provided by the Government of India to build trust with private sector in order to improve input-use efficiency and for increasing productivity. This could be done by dedicating specific zones, villages/districts to private players, especially skilled youth, who are interested in contract farming, technology transfer, establishing market-oriented production system, and playing a critical role in price stability and ensuring environment sustainability.

20. Adoption of public sector hybrids and biofortified crops needs to be enhanced through public-private partnerships and enabling policy support. Differential price fixation for better quality in terms of nutritional value like quality protein maize (QPM), high oleic groundnut, high zinc or iron containing crop varieties would ensure their faster adoption which is quite critical for nutritional security.

21. Despite the fact that maize has immense potential to diversify the rice-based cropping system, currently the policy as well as market regime do not favour maize production. Maize farmers must be supported with appropriate production incentive (on account of saving water and addressing issues like residue burning, energy saving, etc.) and paid the price differential (on account of differences between market price and MSP). Seed to seed mechanization of maize cultivation needs to be focused to address the labour issues. Medium-sized dryers and silos need to be built at the village/block level to address the problem of post-harvest losses and aflatoxin contamination. Also, there is a need to declare soybean as a food crop instead of its current classification as an oilseed crop. Adoption of soybean in Punjab and Haryana in place of rice has to be facilitated through policy support, such as provision of MSP and its procurement. Area under North-East region (a sleeping giant) needs to be brought under new crops by providing enabling policy environment. Maize, soybean, lentil, rapeseed mustard, etc. offer great opportunity in this regard, and hence their cultivation must be intensively promoted.

22. For faster adoption of public bred high yilelding varieties (HYVs) or hybrids, a new policy decision by the ICAR/MoA&FW is urgently needed for grant of exclusive area-wise licensing to well-established R&D private seed companies for production and distribution of quality seeds to the farmers.. This will surely accelerate seed production and availability in order to bridge the existing yield gaps in different crops. Also, state governments must be advised to stop henceforth thepractice of procuring certified seeds of improved varieties through open tender system. Instead, they need to be advised to adopt an advance contract system with legitimate organisations to produce and supply quality seeds of only the indented varieties/hybrids.
23. It would be desirable to adopt Global Yield Gap Atlas (GYGA) protocol and project the yield gap data generated by AICRPs on India's GYGA map. This is necessary since as per the UN guidelines, a country's report on SDG 2 will be judged on the basis of GYGA.
24. There is need to organize the farmers in the form of farmers' groups/ cooperatives/FPOs and link them directly to the industry. The price differential then, may be paid to the farmer groups/cooperatives/FPOs who in turn will pay the differental to the concerned farmers. Such farmer groups/cooperatives/ FPOs need to be provided with medium capacity dryers with storage facilities under subsidy.

Program

26 AUGUST, 2021 (9.30-17.00 HRS)

9.30-10.20	**INAUGURAL SESSION**	
Co-Chairs	**: Dr RS Paroda,** Former Secretary, DARE & DG, ICAR; and Chairman, TAAS **: Dr RB Singh,** former President, NAAS	
9.30-9.40	**Welcome & Setting the Context**	**Dr R S Paroda,** Chairman, TAAS
9.40-9.50	**Special Remarks**	**Dr RB Singh,** former President, NAAS
9.50-10.00	**Special Remarks**	**Dr Jacqueline Hughes,** DG, ICRISAT
10.00-10.20	**Inaugural Address**	**Dr Trilochan Mohapatra,** Secretary, DARE & DG, ICAR
10.20-13.00	**Thematic Presentations on Strategy for Bridging Yield Gaps**	
Co-Chairs	**: Dr PL Gautam,** former Chairperson, PPV&FRA **: Dr TR Sharma,** DDG (Crop Science), ICAR	
10.20-10.40	**Rice : Dr. Dipankar Maiti,** Director, CRRI	
10.40-11.00	**Wheat : Dr GP Singh,** Director, ICAR-IIWBR	
11.00-11.20	**Maize : Dr Sujay Rakshit,** Director, ICAR-IIMR	
11.20-11.40	**Sorghum & Pearl Millet : Dr VA Tonapi,** Director, IIMR	
11.40-12.00	**Pulses : Dr NP Singh,** Director, IIPR	
12.00-13.00	Discussion	
13.00-14.00	*Lunch Break*	
	PANEL DISCUSSION	
Co-Chairs	**: Dr RS Paroda,** Chairman, TAAS **: Dr BS Dhillon,** Former Vice-Chancellor, PAU	

14.00-15.30	***Panelists***
	Dr SK Vasal, Distinguished Scientist, CIMMYT
	Dr HS Gupta, Former DG, BISA
	Dr KV Prabhu, PPV&FRA
	Dr AK Singh, Director, IARI
	Dr Ram Kaundinya, DG, FSII
	Dr Arun Joshi, CIMMYT
	Dr Nafees Meah, IRRI
	Dr Rajeev Varshney, ICRISAT
	Dr Ashutosh Sarkar, ICARDA
	Dr OP Yadav, Director, CAZRI
	Dr C Tara Satyavathi, PC, Pearl Millet
15.30-16.30	**General Discussion**
16.30-17.00	**CONCLUDING REMARKS**
	Dr TR Sharma, DDG (Crop Science), ICAR
	Dr RB Singh, Former President, NAAS
	Dr RS Paroda, Chairman, TAAS
	Vote of Thanks **Dr Bhag Mal,** Secretary, TAAS

List of Participants

1. **Dr. Anuradha Agarwal**
Principal Scientist, ICAR-NBPGR,
Pusa Campus, New Delhi - 110012
Email: anuagrawal1@yahoo.co.in

2. **Dr. P.K. Agrawal**
Vice Chancellor, Odisha University of Agriculture and Technology,
Bhubaneswar (Odisha)
Email: vcouat@gmail.com; vc@ouat.nic.in

3. **Dr. Aruna C.**
Principal Scientist (Plant Breeding) & PI (Kharif Sorghum),
ICAR-IIMR, Hyderabad (Telangana)
Email: aruna@millets.res.in

4. **Dr. Rajendra R. Chapke**
Principal Scientist, ICAR-Indian Institute of Millets Research (IIMR), Hyderabad (Telangana)
Email: chapke@millets.res.in

5. **Dr. S.L. Choudhary**
Chairman, Asian Agri-History Foundation, 105 Vidhya Nagar,
Hiran Magri, Sector 4, Udaipur-313 002, (Rajasthan)
Email: slchoudhary1946@gmail.com

6. **Dr. J.L. Choudhary**
Director (Planning & Monitoring),
MPUAT, Udaipur (Rajasthan)
Email: chaudharyjl@yahoo.com

7. **Dr. Sain Dass**
C141 Second Floor, Front side
Motinagar, New Delhi 110015
Email: sdass2010@gmail.com

8. **Dr. Ramesh Deshpande**
Former Principal, Financial Operations, The World Bank,
Washington DC
Email: ramesh@deshpande.name

9. **Dr. H.K. Dikshit**
Division of Genetics, ICAR-IARI,
New Delhi 110012
Email: hk_dikshit@rediffmail.com

10. **Dr. S.C. Dubey**
ADG (PP&B), ICAR,
Krishi Bhawan, New Delhi 110001
Email: adgpp.icar@nic.in

11. **Prof. Col. A.K. Gahlot**
Gahlot Kuteer, B-30 Karni Nagar,
Nageniji Road, Pawanpuri, Bikaner 334003 (Rajasthan)
Email: ajeygahlot@gmail.com; ajeygahlot@hotmail.com

12. **Dr. Harish Gandhi**
Cluster Leader, Crop Breeding,
ICRISAT, Patancheru (Telangana)
Email: h.gandhi@cgiar.org

13. **Dr. Prakash Gangashetty**
Scientist, Pigeonpea Breeding,
ICRISAT, Patancheru (Telangana)
Email: p.gangashetty@cgiar.org

14. **Dr. P.L. Gautam**
Former Chairperson, PPVFRA,
NASC Complex, New Delhi 110012
Email: plgautam47@gmail.com

15. **Dr. S. Geetha**
Director, Centre for Plant Breeding and Genetic, TNAU,
Coimbatore (Tamil Nadu)
Email: directorcpbg@tnau.ac.in

16. **Dr. H.S. Gupta**
Former DG, BISA
NASC Complex, DPS Marg,
New Delhi 110012
Email: hsgupta.53@gmail.com

17. **Dr. Sanjeev Gupta**
Assistant Director General (O&P),
ICAR, Krishi Bhawan,
New Delhi-110001
Email: adgop.icar@gmail.com

18. **Dr. S.K. Gupta**
Principal Scientist,
Pearl millet breeding, ICRISAT,
Patancheru (Telangana)
Email: s.gupta@cgiar.org

19. **Dr. A.S. Hariprasad**
Principal Scientist,
ICAR-Indian Institute of Rice Research, Rajendranagar,
Hyderabad (Telangana)
Email: hari.prasad1@icar.gov.in

20. **Dr. Hariprasanna K.**
Principal Scientist (Plant Breeding),
ICAR-IIMR, Hyderabad (Telangana)
Email: hari@millets.res.in

21. **Dr. V.S. Hegde**
Division of Genetics,
ICAR-IARI, New Delhi 110012
Email: vshegdeiari@gmail.com

22. **Dr. Jacqueline Hughes**
Director General, ICRISAT,
Patancheru (Telangana)
Email: j.hughes@cgiar.org

23. **Dr. Janila**
Prinicpal Scientist,
Groudnut Breeding, ICRISAT,
Patancheru (Telangana)
Email: p.janila@cgiar.org

24. **Dr. S.L. Jat**
Senior Scientist, ICAR-Indian Institute of Maize Research,
Ludhiana (Punjab)
Email: sliari@gmail.com

25. **Dr. Arun Joshi**
Country Representative, CIMMYT,
NASC Complex, DPS Marg,
New Delhi 110012
Email: a.k.joshi@cgiar.org

26. **Dr. Meera Kar**
Principal Scientist, Crop Improvement Divn, ICAR-NRRI, Cuttack (Odisha)
Email: meerakkar@gmail.com

27. **Dr. J.L. Karihaloo**
B-1/15, Agrasen Apartment, Sector 7, Plot 10, Dwarka, New Delhi - 110075
Email: jlkarihaloo@gmail.com

28. **Dr. C.G. Karjagi**
Senior Scientist, ICAR-Indian Institute of Maize Research,
Ludhiana (Punjab)
Email: cg.karjagi@icar.gov.in

29. **Dr. J.C. Katyal**
A 104, Park View City 2, Sohna Road,
Sector 49, Gurgaon (Haryana)
Email: jc_katyal@rediffmail.com

30. Dr. Ram Kaundinya
DG, FSII, New Delhi
Email: ram@kaundinya.in

31. Dr. J. Aravind Kumar
Principal Scientist,
Plant Breeding, ICAR-Indian Institute of Rice Research (ICAR-IIRR), Rajendranagar, Hyderabad (Telangana)
Email: aravindjukanti@gmail.com

32. Dr. W.S. Lakra
Former Director & Vice-Chancellor, ICAR-CIFE, 45 Saini Enclave, Vikas Marg, New Delhi - 110092
Email: lakraws@hotmail.com

33. Dr. S.K. Lal
Division of Genetics,
ICAR-IARI, New Delhi 110012
Email: sklal68@gmail.com

34. Dr. O.P. Lathwal
Regional Director,
RRS Kaul, CCSHAU, Hisar (Haryana)
Email: lathwal1414@gmail.com

35. Dr. Dipankar Maiti
Director, ICAR-NRRI,
Cuttak (Odisha)
Email: dipankar_maiti@live.in; Dipankar.Maiti@icar.gov.in

36. Dr. Bhag Mal
Secretary, TAAS,
New Delhi 110012
Email: bhagml@gmail.com

37. Dr. N.P. Mandal
Principal Scientist,
ICAR-NRRI (CRURRS),
Cuttack (Odisha)
Email: npmandal@hotmail.com

38. Dr. Nafees Meah
Regional Representative for South Asia, IRRI,
NASC Complex, DPS Marg,
New Delhi 110012
Email: n.meah@irri.org

39. Dr. G.P. Mishra
Division of Genetics,
ICAR-IARI, New Delhi 110012
Email: gyan.gene@gmail.com

40. Dr. R.K. Mittal
Vice Chancellor, Sardar Vallabhbhai Patel University of Agriculture & Technology, Modipuram, Meerut
Email: vc2016svpuat@gmail.com

41. Dr. T. Mohapatra
Secretary, DARE & DG, ICAR,
Krishi Bhawan, New Delhi – 110001
Email: dg.icar@nic.in

42. Dr. B. Mondal
Principal Scientist, Social Science Divn., ICAR-NRRI, Cuttack (Odisha)
Email: bisumondal@rediffmail.com

43. Dr. P. Muthuraman
Principal Scientist, ICAR-Indian Institute of Rice Research (ICAR-IIRR), Rajendranagar, Hyderabad (Telangana)
Email: headtttiirr@gmail.com

44. Dr. Anuradha Narala
Scientist, ICAR-IIMR,
Hyderabad (Telangana)
Email: anuradha@millets.res.in

45. Dr. C.N. Neeraja
Principal Scientist
ICAR-Indian Institute of Rice Research, Rajendranagar,
Hyderabad (Telangana)
Email: cnneeraja@gmail.com

46. Dr. B. Nirmala
Senior Scientist,
ICAR-Indian Institute of Rice Research, Rajendranagar,
Hyderabad (Telangana)
Email: bnirmala@gmail.com

47. Arvind Padhee
Director, Country Relations,
ICRISAT, NASC Complex,
New Delhi - 110012
Email: a.pathee@cgiar.org

48. Dr. G. Padmavathi
Principal Scientist, ICAR-Indian Institute of Rice Research (ICAR-IIRR), Rajendranagar, Hyderabad (Telangana)
Email: padmaguntupalli6@gmail.com

49. Dr. B.B. Panda
Principal Scientist, Crop Production Divn., ICAR-NRRI, Cuttack (Odisha)
Email: bbpicar@gmail.com

50. Dr. Parashuram
ICAR-IIMR, Hyderabad (Telangana)
Email: parashuram@millets.res.in

51. Dr. R.S. Paroda
Chairman, TAAS,
Pusa Campus, New Delhi 110012
Email: raj.paroda@gmail.com

52. Dr. Deepak Pental
4215 Pocket B 5&6, Vasant Kunj,
New Delhi - 110070
Email: dpental@gmail.com

53. Dr. K.V. Prabhu
Chairperson, PPVFRA,
NASC Complex, DPS Marg,
New Delhi 110012
Email: chairperson-ppvfra@nic.in;
kvinodprabhu@rediffmail.com

54. Dr. S.K. Pradhan
Principal Scientist, Crop Improvement Divn., ICAR-NRRI, Cuttack (Odisha)
Email: pradhancrri@gmail.com

55. Dr. C.S. Prahraj
Head, (Crop Production),
ICAR-IIPR, Kanpur (Uttar Pradesh)
Email: cspraharaj@gmail.com

56. Dr. Ved Prakash
Dean, PGS, Acharya Narendra Deva University of Agriculture & Technology, Kumarganj, Ayodhya (Uttar Pradesh)
Email: vedprakash.ndu1961@gmail.com

57. Dr. Shambhoo Prasad
Associate Professor,
Acharya Narendra Deva University of Agriculture & Technology,
Kumarganj, Ayodhya (Uttar Pradesh)
Email: shambhoonduat@gmail.com

58. Dr. M.V.R. Prasad
#63, Orion Villas, Sy. No. 66/1,
Old Mumbai Road, Raidurgam
(Madhura-nagar Area), Hyderabad
- 500104, Telengana
Email: manohar.maddipatla@gmail.com

59. Dr. Aditya Pratap
Principal Scientist (Genetics & Plant Breeding), Division of Crop Improvement, ICAR-IIPR,
Kanpur (Uttar Pradesh)
Email: adityapratapgarg@gmail.com

60. Dr Sujay Rakshit
Director, ICAR-Indian Institute of Maize Research, Ludhiana (Punjab)
Email: director.maize@icar.gov.in

61. Dr. J.C. Rana
Country Representative, Country Office-India,
Bioversity International,
NASC Complex, New Delhi 110012
Email: j.rana@cgiar.org

62. Dr. B.S. Rana
F109, Indraprastha Aptt. Pkt 3, Sector 12, Dwarka, New Delhi 110078 (Near Rockland Hospital)
Email: ranabs2@gmail.com

63. Prof. S.K. Rao
Vice Chancellor,
Rajmata Vijayaraje Scindia Krishi Vishwa Vidyalaya,
Gwalior (Madhya Pradesh)
Email: pstovc@rvskvv.net

64. Dr. L.V. Subba Rao
Principal Scientist,
ICAR-Indian Institute of Rice Research (ICAR-IIRR),
Rajendranagar, Hyderabad (Telangana)
Email: lvsubbarao1990@gmail.com

65. Dr. Dayakar Rao
ICAR-IIMR, Hyderabad (Telangana)
Email: dayakar@millets.res.in

66. Dr. K.R. Rao
Principal Scientist & OIC, RCRRS, Naira, ICAR-NRRI, Cuttack (Odisha)
Email: rajasekhararao.korada@gmail.com

67. Dr. V. Praveen Rao
Vice-Chancellor, Prof. Jayashankar Telangana State Agricultural University, Admn. Office,
Rajendranagar, Hyderabad–500030 (Telangana)
Email: vcpjtsau@gmail.com

68. Dr. Rajvir S. Rathi
Head-Agricultural Policy & Stakeholder Affairs, Crop Science Dn., Bayer Crop Science Limited, Delta Square, Sector 25, Near IFFCO Chowk, M.G. Road,
Gurugram - 122 002 (Haryana)
Email: rajvir.rathi@bayer.com

69. Dr. N.S. Rathore
Vice Chancellor,
Maharana Pratap University of Agriculture & Technology,
Udaipur (Rajasthan)
Email: vc@mpuat.ac.in; vc_mpuat@yahoo.co.in

70. Dr. (Mrs) Meenal Rathore
Principal Scientist & Head,
Division of Plant Biotechnology,
ICAR-IIPR, Kanpur (Uttar Pradesh)
Email: mnl.rthr@gmail.com

71. Dr. K.K. Rout
Dean, College of Agriculture,
OUAT, Bhubaneswar (Odisha)
Email: deanca@rediffmail.com

72. Dr. V. V. Sadamate
Agril. Extn Specialist & Former Adviser (Agriculture), Planning Commission (now NITI Aayog), GoI, C-59, Nanakpura, South Motibagh, New Delhi-110021
Email: sadamatevv@gmail.com

73. Dr. (Mrs) Uma Sah
Principal Scientist & Head,
Division of Social Science,
ICAR-IIPR, Kanpur (Uttar Pradesh)
Email: umasah@gmail.com

74. Dr. D.P. Saini
Zonal Director Research,
MPUAT, Udaipur (Rajasthan)
Email: dsaini15@yahoo.com

75. **Prof. J.S. Sandhu**
Vice Chancellor,
Sri Karan Narendra Agriculture University, Jobner-Jaipur (Rajasthan)
Email: vc@sknau.ac.in

76. **Dr. Surinder Kaur Sandhu**
Principal Scientist (Maize),
PAU, Ludhiana (Punjab)
Email: surindersandhu@pau.edu

77. **Dr. Ashutosh Sarker**
Head, ICARDA-Food Legume Research, South Asia & China Regional Program, ICARDA,
NASC Complex, DPS Marg,
New Delhi 110012
Email: a.sarker@cgiar.org

78. **Dr. C. Tara Satyavathi**
Project Coordinator,
ICAR-AICRP on Pearl Millet,
Jodhpur (Rajasthan)
Email: aicpmip@gmail.com

79. **Dr. Rachit Saxena**
Principal Scientist-Applied Genomics, ICRISAT,
Patancheru (Telangana)
Email: r.saxena@cgiar.org

80. **Dr. J.C. Sekhar**
Principal Scientist,
Winter Nursery, ICAR-Indian Institute of Maize Research,
Rajendra Nagar, Hyderabad-500030
Email: jc.sekhar@icar.gov.in

81. **Dr. P. Senguttuvel**
Sr. Scientist, ICAR-Indian Institute of Rice Research (ICAR-IIRR),
Rajendranagar, Hyderabad
Email: senguttuvel@gmail.com

82. **Dr. T.R. Sharma**
DDG (Crop Sciences), ICAR,
New Delhi 110001
Email: ddgcs.icar@nic.in; trsharma1965@gmail.com

83. **Dr. S.K. Sharma**
Director Research,
MPUAT, Udaipur (Rajasthan)
Email: shantidynamic@gmail.com

84. **Dr. R.B. Singh**
Former President NAAS & Former Chancellor, CAU, Imphal (Manipur)
Sector-D, Flat No. 1/1241,
Vasant Kunj, New Delhi 110070
Email: rbsingh40@gmail.com

85. **Dr. G.P. Singh**
Director, ICAR-Indian Institute of Wheat and Barley Research,
Karnal (Haryana)
Email: director.iiwbr@icar.gov.in

86. **Dr. N.P. Singh**
Director,
ICAR-Indian Institute of Pulses Research, Kanpur (Uttar Pradesh)
Email: director.iipr@icar.gov.in

87. **Dr. A.K. Singh**
Director, ICAR-IARI,
Pusa Campus, New Delhi - 110012
Email: director@iari.res.in

88. **Dr. Gurbachan Singh**
Chairman, GSFRED, Beant Villa Buidling, Adjacent Adarsh Public School Campus, Kunjpura Raod,
Karnal - 132001 (Haryana)
Email: dr.gurbachan@gmail.com

89. Dr. Brahma Singh
E-713, Mayur Vihar - 2, Delhi 110091
Email: brahma88@gmail.com

90. Dr. R.P. Singh
Former Head (Agronomy),
ICAR-IARI. EA-77 1st Floor,
Inderpuri, New Delhi - 110012
Email: drsinghrp@rediffmail.com

91. Dr. S.S. Singh
Former Director, ICAR-IIWBR,
215, Sainik Vihar, Pitampura,
Delhi - 110034
Email: sssinghindia@rediffmail.com

92. Dr. R.K. Singh
ADG (CC), ICAR, Krishi Bhawan,
New Delhi - 110001
Email: adgcc.icar@nic.in

93. Dr. Y.P. Singh
ADG (F&FC),
ICAR, Krishi Bhawan,
New Delhi - 110001
Email: ypsingh.icar@gov.in;
ypsingh1777@gmail.com

94. Dr. Bijendra Singh
Vice Chancellor,
Acharya Narendra Deva University
of Agriculture and Technology,
Kumarganj, Ayodhya (Uttar Pradesh)
Email: vcnduat2018@gmail.com

95. Dr. I.P. Singh
Project Coordinator (Pigeonpea),
ICAR-IIPR, Kanpur (Uttar Pradesh)
Email: ipsingh1963@yahoo.com

96. Dr. Farindra Singh
Head, (Crop Improvement)
ICAR-IIPR, Kanpur (Uttar Pradesh)
Email: farindra.singh@rediffmail.com

97. Dr. S.P. Singh
Division of Genetics,
ICAR-IARI, New Delhi 110012
Email: sumerpalsingh@yahoo.com

98. Dr. Harish Chandra Singh
Prof. Agri. Engg.,
Acharya Narendra Deva University
of Agriculture & Technology,
Kumarganj, Ayodhya (Uttar Pradesh)
Email: hcsnduat@yahoo.com

99. Dr. N.K. Singh
Professor, Genetics and Plant
Breeding, GBPUA&T, Pantnagar
(Uttarakhand)
Email: narendraksingh2@gmail.com

100. Dr. Pratibha Singh
ACIAR, E102, Sanmati Kunj,
Plot no. 19A, Dwarka Sector 06,
New Delhi-110075
Email: singhpratibha@outlook.com

101. Dr. Shyam Bir Singh
Principal Scientist,
ICAR-Indian Institute of Maize
Research, Ludhiana (Punjab)
Email: sb.singh@icar.gov.in

102. Dr Umesh Srivastava
Former ADG (Hort),
ICAR & Consultant, TAAS,
New Delhi 110012
Email: srivastavaumesh@gmail.com

103. Dr. J. Stanley
Senior Scientist (Agrl Entomology),
ICAR-IIMR, Hyderabad (Telangana)
Email: stanley@millets.res.in

104. Dr. R.M. Sundaram
Director,
ICAR-Indian Institute of Rice
Research, Rajendranagar,
Hyderabad (Telangana)
Email: director.iirr@icar.gov.in

105. Dr. Nigamananda Swain
Scientist, ICARDA, NASC Complex,
DPS Marg, New Delhi 110012
Email: n.swain@cgiar.org

106. Dr. P. Swain
Head, Crop Physiology &
Biochemistry Divn., ICAR-NRRI,
Cuttack (Odisha)
Email: pswaincrri@gmail.com

107. Dr. AVSR Swamy
Principal Scientist,
ICAR-Indian Institute of Rice
Research, Rajendranagar,
Hyderabad (Telangana)
Email: swamyavsr@gmail.com

108. Dr. B.S. Tomar
Head, Division of Vegetable
Science, IARI, New Delhi 110012
Email: bst_spu_iari@rediffmail.com

109. Dr VA Tonapi
Director,
ICAR-Indian Institute of Millets
Research, Hyderabad (Telangana)
Email: director.millets@icar.gov.in;
tonapi@millets.res.in

110. Dr. Umakanth
ICAR-IIMR, Hyderabad (Telangana)
Email: umakanth@millets.res.in

111. Dr. Rajeev Varshney
Research Program Director,
Accelerated Crop Improvement,
ICRISAT, Patancheru (Telangana)
Email: r.k.varshney@cgiar.org

112. Dr. S.K. Vasal
Distinguished Scientist, CIMMYT
C2-2394, Vasant Kunj,
New Delhi 110070
Email: skvasal@gmail.com

113. Dr. M. Velayutham
Metrozone Apartments, S-Tower,
Flat 804 Anna Nagar,
Chennai - 600040 (Tamil Nadu)
Email: velayutham42@yahoo.co.in

114. Dr. Rekha Vyas
Zonal Director Research,
MPUAT, Udaipur (Rajasthan)
Email: rekhavyas4@rediffmail.com;
rekhavyas1963@gmail.com

115. Dr. D.K. Yadav
ADG (Seed),
ICAR, Krishi Bhawan,
New Delhi - 110001

116. Dr. O.P. Yadav
Director,
ICAR-CAZRI, Jodhpur (Rajasthan)
Email: opyadav21@yahoo.com
Email: adgseed.icar@gmail.com

117. Dr. M.P. Yadav
H.No. 365, Sector 45,
Gurugram 122003 (Haryana)
Email: yadav_mp@hotmail.com

118. Dr. Rajbir Yadav
Division of Genetics,
ICAR-IARI, New Delhi 110012
Email: rajbiryadav@yahoo.com

119. Dr. Shiv Kumar Yadav
Pr. Scientist, Division of Seed
Science and Technology,
ICAR-IARI, New Delhi 110012
Email: sky_sst@yahoo.com

Recent TAAS Publications

1. Report on Policies and Action Plan for a Secure and Sustainable Agriculture in Hindi, October, 2021
2. Youth as Advisory Agents, Input Providers and Entrepreneurs – Article by Dr. R.S. Paroda, September, 2021
3. Brainstorming Session on Regenerative Agriculture for Soil Health, Food and Environmental Security - Proceedings and Recommendations, 26 August, 2021
4. Stakeholders Dialogue on Enabling Policies for Harnessing the Potential of Genome Editing in Crop Improvement - Proceedings and Recommendations, 17 March, 2021
5. Harnessing Genome Editing for Crop Improvement – An Urgency : Policy Brief, May, 2021.
6. Accelerating Science-Led Growth in Agriculture: Two Decades of TAAS, April, 2021.
7. A Road Map on Stakeholders Dialogue on Strategies for Safe and Sustainable Weed Management, January, 2021.
8. Fish Farming in North India-A Success Story by Dr Sultan Singh, December, 2020.
9. Dr MS Swaminathan Award for Leadership in Agriculture - A Compendium, October, 2020.
10. A Road Map on Stakeholders Dialogue on Current Challenges and Way Forward for Pesticide Management, September, 2020.
11. A Road Map on Stakeholders Dialogue on Way Forward for the Indian Seed Sector, June, 2020.
12. Biofertilizers and Biopesticides for Enhancing Agricultural Production – A Success Story by Dr Basavaraj Girennavar, June, 2020.
13. A Road Map on Policy Framework for Increasing Private Sector Investments in Agriculture and Enhancing the Global Competitiveness of Indian Farmers, December, 2019.
14. Crop Biotechnology for Ensuring Food and Nutritional Security – Strategy Paper by Dr J.L. Karihaloo and Dr R.S. Paroda, December, 2019.
15. National Dialogue on Land Use for Integrated Livestock Development –Proceedings and Recommendations, 1-2 November, 2019.
16. Horticulture for Food and Nutritional Security - Strategy Paper by Dr K.L. Chadha and Dr V.B. Patel, October, 2019.
17. Urgency for Scaling Agricultural Innovations to Meet Sustainable Development Goals (SDGs) – Strategy Paper by Dr R.S. Paroda, April, 2019.

18. Tenth Foundation Day lecture on “Can India Achieve SDG 2 – Eliminate Hunger and Malnutrition by 2030” by Dr Prabhu Pingali, Professor in the Charles H. Dyson School of Applied Economics and Management at Cornell University, January 24, 2019.
19. Motivating and Attracting Youth in Agriculture - Strategy paper by Dr R.S. Paroda, November, 2018.
20. Road Map on Motivating and Attracting Youth in Agriculture (MAYA), November, 2018.
21. Regional Conference on Motivating and Attracting Youth in Agriculture (MAYA) - Proceedings and Recommendations, August 30-31, 2018.
22. Brainstorming Meeting on Harnessing Intellectual Property to Stimulate Agricultural Growth – Proceedings and Recommendations, July 27, 2018.
23. Women Empowerment for Agricultural Development - Strategy Paper by Dr R.S. Paroda, May, 2018.
24. Policy Brief on Agricultural Policies and Investment Priorities for Managing Natural Resources, Climate Change and Air Pollution - April, 2018.
25. Strategy for Doubling Farmers’ Income - Strategy Paper by Dr R.S. Paroda, February, 2018.
26. Livestock Development in India - Strategy Paper by Dr A.K. Srivastava, Member, ASRB & Trustee, TAAS, February, 2018.
27. Policy Brief on Scaling Conservation Agriculture in South Asia, December, 2017.
28. Indian Agriculture for Achieving Sustainable Development Goals -Strategy Paper by Dr R.S. Paroda, October, 2017.
29. Retrospect and Prospect of Doubling Maize Production and Farmers’ Income – Strategy Paper by Dr N.N. Singh, September 10, 2017.
30. Regional Policy Dialogue on Scaling Conservation Agriculture for Sustainable Intensification, Dhaka, Bangladesh, September 8-9, 2017.
31. Policy Brief on Efficient Potassium Management in Indian Agriculture, August 28-29, 2017.
32. National Conference on Sustainable Development Goals: India’s Preparedness and Role of Agriculture, May 11-12, 2017.
33. Delhi Declaration on Agrobiodiversity Management – Outcome of International Agrobiodiversity Congress 2016, November 6-9, 2016.
34. Awareness-cum-Brainstorming Meeting on Access and Benefit Sharing –Striking the Right Balance – Proceedings, October 22, 2016.
35. Round Table Discussion on Promoting Biotech Innovations in Agriculture and Related Issues - Proceedings & Recommendations, August 4, 2016.


Indian Institute of Rice Research, Hyderabad


Ask to Unmute
R B Singh
Dr Bhag Mal
K V Prabhu
DR R.P. SINGH
Raj Paroda
Gurinderjit Rand...
Ram Kaundinya
TRSharma DDG CS
Dr Sanjeev Gupta
C N Neeraja IIRR
HS Gupta
BB Panda