ANNUAL REPORT
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ICAR-CGIAR Centres
(Partnership for Science-led Agriculture)

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INDIAN COUNCIL OF AGRICULTURAL RESEARCH
Department of Agricultural Research and Education
Ministry of Agriculture & Farmers' Welfare
Krishi Bhavan, New Delhi 110 001

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सत्यमेव जयते

भाकृअनुप
ICAR

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FOREWORD

Technology enabled development of agriculture is evidenced by the ushering of green revolution followed by the yellow, white and blue revolutions in India. The Indian Council of Agricultural Research (ICAR) along with its partners in the National Agricultural Research and Education System (NARES) and in collaboration with the Consultative Group on International Agricultural Research (CGIAR) for research and technology developments, has led to achieve the all time high production of 289.83 million tonnes of foodgrains, 25.23 million tonnes of pulses and 305.4 million tonnes of fruits and vegetables during 2017-18. Similarly, many fold increase in production and productivity of rice, wheat, maize, pearlmillet, oilseeds, cotton, sugarcane, jute, milk, fish, eggs and meat since 1950-51, has made a visible impact on the national food and nutrition security.

The CGIAR is a global research partnership for a food-secure future. It works through 15 research centres located worldwide. ICAR, as the nodal body, has signed Memorandum of Understanding or Agreement with 12 of them. Agricultural research and education in the country is precisely undertaken in the areas of mutual interest identified in the Work Plans, which are developed for three to five years. An annual meeting of the Heads of CGIAR centres in India is held with the senior officers of the ICAR in which all the ongoing programmes are discussed and priorities are decided considering the national requirements and the areas where the CGIAR centres could assist the ICAR institutions and agricultural universities to address the existing as well as the emerging issues. ICAR acknowledges the importance of partnerships and synergies of CGIAR centres in providing technical solutions for agriculture through exchange of germplasm, technologies, technical cooperation, joint experimentation, joint publications and capacity enhancement in several frontier areas of research.

Growing population, changing lifestyles, expanding urbanization and accelerated climatic changes are posing new challenges to the agricultural research system both nationally as well as globally. The food requirement will shift from adequate food to adequate nutrients to promote health and then, to meet the optimal nutrients based on individual's genetic profile. This will require periodic monitoring of progress and reorienting our approaches. Collaboration with CGIAR centres, which have the global experience will assist in addressing these and related issues in India. This productive association might also help India to be a pro-active partner in south-south cooperation.

The Annual Report 2019-20 provides a glimpse of salient outputs and outcomes of the R&D activities of CGIAR centres along with their contribution to India. I do hope that the document will excite more precise and action oriented ICAR-CGIAR joint research efforts in order to solve specific problems afflicting Indian agriculture.

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and
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ICAR-CGIAR Agricultural Cooperation – A Perspective

Consultative Group on International Agricultural Research (CGIAR), a global partnership that unites international organizations working on food and agriculture, is having close collaboration with the Department of Agricultural Research & Education (DARE) and the Indian Council of Agricultural Research (ICAR). It works through its 15 Research Centres. Out of these 15 Centres, International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) has its headquarter at Hyderabad in the State of Telangana, India. The remaining CGIAR research organizations have headquarters elsewhere, but 10 of them have their regional/country offices located in India. Secretary, DARE and Director General, ICAR is the Ex-Officio Vice-Chair of the Governing Board of ICRISAT and is currently also a member in the Board of Trustees of Bioversity International, ICARDA and IRRI.

India is a donor member of CGIAR System from decades and contributes substantially through Window-I and Window III of the CGIAR System. Presently, India is one of the voting members in the CGIAR System Council representing the South Asia Constituency of the Council along with other two alternate representatives from South Asia namely Bangladesh and Sri Lanka. Secretary DARE & Director General, ICAR is the officio member in the CGIAR System Council from India.

DARE/ICAR works closely with 12 of the CG Centres through agreements/work plans with approval of the Government of India. This first agreements were signed with CIMMYT and IRRI in the year 1974 (Table 1).The broad areas of research collaboration with CGIAR system involves: enhanced cooperation in the areas of priority besides genetic improvement, germplasm supply, technology development to achieve targeted crop and animal productivity and quality in India, focused strategies for joint efforts to address the issues like utilization of rice fallows, agroforestry

Table 1: Status of MoA /MoU and Work plan with CG Centres

S.No.	Name of CG Centre	Agreement Date	Work Plan Period
1.	International Maize and Wheat Improvement Centre (CIMMYT), Mexico	15.03.1974	2018-2022
2.	International Rice Research Institute (IRRI), Philippines	15.03.1974	2017-2022
3.	International Potato Centre (CIP), Peru	17.11.1975	2018-2022
4.	International Research Centre for Semi-Arid Tropics (ICRISAT), India	15.07.1976	2019-2023
5.	World Agroforestry (ICRAF), Kenya	31.10.1985	2016-2020
6.	International Centre for Agricultural Research in the Dry Areas (ICARDA), Beirut, Lebanon	15.12.1986	2017-2022
7.	International Food Policy Research Institute (IFPRI), USA	01.08.1988	2020-2025
8.	WorldFish, Penang, Malaysia	15.07.1996	2019-2024
9.	Biodiversity International (BI), Rome, Italy	19.07.1996	2017-2021
10.	International Water Management Institute (IWMI), Sri Lanka	25.11.1996	2018-2022
11.	International Centre for Tropical Agriculture (CIAT), Cali, Columbia	17.06.1998	2017-2020
12.	International Livestock Research Institute (ILRI) , Kenya	07.06.2004	2019-2022

and watershed development, rainfed/dry land agriculture and water management, and fish breeding protocols and capacity building.

ICAR works closely with the Consultative Group on International Agricultural Research (CGIAR) since 1974 , which is an international R&D network having 15 Research Centres [Africa Rice Center (West Africa Rice Development Association, WARDA), Bioversity International, Center for International Forestry Research (CIFOR), International Center for Tropical Agriculture (CIAT), International Center for Agricultural Research in the Dry Areas (ICARDA), International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), International Food Policy Research Institute (IFPRI), International Institute of Tropical Agriculture (IITA), International Livestock Research Institute (ILRI), International Maize and Wheat Improvement Center (CIMMYT), International Potato Center (CIP), International Rice Research Institute (IRRI), International Water Management Institute (IWMI), World Agroforestry Centre (International Centre for Research in Agroforestry (ICRAF), WorldFish Center (earlier International Center for Living Aquatic Resources Management, ICLARM)]. India is a donor member of CGIAR System for decades and contributes substantially through CGIAR System Council mechanisms. India contributes US$0.75 million to CGIAR as annual membership fee through Window-I for carrying out collaborative research actives as per Work Plans signed between ICAR and CG Centres (Table 2).

Out of these 15 Centres, International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) has its headquarter at Hyderabad in the State of Telangana, India. The remaining CGIAR research organizations have headquarters elsewhere but have a strong presence in India. They have South Asia Regional or Country offices in India. Through mutual agreements and work plans, ICAR participates in global agricultural research and they benefit Indian agriculture *per se*. The broad areas of research collaboration with CGIAR system involves: enhanced cooperation in their areas of priority besides germplasm and technology development to achieve targeted crop and animal productivity and quality in India, focussed strategies for joint efforts to address the issues like utilisation of rice fallows, watershed development, rainfed/dryland agriculture and water management and working together for doubling farmer's income and capacity building.

As the mandate of DARE-ICAR is research and education in Agriculture and allied fields, the MoUs and Work Plans generally cover areas like advanced Agricultural Research and Education through study visits and training of scientists, exchange of literature, exchange of germplasm and capacity building programmes. During the last five years, over 1600 Scientists/science leaders were deputed abroad under the foreign collaborative programmes. During the past five years, we could import 175098 germplasm/accessions and export 4153 accessions of germplasm (Tables 3 and 4).

Table 2: Contribution to CGIAR and its Centres in India through Window I, II & III

S. N.	Period	Contribution under WINDOW-I (in INR)	Contribution under WINDOW-III (in INR)
1	2013-14	4,51,50,000	31,86,00,000
2	2014-15	4,69,80,000	34,50,00,000
3	2015-16	4,87,50,000	40,00,00,000
4	2016-17	5,12,64,252	42,99,30,000
5	2017-18	4,76,32,500	45,63,00,000
6	2018-19	5,16,45,000	45,48,00,000
7	2019-20	5,16,45,000	45,47,00,000

- *India is part of the CGIAR System Council*
- *CG centres do get projects from different departments/ministries and from States including that of RKVY (some without informing DARE, which is the nodal administrative ministry for international collaborations in agricultural R&D as per the Allocation of Business Rules of GoI)*

Table 3: Status of Germplasm Exchange with CGIAR Institutions: Import – [1976-2019]

CG Institute	Number of accessions	Crop(s)
IRRI, Philippines	1,23,253	Paddy
CIMMYT, Mexico	61,742	Wheat, Maize, Barley
ICARDA, Syria	25,853	Wheat, barley, lentil, chickpea,
IITA, Nigeria	7,628	Cowpea, soybean, cassava, maize
ICRISAT, Niger	6,708	Pearl millet, sorghum, pigeonpea, chickpea, groundnut, small millets
CIAT, Columbia	1986	French bean, forage legumes and grasses
CIP, Peru	3668	Potato, sweet potato
Bioversity (INIBAP), Belgium	433	Banana
Total	**2,31,271**	*Note: Additionally, a total of 27,79,878 samples of nurseries/ trials are received CG Consortium Centres for multi-location evaluation and testing*

Table 4: Status of Germplasm Exchange with CGIAR Institutions: Export – [1976-2019]

CG Institute	Number of samples	Crops
IRRI, Philippines	1,612	Paddy
CIMMYT, Mexico (Collaborating institutes in different countries)	42,243	Maize, Wheat, Barley
ICARDA, Syria, Morocco	92	Chickpea, barley
INIBAP, Belgium	58	Banana
Total	44,005	*Note: Additionally, a total of 7,41,485 samples of ICRISAT mandate crops were quarantined and facilitated for export to its collaborating centers through Reginal Station, Hyderabad*

These exchanges helped in development of new varieties, which in turn play significant role in reducing poverty, enhancing food and nutrition security, and improving natural resources. For instance, CGIAR's biggest contribution is in providing or facilitating transfer of genetic material of different crops from various parts of the world which has been utilized for breeding new and improved varieties of the crops. Faced with food grain crisis, India realized the benefits of dwarf wheat varieties and production was doubled within five years (1966-1971), leading to the world-famous event of "Green Revolution". This had a great impact on income of farming community in India. Since then, many varieties such as, first flood tolerant rice variety Swarna-Sub 1, Groundnut variety ICGV 91114, pigeon pea cultivar ICPH, pearl millet early maturing hybrid HHB, cassava varieties Sree Padamnabha, *etc* have been released in the country.

Highlights of CGIAR contribution to Indian Agriculture

- With ICRISAT, the NARS developed about 316 improved varieties/hybrids which include sorghum (41), pearlmillet (170), chickpea (45), pigeonpea (29) and groundnut (31). With collaboration and support from ICRISAT, the NARS released the first set of genomics-assisted breeding varieties for drought tolerance and fusarium wilt resistance in chickpea. The pigeon pea cultivar ICPH and pearl millet early maturing hybrid HHB67 in Rajasthan yielded significantly higher, covered greater area and provided more financial benefit to the farmers.

- IRRI enabled the development of the first flood tolerant rice variety, Swarna-Sub 1 and several high yielding rice varieties which are tolerant to biotic and abiotic stresses suited to various environments, hybrid rice, stress proof rice (tolerant to flash flood, stagnant flood, drought and salinity *etc*.)
- Many wheat varieties comprising of durum and bread wheat have been released in the country possessing CIMMYT parentage.
- Collaboration with ICARDA resulted into development of 15 lentil varieties and the work on Fe and Zn rich varieties for short season environment is in progress. In Kabuli chickpea, seven and in barley eleven varieties were developed by using ICARDA germplasm and 67 spineless cactus accessions were introduced for fodder from international sources.
- Under the CIP-CPRI collaboration, eight potato varieties were developed out of which two of the processing varieties are occupying over 100,000 ha area in country. In potato, 33 germplasm accessions including six accessions rich in nutrients (Fe, Zn and Vitamin-C) were imported and established at Shimla, which are being utilized for developing indigenous nutrient rich varieties.
- Through collaboration with CIAT, the CTCRI has been able to release seven cassava varieties, such as Sree Padamnabha, Sree Reksha, Sree Pavitra, Sree Sahaya, CR-43-7, *etc*., which have resistance to Cassava Mosaic Virus, Sri Lankan Cassava Mosaic Virus and drought.
- ICAR collaborative approach with IWMI and ICRAF complemented and added value to ongoing research priorities of natural resource management.
- IWMI-ICAR demonstrated a new concept of water influence zone (WIZ) in Sina irrigation command, brought out weekly drought bulletins and successfully piloted index-based flood insurance.
- With World Fish, several protocols for fish breeding and aquaculture were developed.
- IFPRI played important role in the development of Indian agriculture through its policy research.

Overall**,** partnership with these CG Centres have been enabling greater access to global elite germplasms, globally successful and replicable models, access to global methodologies for data analysis and for policy. In addition, these Centres build the capacities of Indian Scientists in frontline areas.

Annual Progress (2019-20)

Bioversity International (BI)

Bioversity International focuses on the three main goals of Convention on Biodiversity viz. the conservation of biological diversity (or biodiversity); the sustainable use of its components and the fair and equitable sharing of benefits arising from genetic resources. In the light of these goals Bioversity International has been facilitating exchange of germplasm from different countries. During the year under report, two banana varieties developed from genotypes whose import was facilitated by Bioversity International were released by the Central Variety Release Committee. The first one, Kaveri Saba (ITC 0636) is a dual purpose, dwarf variety tolerant to soil moisture deficit stress (drought). It is suitable for saline sodic and marginal soils. It has extended green life of 7-8 days. More than 20,000 plants of this variety have been distributed to farmers in the last 5 years. It has spread by more than 1.00 lakh clumps in the states of TN, Kerala, Andhra Pradesh. It is highly valued for its drought tolerance and suitability to marginal production conditions. The second one Kaveri Kanya (ITC 0627) is also a dual-purpose variety that allows for staggered harvest. It needs no propping and thus reduces production cost. It is suited for areas prone to high winds.

Another significant activity of Bioversity International is the measurement of Agrobiodiversity using an index called the Agrobiodiversity Index (ABD Index). Work on this over the years has led to the finalisation of a protocol for calculating ABDI. The ABD index is applicable at three levels *viz.* Country Index, Company Index and Project Index. The index focuses on determining the sustainability through three dimensions also called the three pillars *viz.* healthy diets which seeks to capture the contribution of countries/companies/projects to improving food biodiversity for healthy diets. Sustainable agriculture which seeks to capture the contribution of countries/companies/projects to improving biodiversity for sustainable agricultural production and Current and future use options which seeks to capture the contribution of countries/companies/projects for improving the management of agrobiodiversity of genetic resources for current and future options.

A Brainstorming meeting was held in New Delhi on 15 & 16 April 2019, to discuss the Agrobiodiversity Index developed by Bioversity International and its application in Indian context. The meeting was attended by 66 participants - 10 ICAR and GOI institutes, 2 SAUs, besides the Bioversity International staff including four from abroad. In depth discussions were held with ICAR scientists on ABDI developed by Bioversity International for applicability under Indian conditions.

As part of its activities on human resource development, ICAR-NBPGR and Bioversity International jointly organised the eighth International Training Course on "*In Vitro* and Cryopreservation Approaches for Conservation of Plant Genetic Resources" from November 5-19, 2019. There were 20 lectures and 14 practicals delivered by faculty of 28 scientists from 5 countries to 22 participants from 13 countries. The average knowledge gain by the participants from the training was 27%.

Bioversity International has also been facilitating scientific exchanges. During the year it organised the BAPNET meeting in China from April 7-9, 2019 in which participation of 3 ICAR Scientists was facilitated. Bioversity International also participated in the sensitization meeting of stakeholders on TR4 organised in October 2019 for the north-eastern states.

Four major initiatives during 2019-20, and the salient results are given below:

Initiative 1. Management and mitigation of the spread of Tropical Race 4 of Fusarium wilt on Banana

The Bioversity International facilitated the import of improved parthenocarpic diploids and hybrids from IITA, for field evaluation at ICAR-National Research Centre for Banana (NRCB). Presently, five genotypes are under field evaluation and 19 under *in vitro* at NRCB, Trichy. Field evaluation is being carried out for FoC race 1 at sick plots in Theni, Tamil Nadu by ICAR-NRCB. Three hybrids of 3x X 2x crosses & 5 hybrids of 2x X 2x crosses were found resistant/ field tolerant under pot screening.

Initiative 2. Facilitation of germplasm exchange of the selected crops including wild species of temperate fruits, cotton, winter wheat, trait specific soybean, oil palm, olive and other species as prioritized by ICAR-NBPGR.

Bioversity International facilitated scientific exchanges with the Uzbek Research Institute of Horticulture, Viticulture and Winemaking (URIHVW), Samarkand & Institute of Horticulture, Viticulture & Winemaking, Tashkent. Drs SP Ahlawat, (ICAR-NBPGR), JC Rana and Muhabbat (Bioversity International), participated in the exchange meetings from September 21-28, 2019. Consequently, a list of 208 accessions of 22 temperate fruit crops from Uzbek institutes were obtained and handed over to ICAR-NBPGR for mutual exchange.

Initiative 3. A. Exploration, collection, conservation, evaluation, nutritional profiling of Neglected and Underutilized Species (NUS), Crops Wild Relatives (CWR) and other landraces and species of economic importance

A total of 23 accessions of underutilized fruit crops were added to the genetic diversity park at Bengaluru. The total collection now stands at 265 varieties belonging to 118 species, 67 genera and 35 families. As regards to evaluation, 48 genotypes of Jackfruit were analysed for Genetic diversity using SSR markers in collaboration with University of Horticultural Sciences, Bagalkot. Dendrogram results (Fig. 1) showed 2 major clusters. The first cluster comprised of two wild species *viz*. Monkey jack and Morang and the cultivated PLR-1 genotype. Second cluster included cultivated species from both India and South East Asia types. Biochemical profiling of 34 fruit species were also undertaken during the year.

Initiative 4. Studies on Ecosystem Services (including the direct and indirect services of pollinators, natural enemies of pests, soil arthropods *etc*.) and their economic valuation.

Studies on Quantitative Assessment of Ecosystem Services were carried out in Adilabad, Karimnagar and West Godavari districts along the river Godavari in collaboration with ICAR-National Bureau of Fish Genetic Resources (NBFGR), Lucknow and National Bureau of Agriculturally Important Insect Resources (NBAIR), Bengaluru. The objective was to make a quantitative assessment of the impact of agriculture on terrestrial and aquatic ecosystem

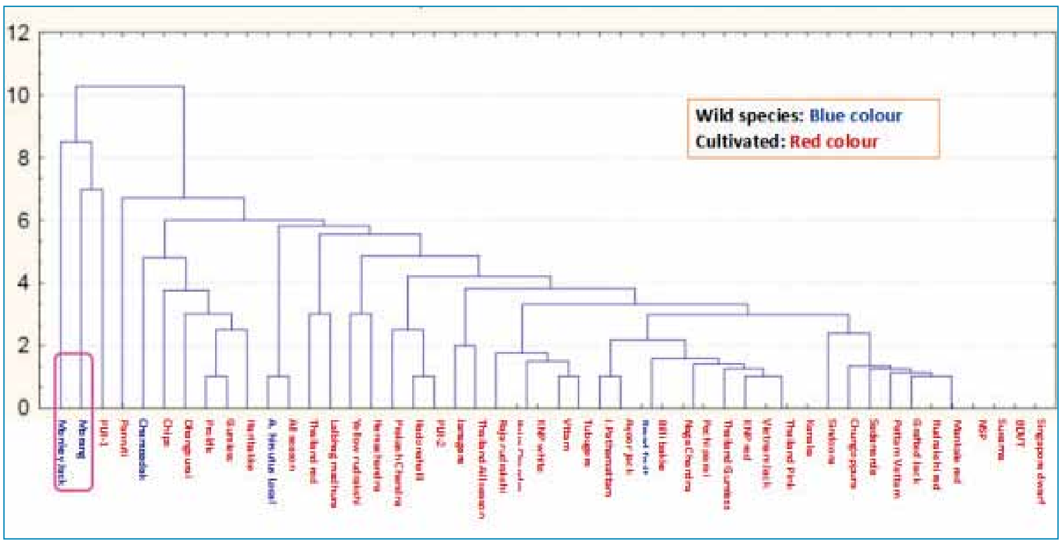


Fig. 1. Genetic diversity of Jack fruit accessions

services to assist in developing alternate scenarios. The fish and aquatic insect diversities, water quality *viz.,* pesticides, heavy metals and antibiotics content, socio-economic status and sediment retention/loss were studied during the year and the salient results are presented below:

Fish diversity: A total of 70 species comprising 20 brackish water species from the estuarine areas, 47 freshwater species from the river stretch and 3 crustacean species were recorded. The fishes belonged to 12 orders, 33 families and 53 genera. Perciformes was the most dominant order (12 families) followed by Siluriformes (5 families). Cyprinidae was the most dominant family (18 species, 26%), followed by family Bagridae (6 species, 9%). In the samples collected it was found that four species belonged to Near Threatened category and one species each belonged to the Endangered and Vulnerable category.

Diversity studies indicated that maximum species and number is present in West Godavari district (Table 5). Being an estuarine area, Richness index too was the highest in this district. Evenness values indicated a slight uneven distribution of species in all the three districts. However, Dominance index values revealed no dominance of any species in all the three districts indicating stable environments, which was corroborated by Equitability index values. Shannon Weiner Diversity indices were higher (>3) for West Godavari and Adilabad indicating good diversity. Individual Rarefaction curve (Fig. 2) indicated that in West Godavari and Adilabad districts, the chances of getting more species by more sampling is low while in Karimnagar district there is a high probability of finding higher number of species with more samplings.

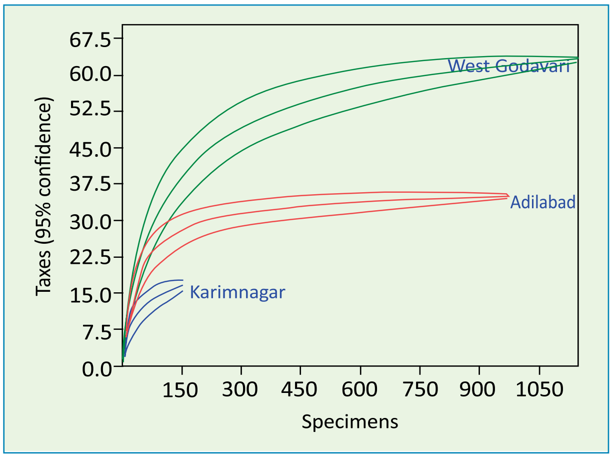


Fig. 2. Individual rarefaction curve of the three districts

Diversity of aquatic insects: The surveys showed the occurrence of two major orders *viz.* Odonata and Coleoptera. The aquatic insects belonging to three families *viz.*, Dytiscidae, Gerridae and Belastomatidae were collected from all the sampled locations. The data when subjected to species diversity analysis showed that the diversity was low over all, but Karimnagar recorded relatively higher diversity index (Shannon Weiner index – 1.07) richness index (Margalef richness index 1.17) and abundance of aquatic insects compared to the other two locations.

Diversity of pollinators: Around ten species of insect pollinators belonging to five subfamilies of family Apidae of order Hymenoptera *viz., Apis dorsata, A. cerana indica, Xylocopa fenestrata, X. pubescens, Ceratina unimaculata, Amegilla violacea, A. confusa, A. zonata, Nomia sp* and *Nomia curvipes* were found foraging in the area. The diversity of bee pollinators was low but was relatively higher at Polavaram (Shannon Weiner

Table 5: Diversity Indices of fish species at sampled locations

S. No	Index/ District	Adilabad	Karimnagar	West Godavari
1	Number of Species	35	17	63
2	Number of Individuals	989	163	1160
3	Margalef Richness Index	4.93	3.141	8.787
4	Evenness Index	0.5919	0.47	0.4773
5	Dominance Index	0.06956	0.2113	0.05141
6	Equitability Index	0.8525	0.7335	0.8215
7	Simpson_1-D	0.9304	0.7887	0.9486
8	Shannon-Weiner Diversity Index	3.031	2.078	3.404

diversity index – 0.91) compared to Bhimavaram (0.54). Richness index of bee pollinators was also higher at Polavaram (0.62) compared to Bhimavaram (0.39).

Water quality: Oxidation reduction potential (ORP) an indication of the health of the water in terms of its oxygen content, was low in all the water samples indicating low productivity potential of the water body. Cr, Pb, Cu, Hg and Ar were recorded in all water samples but were within the permissible limit, however, there is threat of their biomagnification and bio-accumulation. Four insecticides (Propuxur, Carbaryl, Phosalone and Ethion) were also detected in the water samples.

Land use land cover (LULC) pattern in study area and Modelling Sediment Loss/Retention. The changes in LULC classes data from Bhuvan (Indian Geo-Platform from ISRO) and sediment loss from each of the LULC classes were studied using GIS and models. The study showed that croplands accounted for about 60-70% of the landuse in Karimnagar and West Godavari while in Adilabad it was less than 50%. Deciduous Needle leaf forest accounted for a significant proportion of the landcover in Adilabad (32.75 %) while in Karimnagar it was about 16.22 % and in West Godavari it was 20.79 %.

Study of the changes in LULC over the three decades (1985, 1995, 2005) in the three districts showed that the area under cropland increased over the years in Adilabad and Karimnagar while it decreased from 5735.13 km^2 in 1985 to 5122.41 km^2 in 1995 but improved slightly to 5330.42 km^2 in 2005 in West Godavari. Significantly, the water bodies class increased in 1995 and 2005 in this district over that in 1985. In Adilabad and Karimnagar, however, the area under water bodies decreased to almost negligible over the years.

Modelling Sediment Delivery Ratio (SDR). The Sediment Delivery Ratio module of InVEST model was used to assess the sediment losses from different LULC classes in the three selected landscapes. The input data required as well as the conceptual model is shown in Fig. 3 and included 2004-05 LULC classification at 100 m resolution, elevation raster dataset (ASTER DEM) at 30 m resolution, a normalised raster dataset with an erosivity value for each cell derived using information on sand/

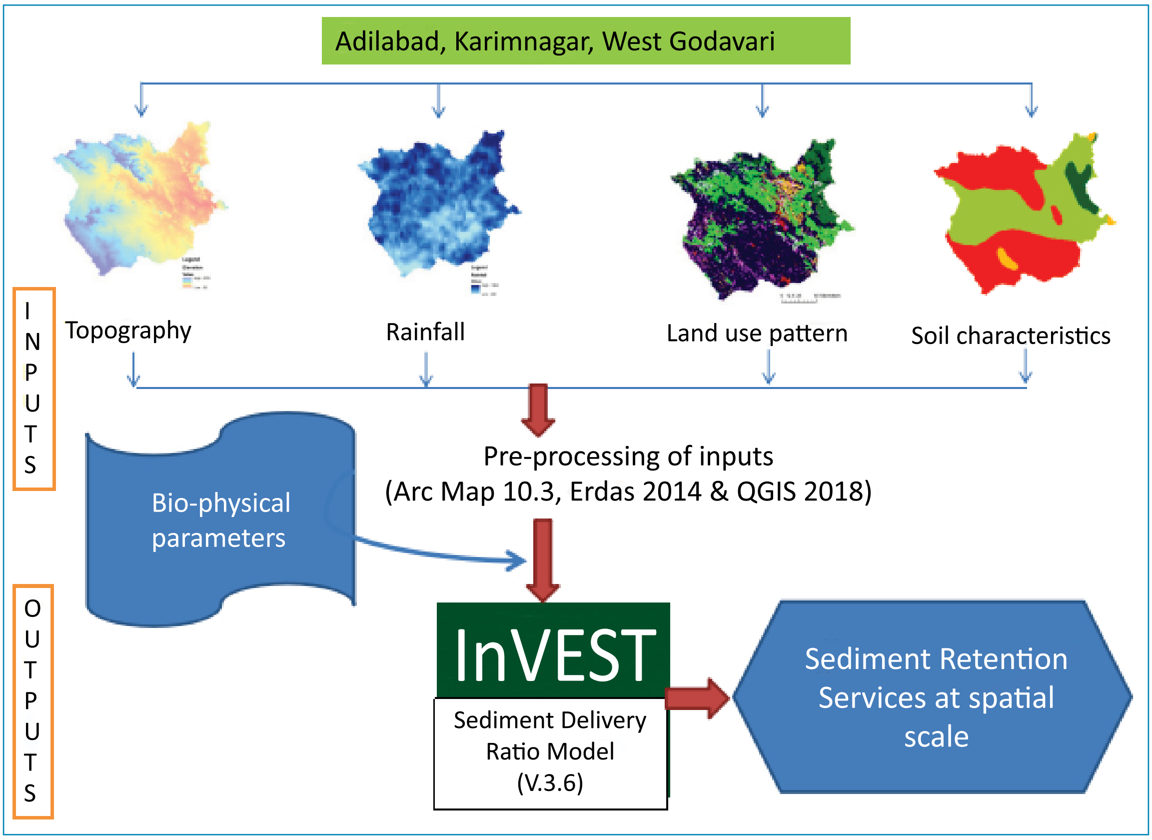


Fig. 3. Input data and conceptual diagram of Sediment Delivery Ratio module

silt/clay/organic carbon. Published procedures were used to derive values of cover management factor (C) and support practice factor (P) in the biophysical table and calibration parameter Borselli K. Other calibration parameters *viz.,* Borselli IC0 and SDRmax were set as default.

The model estimated total annual sediment export from the landscapes understudy were 2.23 t/ha/yr in Adilabad landscape while that of Karimanagar and West Godavari it was (0.72 t/ha/yr) and (1.29 t/ha/yr) respectively. About LULC classes, the top sediment exporting LULC class (total quantity) in Adilabad and West Godavari landscape was Deciduous Needle leaf Forest while in Karimnagar it was from Cropland. The estimated sediment retention of Adilabad, Karimnagar and West Godavari landscapes were 18.11, 6.49 and 11.95 MT/yr respectively. Further studies on the effect of conservation practices on sediment export/retention are in progress.

Soil Health Assessment. A conceptual framework for developing minimum data set of soil health indicators and management advisories was also developed. This framework enables identification of minimum data set of soil physical, chemical and biological indicators. The framework involves adapting the Distinctness, Uniformity and Stability (DUS) criteria used for plant variety regulation and protection as DUS (Soil) to represent Distinctness, Utility and Simplicity of soil health indicators. The six soil health indicators selected on this basis were texture, pH, soil carbon, water stable aggregates, porosity, and soil macro fauna. Each of the six indicators were classified into three classes for developing the field management schedules for each of the three levels of the six indicators. A database of management schedules for different combinations of the indicators status was also developed for Chittoor district. This framework is expected to be useful for complimenting the soil health card thrust in India.

International Centre for Tropical Agriculture (CIAT)

The International Centre for Tropical Agriculture (CIAT)is non-profit international agricultural research organization with a global mandate to conduct research on genetic resources of cassava, beans and forages, crop genetic enhancement and improvement, integrated crop management and sustainable management of natural resources. CIAT's mission is to reduce hunger, and poverty, and improve human nutrition in the tropics through research aimed at increasing eco-efficiency of agriculture. CIAT's has its headquarters in Cali, Colombia with staff and activities in locations across Africa, Asia and Latin America. CIAT is a member of the Alliance of the CGIAR Centres, a network of 15 research centres mostly located in the developing world and supported by more than 60 donor members. CIAT is privileged being under the Special MoU between the World Bank and the United Nations Development Program. CIAT office for South Asia is opened at NASC Complex, New Delhi.

CIAT works with hundreds of partners to help developing countries make farming more competitive, profitable, and resilient through smarter, more sustainable natural resource management. It helps policymakers, scientists, and farmers respond to some of the most pressing challenges of our time, including food insecurity and malnutrition, climate change, and environmental degradation. CIAT develops more resilient, productive, and profitable varieties of cassava and common bean, together with improved tropical forages for livestock. In Latin America and the Caribbean, CIAT also works to boost rice production and the competitiveness of the region's rice sector. These crops are vital for global food and nutrition security.

The Centre's Bioscience Platform includes the largest gene-bank in Latin America and advanced laboratories where scientists work to accelerate improvement. CIAT works with partners across Latin America to uphold international standards on biotechnology and helps train the next generation of scientists. CIAT's cross-cutting research on decision and policy analysis is aimed at harnessing the power of new information tools and participatory methods to influence decisions, practices, and policies on three key issues: climate change, ecosystem services, and linking farmers to markets. Through the close involvement of farmers, this work contributes to the development of policies that help boost productivity, efficiency, and sustainability, enabling farmers and governments to plan for the future. Catering to decision makers in the private and public sectors, CIAT provides novel and accurate information in interactive forms together with easy-to-use methods for analysing agricultural systems at all levels – from individual farms to entire continents.

CIAT produces scientific evidence and proposes concrete and viable solutions to sustainably manage agroecosystems and landscapes through research on three themes: soils and water management, landscape restoration, and ecosystem services and environmental impacts, and on the political and economic dimensions needed to support agricultural sustainability. With these elements, CIAT works on agricultural and livestock management and landscapes arrangements for maximizing food production, provision of ecosystems services (to and from agricultural landscapes), and the efficient use of resources (capital, labor, water, land, *etc*.), in a viable socioeconomic and competitive manner.

With this approach, CIAT is addressing the current paradigms for agricultural sustainability: sustainable intensification and landscape restoration. CIAT's gene bank maintains 67,700 samples, includes world's largest collection of beans and cassava (along with their wild relatives) as well as tropical forages. CIAT scientists use these collections to search for traits that can help breeders develop hardier crops. It also provides freely materials to researchers around the world under the terms of the United Nations' International Treaty on Plant Genetic Resources for Food and Agriculture. In addition, the Centre has deposited nearly 31,000 seed samples in the Svalbard Global Seed Vault as a safety backup.

CIAT's global research contributes to several of the United Nations' Sustainable Development Goals, and cuts across four key themes: big data, climate-smart agriculture, ecosystem action, and sustainable food systems. In India CIAT is working on identifying strategies for gender transformative climate information services. Rural information and advisory services have the potential to protect and empower women if they recognize these differing needs, and design services and communication channels to overcome the obstacles women face.

CIAT would continue focusing on developing high starch and waxy starch containing, and drought tolerant (water use efficient) cassava varieties, and high biomass, short duration maturity and high nutritive quality grass and legume forages for tropical regions, and bio-fortified Rajmah beans, including 'barbatti', which are preferred vegetables among the hilly and mountainous regions and tribal populations in India. CIAT has large collection of cassava, forages and bio-fortified beans in its Gene Bank and has specially designed programs in its Agrobiodiversity Research Area. In addition, in line with the recent discussions with ICAR's DDG Horticulture and Crops, CIAT would also be focusing on 'Phenomics' studies using ground penetrating radar mounted on small and medium load capacity drones for monitoring and control of pests in banana, cassava and other crops, and below ground biomass yield estimates, including carbon sequestration, with non-destructive methods. CIAT has pioneered in this area. As CIAT has also pioneered in Digital Agriculture, ICAR collaboration with CIAT will take up training of Indian scientists in this area, as well as in other thematic areas, including Big Data Analysis, Gene Editing, and Cassava Modelling. Additionally, the CIAT led work being carried out through CCAFS, Harvest Plus and WLE-CRP will continue throughout their life span.

CIAT has sequenced using next generation technology (Illumina) more than 1000 accessions and 500 breeding lines leading to the identification of crop's sub-populations and family structure, and that has significantly changed the breeding strategy. CIAT has in the past supplied about 120 accessions and 164 SSR marker tested pre-breeding line to CTCRI to develop cassava mosaic virus resistant, nutrient efficient and drought tolerant varieties for India. Seven Cassava varieties developed using this material have been locally released and are widely grown in Kerala, Tamil Nadu, Andhra Pradesh and Odisha. Some varieties also have low post harvest deterioration levels. The demand for high waxy starch containing cassava varieties for industrial uses is also being fulfilled by CIAT. As of now CTCRI maintains 7 sources of waxy starch; 3 varietal sources of small-granule starch; 10 landraces and 15 pre-breeding lines with PPD tolerance. Additional material with desired characteristics will be accessed from more than 6500 accessions maintained at CIAT Gene bank. CIAT has trained 15 scientists from CTCRI in the past at its HQ and other regions in different innovative technologies, such as marker assisted selection, crop modelling, *etc*.

India is deficit in fodder, both dry and green fodder, to the tune of 60% throughout the country except few states, and the deficit is more sever in semi-arid/arid, and sub temperate climates. CIAT and IGFRI have been collaborating on the exchange of tropical forages germplasm, and IGFRI scientists' participating in developing collaborative research programs, meetings and conferences. CIAT has a large collection of forage grasses and legumes as well as their improved varieties.

In a recent meeting (January 2020) with CIAT at IGFRI, the forage species identified are: *Pennisetum (bajra napier), Cenchrus ciliaris, Brachiaria sp, Stylosanthes, Centrosema molle, Cratylia argentea, Mucuna pruriens and Dismodium velutinum.* Some of these materials have been earlier supplied and evaluated, and others are being prepared by CIAT for shipment. Arrangements have also been made to supply the Brachiaria hybrids (apomictic) developed by CIAT, which do not have any IPR and royalty payment issues.

Rajmah and Barbatti are popular beans in India, of which, both dry grains as well as green pods are used as vegetables. While Rajmah is popular throughout the country, Barbatti is a preferred item among tribal populations. 'Kolar', a popular bean in the north-eastern region of the country is also a kind of Rajmah. In view of the importance of the Rajmah in human nutrition, CIAT has developed bio-fortified varieties and breeding lines and have provided them to the Indian Institute of Pulse Research for evaluation and further breeding to suit the local conditions. As the development of new material is continued at CIAT, new material will also be provided to the IIPR for multi-location testing.

CIAT- Cali has supplied a large number of the following: Advanced bio-fortified (Zn, Fe and Cu) bean (Rajma) lines, which also have other desirable characteristics, such as, higher yield, short duration, mildew resistance, and frost tolerance to the ICAR'S Pulse Research Institute. This is being evaluated. A set of cassava germplasm and pre-breeding lines for developing varieties with desired characteristics, such as small granule starch and CMD resistance.

A set of forages, including Brachiaria hybrids (apomictic) without having any IPR issues, with higher bio-mass, shorter duration and higher nutritive quality is assembled at CIAT HQ for shipment, respectively to CTCRI and IGFRI.

CIAT facilitated the participation of two Indian scientists in Big Data Analysis and of three scientists in Cassava research. In addition, another scientist from CTCRI participated in the ACIAR funded regional program on cassava in Laos. Likewise, CIAT scientist has provided orientation and on hand training to the staff from Banana Research Centre in December 2019. CIAT sponsored the visit of the ICAR'S DDG Horticulture and Crops to CIAT HQ advanced laboratories and discussions with the Research Area Leaders and the Senior Management for prioritizing collaborative themes and identifying new priority areas for collaboration.

Dr Anand Kumar Singh, ICAR Deputy Director General for Horticulture and Crops, and Dr Virendra Pal Singh CIAT's Regional Representative for South Asia along with Dr. Dindo Campilan CIATs Regional Director for Asia in year 2019 visited CIAT's headquarters in Cali, Colombia and had extensive discussions with the Research Area Leaders and the Senior Management and visited the laboratories and gene bank. The DDG lauded CIAT's collaboration with India and expressed hope that the Centre's contributions to food security, nutrition and economic opportunities in India will increase in the future. Government of India wants a more robust cooperation between CIAT and the national research institutions. The CIAT scientists have visited Indian partner research institutions, such as the CTCRI, IGFRI, and CIAT has also invited Indian scientists for planning details of the proposed collaboration.

The following are the main areas on which ICAR-CIAT collaboration focused research efforts in year 2019. The report includes four areas which were identified as the main ones during the ICAR Review during the year. The progress made under each area is briefly narrated below:

Germplasm transfer, including the processing of phytosanitary and other regulatory permits

Though the official ICAR-CIAT collaboration has been only for one year, the two institutions have historically been exchanging germplasm of forages and cassava over years. The protocol and other formalities for germplasm transfer of Forages, Cassava and Beans have been continually formalized according to the identified germplasm material to be brought into India.

Following the completion of the protocols, some of the germplasm material has been transferred to India and other is ready for shipment. In fact, a couple of cassava varieties having germplasm components from previously supplied CIAT material have been released and widely grown in India. The ready for shipment material has been cleared in Colombia and is awaiting receiving the import permit from Indian authorities. The details by commodity are below.

Tropical Forages: CIAT and IGFRI have been collaborating on the exchange of tropical forages germplasm, and IGFRI scientists' participation in developing collaborative research programs, meetings and conferences. The forage species identified through joint development of research are: *Pennisetum (bajra napier), Cenchrus ciliaris, Brachiaria sp, Stylosanthes, Centrosema molle, Cratylia argentea, Mucuna pruriens and Dismodium velutinum.* Some of these materials have been earlier supplied and evaluated.

The list of new batches (Table 6), including the Brachiaria hybrids (apomictic) developed by CIAT, which do not have any IPR and royalty payment issues, is ready for shipment. Their import permit is being processed by IGFRI. This batch also includes the material that has only 100 seeds in stock, and all the material meets higher bio-mass, shorter duration and higher nutritive quality parameters.

Table 6: List of new batches of forage seeds ready for shipment

S.N.	Species	Variety	Origin	Availability in stock	Amount to be shared with ICAR
1	*Canavalia brasiliensis*	CIAT 17009	CIAT Colombia	5 kg	100 g
2	*Centrosemamolle*	CIAT 15160	CIAT Colombia	5 kg	100 g
3	*Cratylia argéntea*	CIAT 22375	CIAT Colombia	5 kg	100 g
4	*Desmodium velutinum*	CIAT 33443	CIAT Colombia	200 g (~95238 seeds)	100 g
5	*Lablab purpureus*	CIAT 22759	CIAT Colombia	5 kg	100 g
6	*Stylosanthes guianensis*	CIAT 11995	CIAT Colombia	200 g (~80000 seeds)	100 g
7	*Leucaena diversifolia*	CIAT 17503	CIAT Colombia	5 kg	100 g
8	*Desmodium heterocarpum*	CIAT 13651	CIAT Colombia	200 g (~117647 seeds)	100 g
9	*Brachiaria brizantha* cv. *Toledo*	CIAT 26110	CIAT Colombia	Available	100 g
10	*Brachiaria brizantha* cv. *Piata*	-	CIAT Colombia	limited	100 seeds
11	*Panicum maximum* cv. *Mombasa*	-	Michael Hare, Thailand	In stock	Available
12	*Stylosanthes guianensis* cv. *Ubon*	CIAT 2340 (GC 1480), CIAT 11833 (GC 1463, GC 1517, and GC 1579)	Michael Hare, Thailand	In stock	Available
13	*Paspalum atratum* cv. *Ubon*	BRA 009610	Michael Hare, Thailand	In stock	Available

Cassava: CIAT has sequenced using Illumina technology more than 1000 accessions and 500 breeding lines, leading to the identification of crop's sub-populations and family structure, and that has significantly changed the breeding strategy. CIAT has in the past supplied about 120 accessions and 164 SSR marker tested pre-breeding lines to CTCRI to develop cassava mosaic virus resistant, nutrient efficient and drought tolerant varieties for India. Seven Cassava varieties developed using this material have been locally released and are widely grown in Kerala, Tamil Nadu, Andhra Pradesh and Odisha. Some varieties also have low post harvest deterioration levels. The demand for high waxy starch containing cassava varieties for industrial uses is also being fulfilled by CIAT.

As of now from the CIAT accessions supply CTCRI maintains 7 sources of waxy starch; 3 varietal sources of small-granule starch; 10 landraces and 15 pre-breeding lines with PPD tolerance; 150 sources of high b-carotenoid, 50 pre-breeding lines with resistance to whiteflies, 3 sources of stable dry-matter content, a pre-breeding population for drought tolerance; 5 materials with outstanding cooking qualities (15-20 min); and 2 sources of CMD resistance.

Additional material with desired characteristics is in the plan to be accessed from 6592 accessions maintained at CIAT Gene-bank (5709 clones on *Manihot esculenta* and 883 wild species).

Bean crop improvement, nutrition and abiotic stress management*:* These aspects are being taken up with the Indian Institute of Pulse Research. Rajmah, Barbatti and ''Kholar are popular beans in India, of which, both dry grains as well as green pods are used as vegetable. While Rajmah is popular throughout the country, Barbatti is a preferred item among tribal populations and 'Kholar', is popular in the north-eastern region of the country. Kholar is believed to be a kind of Rajmah and Barbatti, a kind of climber cowpea.

In view of the importance of the Rajmah in human nutrition, CIAT has developed bio-fortified (Zn, Cu and Fe rich) varieties and breeding lines and have provided them to the Indian Institute of Pulse

Research for evaluation and further breeding to suit the local conditions. This set of material also has other desirable characteristics, such as higher yield, short duration, mildew resistance, and frost tolerance. As the development of new material is continued at CIAT, based on the response and feedback from the previous assessment, new material will also be provided to the IIPR for multi-location testing. The Kholar germplasm has been collected from Nagaland and Mizoram and the seeds of 22 accessions, having varied grain size, color and cooking quality been purified and are being assessed through multi-location trials in these states. While the research on Rajmah and Kholar (as a sub-set of Rajmah) will be continued, studies on Barbatti will be taken up in subsequent seasons.

Inclusion of ICAR institutions (e.g. CTCRI, IGFRI, NBPGR, IIPR, and others) for capacity building

CIAT has included ICAR scientists from CTCRI, National Research Centre for Banana, IGFRI and IARI in various programs and interactions, including the Big data analysis concepts and protocols. The CTCRI staff was engaged in the national cassava research planning at CTCRI, and one of its staff was among participants in the Value chain development in Cassava in Laos. Similarly, the CTCRI staff was engaged in a two-day planning workshop by CIAT Cassava Physiologist at CTCRI in January 2020. The National Research Centre for Banana staff participated in Phenomics design and operations demonstration at the centre, and IARI staff in the Big Data analysis applications at Hyderabad. In continued efforts, CIAT has also in the past trained 15 CTCRI scientists at CIAT HQ and other regions in different innovative technologies, such as marker assisted selection, crop modelling, *etc*.

The entire IGFRI staff has recently (January 2020) been engaged on a three-day workshop at Jhansi on the research strategy and planning for forages research. The workshop was conducted by a team of five CIAT scientists. Similarly, three sub-training programs in Digital Agriculture, *viz.,* a viz Assessing Regional Challenges and Opportunities, Digital Agronomy, and Digital Phenomics have been prepared to be conducted in 2020 at Hanoi, Cali, and India, respectively. These activities are to be carried out through the support of ICAR. However, they have been delayed due to COVID-19 outbreak. There are plans to combine the Big data analysis in Genomics at the time of NBPGR staff visit, which may take place after the inauguration of the Future Seed Bank at CIAT HQ. This has also been delayed due to COVID-19 breakout. CIAT will however continue to include ICAR staff in all its relevant global and regional training programs, including the post graduate students in ICAR priority areas.

In response to ICAR suggestions during 2019 Annual ICAR-CGIAR Review, CIAT has in priority included all the three new areas (Future Seeds and Innovating seed banks, Training of Indian scientists in Impact Assessment, and ICAR participation in Food Systems and value chains) in the collaborative research portfolio with ICAR and its institutions.

The Future seeds and innovating seed banks are one of the flagship areas of CIAT HQ. Future Seed bank is completely solar powered, mobile modular with ceiling adjustments and water foot print positive facility. However, the completion of the construction of this facility has been delayed for few months, and so along with this are the other related and planned activities. This facility was expected to be completed in February 2020 but delayed due to COVID-19 outbreak. The visit and training of NBPGR staff will be assumed after the COVID-19 Pandemic is over.

The Asia Regional Climate and Ecosystems Scientist along with a senior researcher from CIAT had initial discussions with NCAEP, FAO, and IFAD regarding developing the Impact assessment protocol and conducting training for Indian scientists and take up key areas on a pilot basis. The training could be hands on in Hanoi, Vietnam, or in India. The Economist with his team was to return to India in mid-February 2020 to formalize the plan and take the process forward. However, as has been said before this is also delayed by the COVID-19 pandemic.

CTCRI senior staff has participated in a Regional Workshop in Laos on value chain development in Cassava, and three sub-sets of activities are slated to be undertaken in this domain. They would be cassava for food, cassava for livestock feed, and cassava for industrial uses. The former CTCRI Director has also on several occasions discussed and confirmed to take these channels.

CIAT through this collaboration will link up CTCRI with Roots and Tuber Research in the Philippines, Thailand and Indonesia; these countries having done extensive research in this area and have also developed several products at commercial level. Similar approach will be followed with other prioritized commodities by ICAR. Cassava research work, particularly with respect to livestock feed may be expanded in Mizoram and Nagaland in collaboration with the state governments.

Visit of CIAT scientists for planning, consultation and implementation

Fourteen senior scientists from CIAT have visited and spent time in developing detail work plan and implementing the plans with the Indian partners. They included a Senior Cassava Breeder; a Senior Cassava Physiologist, Head of the Decision and Policy Research Area, including Big Data; Leader, Asia Climate Policy Hub; Climate and Ecosystems Scientist; Agri-Food Economist; Forage Breeders, Soil Scientist, NR Specialist, and Regional Coordinator for South Asia.

Whereas other scientists visited in 2019, the visit of Cassava Physiologist, and a team of Forage Breeders and a Soil Scientist has been in the second week of January 2020. They spent 3-4 days at CTCRI and IGFRI, respectively during the initially scheduled ICAR-CGIAR Review which was to take place in January 2020. ICAR's DDG (Horticulture) spent a week at CIAT HQ, visiting laboratories and discussing programs, and has refined the collaborative research agenda. During these visits also emerged new areas (viz., Gene editing, Phenomics and Degraded lands management) and focused collaboration on Banana and Coffee.

CIAT has also included CTCRI in ACIAR funded South East Asian Regional Program on Cassava, and through this program linked CTCRI in other Cassava initiatives undertaken by CIAT in Thailand and Laos.

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

Established in 1977, the International Center for Agricultural Research in the Dry Areas (ICARDA) with its headquarters in Lebanon, is one of the CGIAR centers is engaged in developing and delivering science-led agricultural technologies in non-tropical dray areas, covers over 40% of world's land surface and targeting a population of >2.5 billion These areas grow 44% of the world's food and keep half of the livestock, yet one in six lives in chronic poverty. Dry areas invariably face major challenges, including insufficient rainfall, climate variability and change, land degradation, desertification, recurring droughts, temperature extremes, high population growth, widespread poverty, and unemployment. Additionally, dry areas are home to many fragile and post-conflict states that rely significantly on agrarian economies. To address these challenges and to achieve thriving and resilient livelihoods, ICARDA works in partnership with a wide network of national agricultural research systems (NARS), advanced research institutions, NGOs and private sectors.

With a mission to reduce poverty and enhance food, water, and nutritional security and environmental health in the face of global challenges including climate change, ICARDA through its 10-year strategy contributes to three major System Level Outcomes (SLOs): SLO 1-Reduce Poverty; SLO 2: Improve Food and Nutrition Security for Improved Human Health and SLO 3: Improve Natural Resource and Ecosystem Services. Its research agendas contribute significantly to UN-SDGs targeting no poverty, zero hunger, good health and wellbeing, gender equality, clean water and sanitation, climate action, life on land, and partnerships for impact. To attain such objectives, ICARDA focuses on building and maintaining scientific rigor and excellence in research and capacity development. This is being accomplished through five Strategic Research Priorities: 1. Collect, conserve, and use agricultural biodiversity; 2. Develop climate-adapted crops and livestock; 3. Build climate resilient, integrated crop-livestock farming systems; 4. Promote sustainable value chains, supportive policies and viable off-farm activities; and 5. Support sustainable use and management of scarce water and land resources. These are supported by four cross-cutting themes---scaling up of proven technological packages; gender equality and youth engagement; capacity development; and Bigdata and ICT. Through its decentralized research strategy, ICARDA ultimately focuses on resilient livelihoods in dry areas.

ICARDA is collaborating with ICAR since its establishment, but was confined to genetic enhancement of lentil, Kabuli chickpea and barley, and that too sharing international nurseries only. Through ICAR support, ICARDA opened its regional program (South Asia & China) based in NASC complex in late-2008, and its research platform at Amlaha, Madhya Pradesh in 2016 to expand research collaboration and capacity development programs. Ten ICAR institutions (IIPR, IIWBR, NBPGR CAZRI, IISS, IGFRI, IARI, CIAE, VPKAS, ICAR-NEH) and 13 State Agricultural Universities are effective partners in basic, applied and adaptive research. Research on genetic enhancement of lentil, grass pea, Kabuli chickpea, faba bean, barley, bread and durum wheat; adaptive research on exotic spineless cactus and date-palm; improving silvi-pasture system; enhancing economic water productivity through adopting appropriate crop models; Conservation Agriculture in pulse crops; and profitable alternative cropping systems are underway.

Over the years, ICARDA introduced several thousand genetic materials comprising of landraces and wild species, collected from the Fertile Crescent of Near-East, the region is known to be the Center of Origin and primary diversity of major legumes and cereals. possess enormous variability and rare alleles/genes which are being used by Indian breeding programs. Besides, trait-specific breeding lines and segregating populations constructed using exotic and Indian parents at Lebanon and Morocco have been introduced through International Nursery Network and as special nurseries on specific requests. A considerable number of varieties of lentil, Kabuli chickpea and barley have been released, many are in AICRP and Station trials by partner institutes, emanated from ICARDA-supplied genetic materials. Fifteen lentil varieties so far released by various national institutes using ICARDA genetic materials, adapted to north-west plain and hill regions, central zone and eastern Indian states. These varieties possess traits for phenological adaptation in varying agro-ecologies, resistance to an array of foliar and soil-borne diseases, farmer-preferred seed traits, and suitable to rice fallows and conservation agriculture. One of the ruling varieties, '*Moitree*', a small-seeded with early maturity is popular among farmers of West Bengal, Assam, Tripura and Manipur. Some of the varieties like IPL-220, Moitree, Pusa Ageti are biofortified with iron (up to 113 ppm) and zinc (up to 59 ppm), and their cultivation and consumption are contributing to address micronutrient malnutrition, the 'hidden-hunger'. The variety, 'IPL-316' is medium seeded (around 2.8 g/100seeds) is popular among farmers in Bundelkhand region. Recently released PDL-1 variety is adapted to saline and sodic soils has potential to grow in problematic soils. Besides, several promising lines have been developed which are in all India and station trials for future release. For Kabuli chickpea, ICARDA is targeting traits like bold seed (>45 gm/100-seeds), tall and erect type, frost tolerance and Ascochyta blight resistance. Seven Kabuli chickpea varieties have been released and are being cultivated by farmers. Barley improvement program is addressing feed, food, dual purpose and for malt quality and IIWBR is the main collaborating partner. Eleven barley varieties jointly developed and released for cultivation mainly in Uttarakhand, Himachal, Punjab and Rajasthan states.

India faces about 35% green fodder deficit and spineless cactus can be a potential alternative feed resource. ICARDA introduced 67 varieties in India from exotic sources (Brazil and Italy). Initial adaptation trials revealed that 12 varieties are well-adapted to Indian environmental conditions. ICARDA is working with IGFRI, CAZRI, CSSRI, BAIF and at FLRP-Amlaha to multiply and up-scale the potential varieties. The varieties are palatable and feeding trial at IGFRI has recommended 25-30% green chopped cactus in mixtures with cereal straw. In up-scaling, >189,000 cladodes are supplied to KVKs, district level foundation nurseries, Gram-Panchayat trials and farmers in Uttar Pradesh, Madhya Pradesh, Odisha, Gujarat and Maharashtra.

ICARDA South Asia & China Regional Program, and its on-the-ground research platform in Madhya Pradesh is collaborating with ICAR institutions and SAUs through its three research programs at the Center level: Biodiversity and Crop Improvement, Resilient Agricultural Livelihoods Systems, and Water, Land and Ecosystems. Scientists of these programs are closely working with partner institutions. On Pulses research, IIPR is the nodal institute with 12 other partners involved in lentil, grasspea, Kabuli chickpea and faba bean research on breeding, pathology, agronomy and research demonstrations across major pulse growing areas. On barley and wheat research, ICARDA is working with IIWBR and its partner centers in developing high-yielding promising lines with resistance to biotic and abiotic stresses and quality traits. Genetic materials bred and tested in Lebanon, Morocco, Egypt, Ethiopia and at its research platform in Madhya Pradesh are made available to respective collaborators. NRM research is being carried out with CAZRI, IARI, IISS and CIAE on water and land productivity, conservation agriculture and cropping systems.

Under ICAR-ICARDA work plan, the following five projects are in implementation in collaboration with ICAR institutions and several State Agricultural Universities.

- Identification and deployment of climate-smart traits in Indian Pulse improvement programs to enhance production and improving livelihoods and nutritional security
- Development and deployment of climate-resilient germplasm of barley and wheat for wide adaptation under climate change scenarios
- Improving farmers' income and livelihoods in rain-fed production systems through agricultural intensification and crop diversification
- Climate resilient and cost-effective technologies for rainfed regions

- Capacity development of young researchers and visits of policy makers to various International events for cross learning

Import of genetic materials: Under crop improvement program of legumes and cereals, 1868 germplasm, breeding lines and segregating populations comprised of 37 nurseries across lentil, grasspea, Kabuli chickpea, faba bean, barley, bread and durum wheat were introduced under International Nursery Network. Besides, 4857 lines of lentil, grass pea, faba bean, Kabuli chickpea, durum wheat, and 2 winter wheat nurseries from Turkey were introduced on special requests. The materials have been shared with partner institutes and a set was planted at FLRP, Amlaha. Additionally, selections made at ICARDA's research platform at Amlaha are shared with respective institutes as under:

Lentil: 20 lentil lines with tall, non-lodging and erect growth habit selected at FLRP and 44 lines from Morocco for suitability to machine harvest and herbicide tolerance provided to partner institutes. A total of 53 promising small-seeded lines with earliness (<105 days), Stemphylium blight resistance, heat and salinity tolerance, and a super-early (<85 days) Bangladesh variety 'Barimasur-9' have been identified at FLRP. Altogether, 96 elite lines are shared with IIPR, IARI, NBPGR, BCKV, OUAT, RAK College, CAU-Imphal, ICAR-Barapani.

In AICRP: Eleven promising lines**:** AVT-I (small seed)-5, IVT (Large Seed)-1, IVT (Rice fallow)-5

Lentil variety **PDL-1** is released by IARI adapted to saline and sodic soils. The variety is resistant to Fusarium wilt, rust, powdery mildew and Stemphylium blight under field conditions.

Kabuli chickpea: A total of 145 elite lines for early maturity (105-115 days); tall, non-lodging and erect growth habit, bold seed (>50 gms/100-seeds), and lines with higher podding intensity and yield potential were selected at FLRP, Amlaha and shared with IARI, PAU, JNKVV, RLBCAU, RAK college, BCKV, OUAT.

In AICRP: AVT-1 (6): PhuleG16315, PhuleG16318, BG4009, DK 16-313, DK-17-1306, DBGV503 and FLIP07-314C-S2, FLIP93-93C, FLIP09-272C-S3 lines are in Station trial at Rani Laxmi Bai Central Agricultural University (RLBCAU), Jhansi

Grass pea: Based on early maturity, (<120 days), high biomass (up to 6.5 t/ha) and seed yield (1.39-

1.67 t/ha), 120 promising lines were selected at FLRP and shared with IIPR, IGKVV, BCKV, NBPGR and OUAT.

In AICRP: ECEGP-61-1, a low-toxin line developed using ICARDA parent.

Faba bean: Faba bean lines were evaluated for early to medium maturity (115-120 days) and seed yield across all nurseries, and 26 elite lines were selected and shared with OUAT and BCKV.

Barley: 2214 lines across various trials were shared with national partners and evaluated at FLRP, where selections were made considering 2-row high input, 6-row high input and 6-row low input conditions. 630 lines selected by IIWBR scientists in Morocco and at Amlaha have been shared with IIWBR, CSKHPKV-Kullu, BHU and RARI.

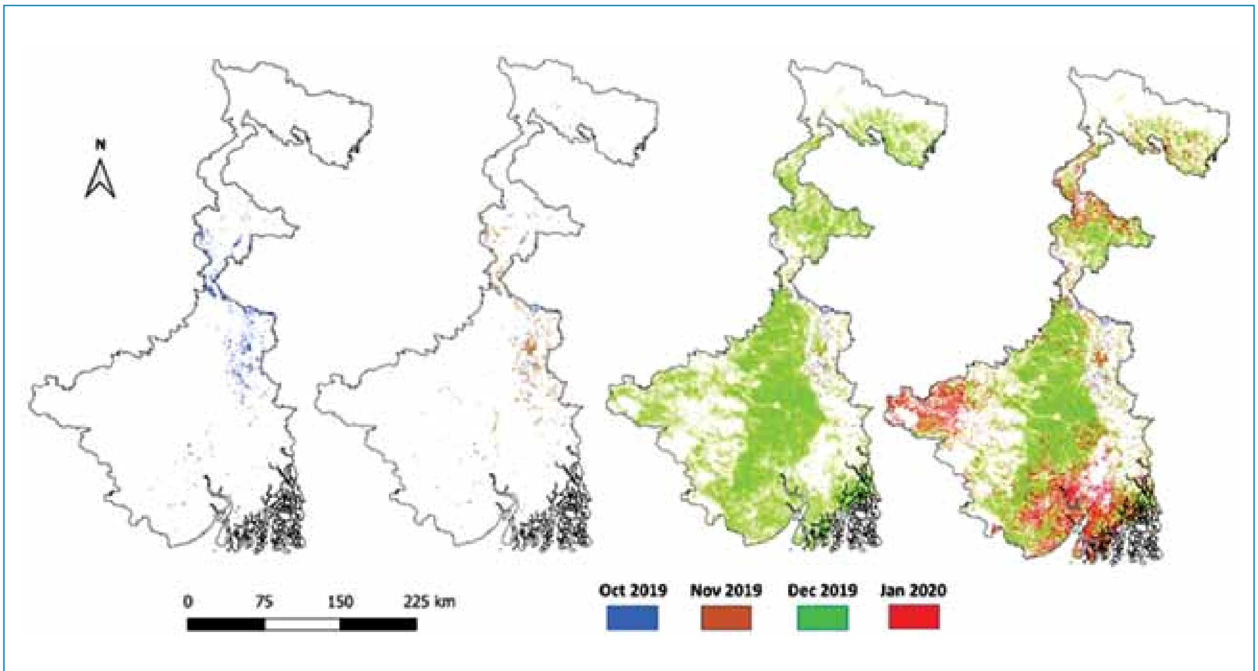
In AICRP: 31 elite lines are in AICRP (24 ICARDA lines as direct introductions and 7 used in crosses) out of total 85 total entries in 2019-20 under testing in All India yield trials.

Wheat: Thirty lines were selected at FLRP from 762 Global durum wheat panel and 72 lines selected by scientists of IARI and IIWBR having traits like water use efficiency, stay green, long spike, medium tall height, days to heading, erect spike, *etc*. have been shared. Two promising entries (Icavere, Margherita) selected by Dr Sai Prasad to include in IVT. 197 bread wheat entries in heat tolerance panel and 20 elite lines from international trials are made available to IIWBR.

Mapping of fallow lands for agricultural intensification and crop diversification

A substantial area (11.6 m ha) in India remains fallow after Kharif rice harvest. There is a national initiative to introduce pulses and oilseed crops in rice fallow lands to increase cropping intensity, and thus enhance farmers' income and household nutritional security. Rice fallow mapping is a pre-requisite to understand the dynamics of rice fallows, considering duration of fallow period, retention of residual moisture, soil characteristics which are important to select crops like lentil, grasspea, chickpea, *etc*. To accomplish this, ICARDA is engaged in mapping rice fallow in the state of West Bengal.

Remote Sensing's wide area coverage, synoptic view and availability of temporal data makes this technology an indispensable tool for agricultural monitoring as well as for decision making. The maps illustrated here show the rice fallow dynamics in West Bengal during October 2019 – January 2020. These maps are generated by analysing the temporal data of Sentinel-2 satellite imageries. These maps demonstrate that during October and November, very less rice fallow fields were present (rice was still in-field), whereas during the month of December, most of the rice cultivating areas reflect fallow land.



Mapping of rice fallows and computation of duration of rice fallow land, synchronized with the availability of soil moisture for a site can be comprehensively utilized for intensification.

Decision tool for mapping suitability of Cactus cultivation in India

ICARDA conducted a study on land suitability for cactus (*Opuntia ficus-indica*) cultivation in India. Nine essential growth factors that includes climate and edaphic components were considered for the period 2000 to 2007. The results of the cactus suitability map show that about 32% of the total geographic area of the country is in the 'high (3%) to moderate suitable (29%)' category. For the remaining area, 46% falls under the 'marginally suitable' category and 22% under the 'low suitable to very low suitable' category. An automated Decision tool was developed and released (Beta version) or Cactus cultivation in India.

Promotion of spineless fodder Cactus

To address fodder deficiency in India, ICARDA introduced 67 diverse spineless cactus varieties from FAO-ICARDA Cactus nursery, Italy and EMBRAPA, Brazil. Nurseries have been developed at IGFRI, CAZRI, CSSRI, BAIF, and at ICARDA-FLRP, Amlaha. Initial adaptation trials revealed 12 varieties performed well under Indian environmental conditions considering morphological traits, such as plant height, number of cladode/plants, cladode length and width, biomass, root surface area, volume and root length. Experiment on time of planting suggests that July planting is the best when there is enough soil moisture for initial establishment. Feeding trials with goat, sheep and cattle at IGFRI recommended 25-30% chopped cactus cladodes mixture with cereals straw or other feed resources.

To date, 189,000 cladodes have been provided to Gujrat, Maharashtra, UP, MP, Odisha states to develop Foundation Nursery and Gram Panchayat Nursery and to farmers to plant in degraded lands. Foundation Nurseries are established in Balangir, Balasore, Koraput, Mayurbhanj, Rayagada, Kalahandi, Khorda, Ganjam, Khandhmal, and Nayagarh districts on Odisha; Bhuj district of Gujrat; Nagpur and Amrabati districts in Maharashtra; and Hosangabad, Katni, Datia, Jhansi, Panna, Sagar, Tikamgarh, Umaria, Ashoke Nagar and Guna KVKs in MP and UP. Besides, Cactus varieties have also been provided to farmers in these states.

Climate resilient and cost-effective technologies for rainfed farming

Introduction of different high yielding pulse crop varieties s and innovative CA-based technologies in cereal-based rainfed cropping systems for northwest and eastern India to evaluate the most productive, resource-use-efficient, and remunerative cropping systems to achieve higher productivity and profitability maintaining the natural resource base.

For north-west rainfed conditions: -application of residue mulch in zero tillage @ 3 ton/ha in pearl; millet-chickpea cropping systems is most effective for improving physical, chemical and biological properties of the soil and obtaining higher yield and net returns under North-west rainfed condition.

For the eastern rainfed conditions: growing of rice-chickpea cropping systems with rice residue mulch in zero tillage at 3 ton/ha is the better option for realizing higher productivity, resource use efficiency and net returns in eastern rainfed conditions of the country. The above finding is recommended to farmers.

Zero-tillage in Soybean field in Madhya Pradesh: RVL-31 lentil variety is best performing (1.43 t/ha)

Improving Crop-water productivity of *Khadin* systems in Rajasthan

Growing crops, vegetables, annual and perennial fruits is traditional *Khadin* cultivation system in Rajasthan for higher production and profitability is an important program which is being pursued with CAZRI. Assured supply of water to the crops can be ensured by constructing water storage structures at a suitable place in the *Khadin* bed and resupply of water for irrigating the crops when need arise (supplemental irrigation to primarily rainfed crops). Two experiments are undertaken to increase the crop-water productivity of *khadins*. These experiments are a) Growth and yield of chickpea, wheat, mustard under limited irrigation in *Khadin* system of Jodhpur, Rajasthan; and b) Yield of different crops under guava-based system with harvested rainwater (outside *khadin*) in the arid regions of Jodhpur, Rajasthan. Farmers received higher production from less use of water. However, the experiment is continuing and recommendations on profitable crops with economic water productivity will be made available to farmers.

Capacity development

ICARDA is engaged in research and capacity development of young scientists as per its mission and mandate. A group training on food legumes was organized in Lebanon, where four young scientists from IARI, RLBCAU, ICAR-NEH and IIPR participated. Besides, wheat and barley scientists from IIWBR and IARI were trained on wheat and barley in Morocco. A PhD student affiliated with Hissar Agricultural University was trained on barley breeding using molecular markers, and quality aspects in Morocco. In addition, 24 students are pursuing higher studies in BCKV, BU, Banasthali University on breeding, agronomy, physiology and pathology. To get acquainted with ICARDA's research activities, six senior scientists and policy makers from IIPR, IIWBR, CAZRI, IARI, BCKV visited Lebanon and Morocco research activities and interacted with scientists to develop future joint research programs. ICARDA also supported three scientists from IIPR, IGFRI and NBPGR to attend international conferences.

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

The International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) conducts agricultural research for development in the semi-arid or dryland tropics of Asia and Sub-Saharan Africa. ICRISAT is the only CGIAR centre headquartered in India (Hyderabad, Telangana). It has two regional hubs (Nairobi, Kenya and Bamako, Mali) and several country offices (Niger, Nigeria, Zimbabwe, Malawi, Ethiopia, Tanzania and Mozambique) in Sub-Saharan Africa. ICRISAT envisions a prosperous, food-secure and resilient dryland tropics. To achieve this, its mission is to reduce poverty, hunger, malnutrition and environmental degradation in the dryland tropics. It approaches this through partnership-based international agricultural research for development. ICRISAT conducts research on six highly nutritious drought-tolerant crops that includes grain legumes (chickpea, groundnut, pigeonpea) and dryland cereals (sorghum, pearl millet, finger millet). It also develops sustainable farming practices for the semi-arid tropic systems through efficient management of natural resources. ICRISAT also supports policies and institutional innovations for improving livelihoods of the smallholders; and in achieving food, nutrition and health security while protecting the environment in the dryland areas.

The partnership between ICRISAT, ICAR institutes and State Agricultural Universities has been very effective in crop improvement. ICRISAT has regularly supplied germplasm and diverse breeding materials of these crops to crop breeding programs in India, that have led to release of 362 varieties/hybrids (46 in chickpea, 54 in pigeonpea, 35 in groundnut, 44 in sorghum, 181 in pearl millet, and 2 in finger millet) in the country. Several of these varieties/hybrids have been widely adopted and contributed to increasing productivity and production. For example, the chickpea varieties developed through ICAR-ICRISAT partnerships accounted for 53% of the total indent of chickpea breeder seed in India for 2019-20. The most popular varieties developed through ICAR-ICRISAT partnerships include JAKI 9218, JG 11, JG 14, RVG 203, Nandyal Gram 119 (NBeG 119), Phule Vikram, Nandyal Gram 49 (NBeG 49), JG 130, JG 6, NBeG 47, and RVG 201. With collaboration and support of ICRISAT, two chickpea varieties -"Pusa Chickpea - 10216" (drought tolerant) and "Super Annigeri-1" (Fusarium wilt resistant) developed through genomics-assisted breeding have been released in 2019 (https://www.icar.org.in/content/development-two-superior-chickpea-varieties-genomics-assisted-breeding). Similarly,

in pigeonpea, the varieties and hybrids developed through ICAR-ICRISAT partners accounted for 52% indent of the breeder seed for 2020. The popular varieties and hybrids included Rajeev Lochan, Asha (ICPL 87119), TJT 501, Rajendra Arhar, Jawahar Tur JKM 189, MARUTI (ICP 8863), LRG 52, PRG 176, TS 3R, Pusa 991, and ICPH 267. In groundnut, ICAR-ICRISAT partnership varieties constituted 17% of total breeder seed indent for the year 2018.

In pearl millet, about two-thirds of the hybrids grown in India include ICRISAT-bred hybrid parents. These hybrids have contributed to tremendous on-farm cultivar diversity and prevented the outbreak of major downy mildew epidemics. In sorghum, over 2 m ha are covered by over 50 hybrids that were developed based on ICRISAT-bred parental lines or their derivatives. The widely adopted sorghum hybrids include JKSH 22, VJH 540, JKSH 234, JKSH 434, MLSH 296, VIKI 540, GK 4009, and GK 4013.

In the recent years, remarkable progress has been made in the development of genomic resources of these crops. The ICRISAT-ICAR partnership together with several other Indian SAUs and partners have generated the genome sequences of pigeonpea, chickpea, pearl millet as well as the resequencing of germplasm collection of pigeonpea, chickpea and pearl millet. Accessibility to high-throughput genotyping platforms has made it possible to develop high density genetic maps. Markers linked to genes and QTLs involved in traits of interests have been identified using genetic mapping or association mapping. These markers are being used in molecular breeding of these crops. Innovations in high throughput phenotyping platforms, bioinformatics, digital data capture, data management, and breeding management system are helping in modernization of breeding programs.

This phase of ICAR-ICRISAT collaborative projects is for five years starting from 2019 and includes (i) Genetic improvement of grain legumes and dryland cereals for improved adaptation, yield potential and quality traits; (ii) Ag-biotech traits, new breeding techniques (NBTs) and enabling technologies for grain legumes and dryland cereal crop pipelines; and (iii) Integrating systems analysis and modelling tools to identify interventions that enhance farming systems resilience and nutrition sensitive agricultural value chains in semi-arid regions of India.

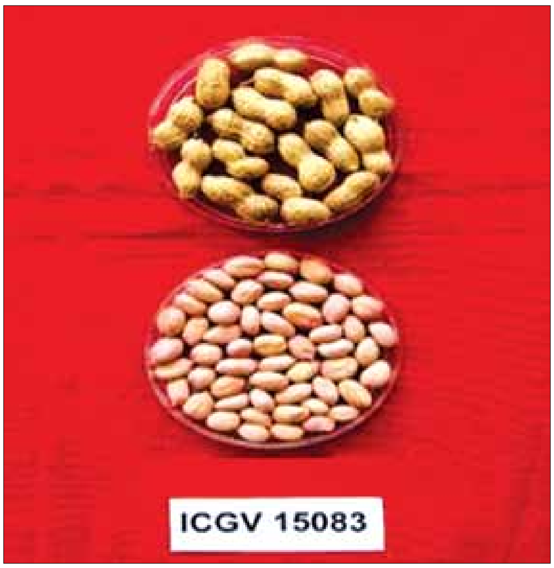
Genetic improvement of grain legumes and dryland cereals for improved adaptation yield potential and quality traits

This project focuses on using integrated breeding approaches for accelerated development of improved breeding materials with diverse traits such as high yield potential, improved tolerance to abiotic and biotic stresses, resilience to climate change, labour-saving traits, market-preferred grain traits, and improved quality of produce. This project has been organized under six sub-projects representing ICRISAT's six mandate crops - chickpea, pigeonpea, groundnut, sorghum, pearl millet, and finger millet.

The key objectives of the sub-project on chickpea include (1) Machine harvestable, high-yielding breeding lines with resistance to fusarium wilt; (2) Early- to extra-early varieties with drought and heat tolerance for rice fallows and new niches, (3) Enhanced resistance to dry root rot (R), Ascochyta blight (AB) and Botrytis grey mold (BGM); (4) Enhanced protein, iron and zinc content; and (5) Sharing of knowledge, breeding materials and human resource development. During 2019, four chickpea varieties, two machine-harvestable (BG 3062 and Phule Vikram) and two from marker-assisted breeding (Pusa 10216 for drought tolerance and Super Annigeri-1 for FW resistance) were released by the Central Varietal Release Committee (CVRC). These were identified for release during Annual Group Meet of All India Coordinated Research Project (AICRP) on Chickpea held during August 27-29, 2019 at Ranchi. Promising breeding lines with combined tolerance to terminal drought and heat stresses were identified. ICRISAT supplied 54 Advanced breeding lines through three International Trials (ICVT-Desi, ICVT- Kabuli and ICVT- Mechanical harvesting) to 29 locations in India. In addition, 3344 samples of breeding lines selected by scientists during Chickpea Scientists' Meet at ICRISAT-Patancheru, and 633 samples of segregating populations and 86 samples of breeding lines requested by scientists were also supplied. A total of 78 advanced breeding lines generated from ICAR-ICRISAT collaborative research were under evaluation under different AICRP trials during 2019-20.

In a pilot experiment conducted during 2019 to compare the potential of genomic selection (GS) for chickpea improvement by ICRISAT and ICAR-

IARI, initial results suggest that selection efficiency of GS over phenotypic selection has advantages of time and screening efficiency. With AICRP-Chickpea, activities on the expansion of a training population for optimization of GS for Indian chickpea breeding program was initiated. A set of 200 promising genotypes that were used as parents during the past 10 years in the chickpea breeding program at ICRISAT were developed as a training population for implementing genomic selection to improve chickpea yields. A total of 30 SNP markers associated with drought (24 SNPs), and Fusarium wilt (6 SNPs) resistance QTLs were identified and tested on the respective panels of diverse genotypes. A set of seven SNPs were identified using QTL-seq for heat tolerance. Re-screening for BGM at Pantnagar confirmed resistance in three pre-breeding lines (ICCP 171033, ICCP 171418 and ICCP 172606) that were used in the crossing program at GBPUA&T, Pantnagar. A total of 28 dry root rot tolerant lines identified were evaluated at four hot spot locations in India, and the promising lines were shared with breeders for use in crossing programs. For establishing the national baseline for nutritional traits (protein, iron and zinc), a set of 50 released varieties of chickpea was established in collaboration with AICRP-Chickpea and ICAR-IIPR. ICRISAT together with ICAR-IIPR and other partners completed whole genome sequencing of 429 lines and identified key candidate genes (REN1, β-1, 3-glucanase and REF6) which can help crops tolerate high temperatures and provide higher yields. Furthermore, chickpea reference set was used for identification of markers associated with key nutrition traits. Large phenotypic variability was observed for 11 nutritional traits including protein content, iron, zinc, beta-carotene, phytic acid and vitamin B in the chickpea germplasm. More than 3,000 seed samples, including advanced breeding lines, trait-specific donors and segregating population were supplied to 25 chickpea breeding programs in India. Eight students are conducting research works on chickpea improvement towards the fulfilment of their Ph.D. and Master's degrees. Seven scientists from ICAR-IARI and ICAR-IIPR were trained on the Digitalization of Breeding Programs & Data Management (BMS).



The sub-project on groundnut has the following main objectives: (1)Develop and release varieties containing high oleic acid; (2) Improve resistance to diseases and diversify the genetic base for resistance; (3) Adaptation to water deficit stress and other environment constraints through characterizing target population of environments (TPEs) and water-deficit patterns in TPEs and identifying traits for adaptation to TPEs; (4) Conduct early generation testing in target sites to fix favourable allele combinations for adaptation to target zone and to new/emerging zones; and (5) Sharing knowledge, breeding materials and human resource development. The first 'high oleic' groundnut varieties were identified for release in India during 2019, a result of collaborative work of ICAR-DGR, SAUs and ICRISAT since 2011. A sound and fast-track breeding strategy that involved genotyping with linked markers for early generation selection, robust phenotyping using NIRS (near infrared reflectance spectroscopy), rapid generation advancement in glasshouse to increase the number of cycles per year from two to three resulted in development and commercialization of agronomically superior high oleic groundnut lines within a short span of eight years. Girnar 4 (ICGV 15083) and Girnar 5 (ICGV 15090) has ca. 80% of oleic acid content of the total fat as against normal groundnut varieties that have ca. 48% oleic acid. Over 100 new high oleic acid lines were shared with collaborators in Africa and other countries in Asia. ICAR-DGR and ICRISAT are engaging in increasing the Nucleus Seed to make it available for cultivation and further seed increase. The high oleic groundnut varieties are preferred by food-industry for enhanced shelf life benefits and consumer health benefits. A high oil groundnut variety, GJG 32 (ICGV 03043) is becoming popular in Maharashtra and Telangana states for high yield and disease resistance and driving new industry options like cold-press oil as the percent oil extracted is higher to an extent of 6-10% compared to normal varieties. Combining production and market traits into a single variety has key area of focus to deliver groundnut varieties for different agro-ecologies in India and meet the industry needs.

The high-quality reference genome assemblies for both the subspecies (hypogaea and fastigiata) of cultivated groundnut were developed and millions of structural variations in the genome identified for use as genetic markers. Sequencing-based mapping approaches used for performing genetic and genomic analysis leading to discovery of candidate genes and linked markers for shelling percentage, seed weight, fresh seed dormancy and resistance to foliar diseases, peanut bud necrosis and stem rot. Three seasons of phenotyping data for heat tolerance on RIL population at Patancheru and 2nd season phenotyping for drought tolerance on MAGIC population at UAS-Dharwad were completed in addition to sequencing of these two genetic populations. Second season phenotyping for A. flavus infection and aflatoxin content completed for 800 Aflatoxin MAGIC lines at ICRISAT. Transcriptome analysis for preharvest-aflatoxin contamination (PAC) and aflatoxin production lead to the discovery of candidate genes and pathways involved. In order to develop improved training population for genomic selection, DNA was extracted from ~1000 breeding lines for genotyping in addition to completing phenotyping data on these lines at ICRISAT-Patancheru. Cost-effective SNP-genotyping tools were used for early generation selection for FAD2B mutant allele for high oleic trait and two major QTLs for rust and late leaf spot (LLS) and the SAUs could take advantage of the services provided by m/s Intertek. Similarly, NIRS was used to select for FAD2A mutant allele and the services at ICRISAT were extended to SAUs for ca. 2,500 samples. A new laboratory assay (detached stem/branch) based on oxalic acid response was standardized to rapidly screen groundnut genotypes against stem rot pathogen (*Sclerotium rolfsii*), which has emerged a major biotic constraint. To broaden genetic base of resistance to late leaf spot and rust, new interspecific derivatives from sources other than *Arachis cardinasii* were used in breeding programs. Further, stem rot resistant introgression lines derived from wild Arachis species have been identified for use in groundnut breeding programs.

The annual Groundnut Network Group-Asia (GNG-A) workshop and Scientists' field day was held on 26-27 September 2019 to engage with private sector and to review the ongoing collaborative work, seek feedback to design Product Profiles, variety development strategy, testing, advancement, and delivery. Fifteen researchers and eight private seed/food/oil industry representatives from India participated in the workshop.

The key objectives of sub-project on pigeonpea include (1) Development of FW and SMD resistant early (120-140 days) and mid-early (141-160 days) maturing varieties and parental lines of hybrids; (2) Development of super-early varieties of pigeonpea for non-traditional areas; (3) Development of efficient cytoplasmic male sterility (CMS) system and identification of fertility restorers; (4) Development of improved tolerance to phytophthora blight; (5) Development of high yielding mid-early hybrids of pigeonpea for central and southern zones; and (6) Sharing of knowledge, breeding materials and human resource development. During 2019, four super-early (ICPL 11255, ICPL 11301, ICPL 20340 and ICPL 11273), one mid-early variety (ICPL 15010), in addition to eight hybrids (ICPH 2431, ICPH 3310, ICPH 3481, ICPH 4788, ICPH 3782, ICPH 3933, ICPH 4200 and ICPH 4788) in short and medium-duration, and six pre-breeding lines, ICPL 15010, ICPIL 17116, ICPL 15072, ICPL 15062, IBTDRG 8 and IBTDRG 10 in mid-early and medium maturity duration groups were included in IVT, IHT and AHT1 of AICRP on pigeonpea. About 239 advance breeding lines, hybrid parental lines and hybrids in medium-duration, mid-early duration, early-duration bred for FW and SMD resistance along with and super-early lines were shared with AICRP partners. Total of 45 resistant lines identified at ICRISAT has been evaluated with National partners at 14 hotspot locations under AICRP disease nursery trials. In addition, 10 multiple disease resistant (phytophthora blight, wilt and SMD) lines identified at ICRISAT through repeated screening has been evaluated with national partners (6 hotspot locations) for identification of stable phytophthora blight resistant lines. High yielding multiple diseases (Fusarium wilt, and Sterility Mosaic Virus) resistant pre-breeding line ICPL 15028 derived from *C. acutifolius* is being used as a donor in the national crossing program of India. Evaluation of pre-breeding populations for phytophthora blight under sick-plot at PAU

Ludhiana identified two lines ICPP 171328 and ICPP 171266 having resistance both at seedling and adult plant stage. These two lines belong to early- to mid-early maturity group with non-determinate growth habit. Trial of 16 advance breeding lines with resistance to FW and SMD in mid-early duration were evaluated at 8 locations viz; IIPR, Bhopal; ARS, Badnapur; MPKV, Rahuri; RAK, Sehore; OUAT, Berhampur; BAU, Ranchi; UAS, Bangalore and RARS, Nandyal during 2019. Promising lines were selected by centers for further used in their breeding program.

To introgress fusarium wilt and sterility mosaic disease resistance QTL in elite pigeonpea cultivars, 27 elite pigeonpea cultivars were crossed with ICPL 20096 (donor parent for FW and SMD resistance. F1s were crossed with recipient parents to generate BC1F1 and seeds are harvested. 10 SNPs each for fusarium wilt resistance and sterility mosaic diseases resistance screening are validated and available on HTPG platform. The BC1F1s generated will be screened with trait associated markers to identify heterozygote plants carrying FW and SMD resistance alleles. Towards marker-assisted selection for important traits, a set of ~90 lines were screened with the INDEL and SNPs markers to identify fertility restorer lines. Based on analysis, 2 InDels (RFQ_1) and RFQ-_4) and six SNPs (snpCC009, snpCC019, snpCC013, snpCC016, snpCC017, snpCC018 markers associated with Rf (for A4 system) are identified for fertility restoration. Also, a SNP-based QC panel of 48 SNPs has been developed at HTPG and 384 elite breeding lines, parental lines and F1s were tested for its polymorphism. BMS was used for creating all trials and nurseries. On advanced bioinformatics support, collaboration has been initiated and several experiments were planned and executed, and data is currently being acquired and analyzed. Pigeonpea workshop cum field day was also organised at ICRISAT, Patancheru during 17-18 December 2019. Over 40 Scientists from ICAR, SAU and Private seed companies participated in this event.

The sub-project on sorghum has the following major objectives: (1) To diversify the rainy season sorghum cultivar base to break the yield plateau and develop new red grained sorghum hybrids with improved grain mold resistance and anti-oxidant properties; (2) To diversify the genetic base of postrainy sorghum for higher yield and quality, development of dwarf restorer lines with high restoration percentage and

Red gain sorghum for brewing and animal feed – 1.5 times higher iron and 2.0 times higher zinc, 72% starch

lines with high productivity under drought; (3) Improved sweet/high biomass sorghum cultivars and hybrid parents developed for higher sugar and biomass yield and assessed the biofuel production potential; (4) Genetic dissection of priority traits in sorghum and accelerating genetic gains in sorghum by using genomics and molecular breeding tools; and (5) Sharing of knowledge, breeding materials and human resource development. New crosses were made with elite *caudatum-durra* lines and selected *guinea* race germplasm accessions with maintainer reaction to diversify the seed parental lines. Similarly, crosses were made for restorer's diversification. ICSV 15013, a red grained OPV with higher grain yield potential and higher grain Fe (50 ppm) and Zn (40 ppm) is under ICRISAT and ICAR-IIMR joint testing. Large-scale seed production of the ICSV 15013 was undertaken at ICRISAT during 2018-19 postrainy season for further testing in multilocation trials in Maharashtra (Parbhani and Akola) towards their commercialization in the next 1-2 years. Grain mold resistance identified (both in white and red grain), IS 20740 was found resistant with 2.0 score (on 1-9 scale) and 10 lines showed moderate resistance with 4-5 score. In Post-rainy sorghum, a new crossing program was initiated between elite postrainy B&R-lines with bold seeded *durra* B&R-lines respectively that have origin in ESA/Yemen, for diversifying the genetic base of postrainy sorghum. To scale the dissemination of improved cultivars, under the postrainy sorghum seed consortium partnership, more than 1000 tons of certified seed was produced in farmer fields (in Western Maharashtra and Marathwada) and procured by Mahabeej (public sector seed corporation) and supplied the seeds to 100,000 farmers in 2019.

During 2019, 150 high biomass yielding sorghum lines identified that have more than 55% IVOMD, the highest among them reached 61%. These lines will be commercialized after appropriate multi-location testing and also, they form good source materials to develop improved forage lines in near future. In sweet sorghum, 50 sorghum lines were developed that have more than 22% brix content. Among them, the line with highest brix% recorded was 24%. All these can be used for commercial ethanol production. These lines can give up to 56 lit of ethanol per ton of green stalks compared to 45 lit per ton in currently available cultivars. Deploying marker in breeding, more than 40 elite sorghum lines are being introgressed with *bmr 6* and *bmr 12* sources to reduce the lignin content in the biomass. Designed SNPs with a set of diverse circa 370 hybrid parental lines (both B- and R-lines) helped to short list linked 12 SNPs is now ready for genotyping. Genomic selection in sorghum was done using multi-location phenotyping data together with genotyping data (2,000 informative SNPs covering entire genome) of the training set encompassing ~300 lines. Second year phenotyping data has been generated in 2019 and the data is being analyzed to improve the accuracy and identify the best genomic prediction models. A Sorghum Scientists Field day was organized during February 2019 where the 35 public sector partners and 15 private sector partners were participated, and we've shared with them 2500 sorghum lines of their choice.

The major objectives of sub-project on pearl millet include (i) Develop hybrids for drought-prone environments in A-1 zone through enhancing genetic diversity of hybrid parents (both seed and restorer parents) to develop hybrids for drought-prone environments; (ii) Support and monitor grain micronutrient traits (grain Fe and Zn) in NARS breeding programs; (iii) Characterization of blast and DM pathogens from different millet ecologies and identification of resistant sources for different isolates/pathotypes, and mapping, validation & deployment of QTLs for blast and downy mildew resistance; (iv) Generate and disseminate cultivars and hybrid parents for high biomass and better forage quality; and (v) Sharing of knowledge, breeding materials and human resource development. About 260 hybrid parental lines (seed and restorer parents) bred for drought adaptation/traits were evaluated at about 10 AICPMIP sites and promising lines were selected by centers for future use. Additionally, selections were made in populations and breeding materials bred for drought ecologies in collaboration with CAZRI under shuttle breeding mode, and promising lines were identified and advanced. Also, 20 promising multi-cut forage pearl millet cultivars were evaluated during summer season and promising ones were identified; and various forage pearl millet nurseries are currently being evaluated with IGFRI. Also, 345 entries from the pearl millet inbred germplasm association panel (PMiGAP) were screened for seedling-stage heat tolerance, to identify alleles for high seedling-stage heat tolerance. Major loci for general combining ability (GCA) and specific combining ability (SCA) were mapped for yield and yield-related traits. Also, major effect QTLs for downy mildew resistance (DMR) for the three new pathotype-isolates were mapped. Promising molecular breeding products in HHB 67 Improved and GHB 538 genetic backgrounds were tested in the EDV trial during rainy season 2019. A panel of 10-SNPs was used to select the drought tolerance alleles from the national breeding programs of the A1 zone. A SNP-based QC panel of 54 and 48 SNPs have been developed from the re-sequencing data of the ~1,000 genomes project. The two 54 and 48 SNP panels were used for assay development using diverse hybrid parental (B- and R-) lines with Intertek. Information on pearl millet heterotic gene pools was generated and published. Also, information on GS model was generated and the model was strengthened considering G×E interactions.

To strengthen the biofortification breeding, 20 High-Fe inbred lines were contributed to the Elite Inbred Joint Biofortification Trial. ICRISAT analyzed about 2,300 pearl millet grain samples from AICPMIP trials for Fe & Zn to help in the entry promotion process. 18 hybrids developed under biofortification project were contributed to the different AICRP-PM trials. QTLs for high grain Fe and Zn content from AIMP 92901 were targeted for the development of SNP markers, and this population is currently being genotyped using GBS platform. To improve the phenotyping for nutritional traits, Harvest master has been standardized for on-field harvest assessment of grain moisture, density and quantity.

To enhance disease tolerance research, 27 isolates of DM pathogen and 41 isolates of blast pathogen were collected, and pure cultures established. Eleven of the 27 DM isolates were found virulent on all the nine differential lines. Nine of the 41

Pearl millet variety Dhanshakti with high grain iron content of 72 ppm

blast pathogen-isolates have been characterized for virulence diversity, and characterization of remaining isolates is in progress. Four pre-breeding populations derived from P. *violaceum* were screened against five pathotypes of blast to identify resistant sources for use in pearl millet breeding programs. Also, major effect QTLs were mapped for downy mildew resistance (DMR) for the three new pathotype-isolates. The largest observed phenotypic variation (R2 of 76.6%) was contributed by the QTL on LG4 for the Sg519 isolate. The mapped and validated 863-P2 LG4 blast resistance QTL is being targeted for development of SNP markers. Double QTL downy mildew resistant hybrids in GHB 538 genetic background were developed and evaluated in multilocation trials at the disease hot-spot locations of Gujarat. The double QTL downy mildew, and high grain Fe and Zn density test-cross hybrids in the HHB 67 Improved genetic background performed very well in the national

varietal testing system under AICRP-PM. These molecular breeding products are being considered for possible release at the State and/or National level(s).

ICRISAT supported AICPMIP for conducting "Estimation of Genetic Gains Trial" at about 30 sites in A- and B- zones during rainy season of 2019. Also, a SNP-based QC panel of 54 and 48 SNPs has been developed. Germplasm lists were curated and imported in BMS for some centres, while two workshops were conducted on Digitalization of Breeding Programs & Data Management with the involvement of AICPMIP scientists.

The sub-project on finger millet has the following objectives: (i) To develop blast-resistant short- (90-100 d) and medium-long (105-130 d) duration varieties of finger millet; (ii) To develop finger millet varieties with drought and heat adaptation; (iii) To develop nutrient-rich varieties of finger millet for high iron, zinc and calcium; and (iv) Sharing of knowledge, breeding materials and human resource development. Blast is the major disease that affects finger millet. To identify sources of resistance, 52 germplasm lines including three checks were screened at three hotspot locations (Vizianagaram and Peddapuram in Andhra Pradesh; and Ranichauri in Uttarakhand) and at ICRISAT-Patancheru. While the data from the hotspot locations is awaited, the Patancheru location trial revealed that Katila and GPU 28 (check variety) exhibited resistance to finger blast (≤10% incidence). All the other lines at this location exhibited more than 10% neck blast resistance. In another trial with 22 lines at same locations identified 14 lines with finger blast resistance (≤10% incidence) and one line (IE 2911) with neck blast resistance (≤10% incidence) at Patancheru location, while the data from the other locations is awaited. Work on developing hybridity confirmation markers is in progress with a set of 15 lines from the current multi-location trial and 34 varieties. Drought tolerance is an important trait for assured yields in rainfed crops. To identify sources of drought tolerance, 16 mini core entries were evaluated with four released varieties. Out of them, IE 4057 was superior to the best check in terms of yield, while five accessions showed tolerance to drought.

In the changing climate, especially in southern India, heat tolerance is gaining importance. From summer 2019 screening of 382 F5 lines, 12 lines were identified showing tolerance to heat. The results were like 2018 summer screening. A strategy for screening RIL population for heat tolerance at hotspot location was developed. New crosses were initiated using germplasm lines to tap variability for grain nutrition (Ca, Fe, and Zn). A calibration curve for non-destructive analysis of grain nutrition in finger millet is being prepared using released varieties and germplasm lines through XRF machine. A set of 300 germplasm accessions developed and evaluated during 2019 at Patancheru in this regard. Estimation of all major and minor elements from first year trial is in progress. During 2019, one staff member and one student from ICAR-AICRP on SM were trained at ICRISAT-Patancheru on genotyping for blast resistance. A training course on “Advanced Genomic Tools for Crop Improvement” was co-organized during November 25-28, 2019 at Bengaluru involving students and scientists from ICAR and SAUs.

Ag-biotech traits, new breeding techniques (NBTs) and enabling technologies for grain legumes and dryland cereal crop pipelines

The sub-project on “Transformative strategies for accelerated breeding pipelines by optimizing speed-breeding / rapid generation turnover methods in grain legumes and nutri-cereals” is on infrastructure development as well as test bed optimizations for regionally adapted germplasm for mainstreaming the Rapid Generation Turnover (RGT). The effects of varying photoperiod and temperature and plant growth regulators (PGRs) on rapid cycling for chickpea, pearl millet and groundnut were optimized for accelerated breeding cycles. The standardization of photoperiod and temperature and plant growth regulators (PGRs) on rapid cycling for a panel of 16 chickpea varieties representing all agro-climatic zones in India was carried out. On an average, 60-95% flowering was induced under the RGT conditions. Of the 15 varieties tested, 6 showed 70 to 100% flowering within a range of 32-35 DAS, the generation time for these genotypes that normally have 100-120-day cycle was reduced to 60-70 days. The long duration genotypes that normally fall under 120-150-day duration class were reduced to 70-80 days. Similarly, the “recipes” for enabling pearl millet was developed in temperature-controlled culture rooms supplemented with LED lights at a temperature of 35/30 °C temperature (day/night) to optimize early flowering and seed harvest at different plant densities to enable rapid cycling of large populations, which is ideal for single seed descent (SSD). In groundnut, three short duration cultivars (less than 90 days duration), Three Medium duration cultivars (100-120 days) and two long duration cultivars (120-140 days) were studied for recipe development. Culture conditions were set between 28/25 °C temperature (day/night) and photoperiod of 12 h to create conditions that leads to early flowering and seed harvest. Within 32 to 36 days, 50-100% entered into reproductive phase treated with PGRs, with no flowering induction under control conditions. These methods are now being standardized with a range of genotypes with different durations. Exposure visits for facility and recipes organized for NARS during three field day visits during 2019.

The sub-project on New Breeding techniques (NBTs) for addressing rancidity in pearl millet for enhanced flour shelf life addresses the problem of rancidity in pearl millet that is a big impediment towards producing commercialized ready-to-cook and ready-to-eat products from pearl millet. Over 30 pearl millet lines stored at accelerated

Recipe Development for Rapid Generation Methods for Accelerated Breeding Pipelines in Test bed Optimization Chambers storage conditions (35°C & 70% RH) for 21 days were analyzed for rancidity indicators. Significant diversity in both oxidative and enzymatic rancidity profile was observed among the selected lines. While acid value showed a continuous increase, enzyme activities increased up to 10th day and then declined gradually. There was also a significant change in the flour odour and taste while becoming rancid with variance of humidity, temperature and the genetic background. However, the rancidity-induced olfactory variations were slow in samples stored at accelerated conditions when compared to the samples wetted with 30% water. Based on the biochemical and organoleptic study, qualitative and quantitative relationships between rancidity indicators are being established during the study. From this subset, a few contrasting lines were subsequently used for systematic analysis of lipase genes, their phylogeny, molecular modelling and docking analysis to assess their affinity for fatty acid ligands. Further the expression analysis of the selected candidate genes was done in different stages of pearl millet seed development, such as milky seed stage, immature seed, mature seed, fresh flour and different intervals of post seed grinding flour. In addition, expression analysis in other tissues such as leaf, root and germinating seed was undertaken to rule out the possibility of their KO hampering vital functions. Protocol for high throughput transformation method in pearl millet is being standardized using immature embryo and leaf segment explants. A 15-day international hands on training program on gene editing technologies was conducted where ten ICAR scientists participated.

The sub-project on Biotechnological approaches for intractable traits in pigeonpea and chickpea for insect resistance and groundnut for resistance to aflatoxin contamination targets two of the most important constraints in these crops. For insect resistance, over 76 putative pigeonpea transgenics developed during 2018, 29 expressed the *cry1Ac2Aa* gene. From these, 18 events were screened for western analysis and seven were identified to be positive. ELISA revealed T2 and T3 progenies carrying *cry1Ac2Aa* in the range of 0.18% to 2.53% of total soluble protein. Based on kanamycin screening method, about 75 kanamycin resistant plants of 18 events were obtained and undergone for molecular characterization by PCR with gene specific primer and 38.66% (29/75) plants showed PCR positive. The well-established plants were transferred to pots and grown in glass house for further studies. All the PCR and ELISA positives plants were subjected to detached pod bioassays which revealed low pod damage rating (25% - 43%) & higher larval mortality (50%-100%) in 9 *cry1Ac* events. Two *cry1Ac* T_6 events (13-1-9-3-8 R8 (code 6158) & 13-1-9-3-1-5) out of these 9 are promising with 83.3% & 100% larval mortality respectively as compared to untransformed control (0%). The application to transfer three (3) stable pigeonpea *cry1Ac* events are now being worked on with IIPR for its transfer to carry out CFT at IIPR. In parallel, *Agrobacterium*-mediated genetic transformation work on chickpea genotype JG11 was carried out to develop newer events for higher expression of gene against *Helicoverpa armigera* resistance using stacked gene construct carrying the Bt genes *cry1Ac2Aa* driven by *35s* double promoter under *pCAMBIA2300*. Molecular characterization has been carried out for these plants and the PCR positives are planned for the detached leaf bioassays. Work is underway to identify more *cry1Ac2Aa* chickpea events with higher protein expression levels by ELISA & Western Blot Analysis.

For aflatoxin resistance, fifty-one F1 seeds of groundnut from eight cross combinations using three elite parents, ICGV 15083, ICGV 03043, ICGV 86015 as the female parent and four transgenic events, two each of defensin and HIGS construct as male parent were advanced to F2 in P2 containment facility at ICRISAT. Subsequently F2 progeny from eight cross combinations using three elite parents, ICGV 15083, ICGV 03043, ICGV 86015 as the female parent and events, two each of defensin and HIGs construct as male parent were characterized based on PCR with gene specific primers (defensin and host-induced silencing; HIGS genes). Overall 40 F2 progenies found to be positive with defensin gene specific primers. The seeds from these F2s were evaluated for aflatoxin resistance, and 55 F2 lines with Def4Ec and 8 F2 lines with HIGS transgene showing aflatoxin content below 20 ppb were transferred to P2 containment facility at ICRISAT. Based on PCR with gene-specific primers, selected F2 plants carrying defensin and HIGS gene in three different backgrounds ICGV 03043, ICGV 15083 and ICGV 86015 were advanced to F3 and backcrossed again with the respective background to obtain F2BC1 seeds. Additionally, a comparative proteomic study has been carried out between JL24 (susceptible) and transgenic OE-Def (resistant) peanut lines adopting a gel-free comparative proteomics to unravel the molecular mechanism behind the seed resistance to *A. flavus* infection to provide significant additional insights compared to the canonical 2-DE-based proteomic exploration. Over 1079 proteins in control and 1103 proteins in transgenic showed differential expression compared to their respective uninoculated controls. Besides, of the six groundnut transgenic events with 4 RNAi constructs in T2 generation, screened under in vitro aflatoxin bioassays, 2 events showed aflatoxin content below 10 ppb. Further molecular characterization of these events using gene-specific primers is underway

Integrating systems analysis and modelling tools to identify interventions that enhance farming systems resilience and nutrition sensitive agricultural value chains in semi-arid regions of India

Whole-farm bio-economic modelling as decision support: Integrated farming systems models were parameterized for 4 districts as decision support system collaboratively with KVKs in Maharashtra, Andhra Pradesh and Telangana. The bio-economic household system model was used to assess the trade-offs and synergies within integrated crop-livestock systems (Figures 4 and 5). Three hands-on training workshops were organized for CRIDA team on integrated whole farm modelling (CLEM/IAT) between June and December in 2019. The CRIDA team now have hands-on capacity to parameterize and run the farming system model. A need-based capacity building activity was also initiated for one CRIDA scientist on cropping systems modelling (APSIM) which will take some time to develop hands-on capacity. The teams of both IARI and CRIDA have completed data collection from their respective project location and were supported for parameterization the whole farm models. We collaborated with IARI team to organize workshop on integrated whole farm modelling on 20th November 2019 at IARI, New Delhi for participants from ICAR and SAUs. A half day orientation workshop on systems modelling was also organized at IIFSR, Modipuram on the 13th February, 2020, where it was agreed to build capacity of a team of scientists of AICRP-Integrated Farming Systems on the use whole farm modelling as a decision support. One Masters student of Sustainable Development from TERI, Delhi was also trained on systems analysis looking at sustainability of farming systems from January to May 2019.

Systems dynamics modelling for value chain analysis: Significant efforts during the current year resulted in development of an initial system dynamics (SD) model for rabi sorghum value chain analysis using available data. A few initial simulations were run to evaluate impact of different policy interventions to test the model. Now we are

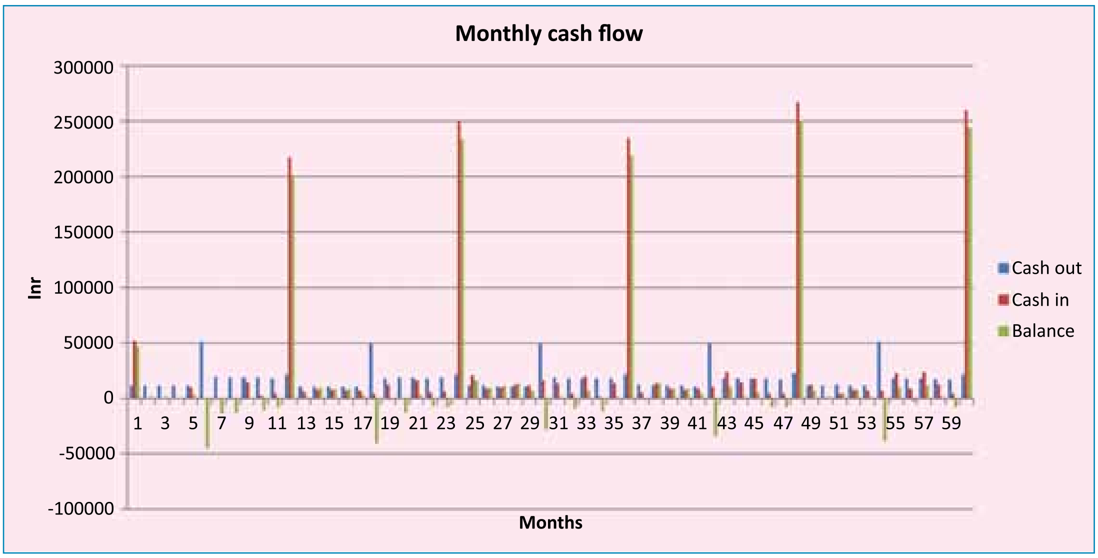


Fig. 4. Whole farm model results on monthly cash flow in farming system for a five years' time horizon, Suryapet district, Telangana (INR)

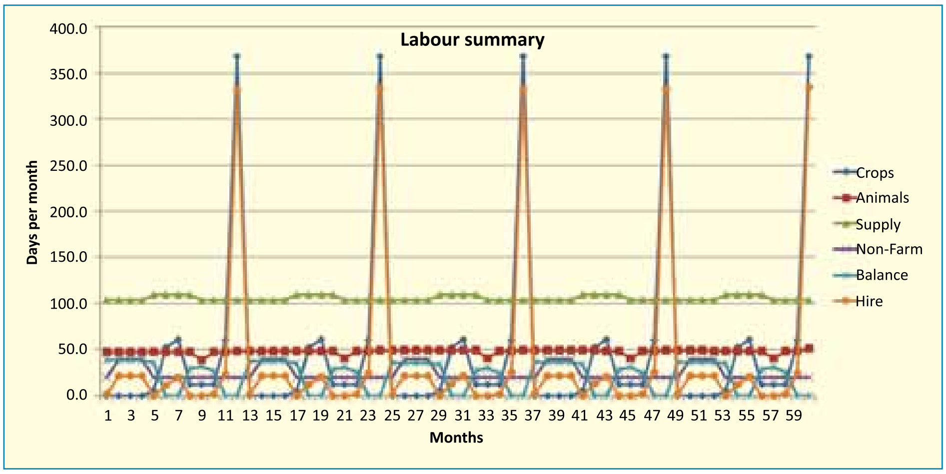


Fig. 5. Whole farm model results on monthly labour use in a farming system for a five years' time horizon, Tirupati district, Andhra Pradesh (Days)

collecting data from all the nodes of the sorghum-dairy value chain starting from production to consumption including processing and trade from major sorghum producing states to develop a fully validated model. A five days' capacity building training on 'system dynamics modelling for value chain analysis' provided hands-on skills to the participants from ICAR and SAUs. As a result, NIAP team has started building SD model for potato value chain for western Uttar Pradesh and IVRI team has now been working on buffalo value chain using the SD model. An advanced training on system dynamics modelling was organized from 9-13 December for two PhD students' one each from TNAU, Coimbatore and UAS, Dharwad. The students were supported in conceptualizing SD models for value chain analysis; one on Fodder sorghum value chain in Tamil Nadu and another on pigeon pea and ragi (finger millet) value chain in Karnataka. Two Master's student of Public Policy from NLSU, Bangalore were also trained as an intern on sorghum value chain and understanding impact of shocks on farm households.

Capacity building activities

- ICRISAT organized a training course on Next Generation Genomics in which more than 60 young scientists from India were trained during Feb 10-15, 2020.
- ICRISAT organized a webinar on Next Generation Genomics and Integrated Breeding for Crop Improvement which had 3388 participants from 68 countries (2917 from India) on May 14, 2020.
- One scientist from IIPR is being hosted at ICRISAT as a part of ICAR FORCAS Attachment trainee program.
- ICRISAT (with CSIRO) organized a 5-day hands-on training workshop on 'Integrative value chain analytics supporting food systems transformation- Application of System Dynamics Modelling for Value Chain analysis' with 22 NARS participations from NIAP, IARI, TNAU, UAS, Dharwad, CRIDA, Indian institute of Soybean Research, Indore and IVRI, Izatnagar; 27-31 May, 2019.
- Four short term training programs on Whole farm systems modelling were organised by ICRISAT with CRIDA and IARI between June to December 2019.

International Food Policy Research Institute (IFPRI)

Food and nutrition security are a complex and multidimensional issue. This is especially true for South Asia, where 40 percent of the world's poor—who survive on less than US$1.25 a day—live and 21 percent of the population is undernourished. Yet countries in South Asia have seen marked improvements in socio-economic developments in recent years. While agriculture is a critical component of food and nutrition security, it is interlinked with water, energy, infrastructure, and policy challenges. Apart from this, natural resources are under additional pressure from population growth, income growth, urbanization, changing consumer preferences, and climate change.

Against this backdrop, the IFPRI South Asia Office (SAO) in New Delhi engages in evidence-based policy research and capacity-building activities related to food and nutrition security in the region. This research focuses on agricultural diversification, climate change, markets and trade, nutrition and health, science and technology and governance. IFPRI's strategy identifies six research areas focused on (i) Ensuring Sustainable Food Production; (ii) Promoting Healthy Food Systems; (iii) Improving Markets and Trade; (iv) Transforming Agriculture; (v) Building Resilience; and (vi) Strengthening Institutions and Governance

IFPRI is based in Washington DC, USA and has a strong presence throughout the developing world, with regional offices and project offices across Africa and Asia. The offices provide local partners with broad access to IFPRI while allowing the Institute to better align its work with the needs of the regions and individual countries. In 2005, IFPRI established its South Asia Office in New Delhi. Cutting the ribbon at the opening ceremony, the then Indian Prime Minister Dr. Manmohan Singh signalled the importance of IFPRI's collaboration with national agricultural research system (NARS) in addressing the region's development challenges. Hope for a world in which hunger, malnutrition, and poverty are distant memories is reflected in IFPRI's mission to seek sustainable solutions for ending poverty and hunger from the world.

Current research priorities of the South Asia Office include agribusiness and smallholder farmers, food and nutritional security, climate change, governance issues, water use/scarcity, gender and malnutrition. IFPRI conducts all its researches in close partnership with the national agricultural research system with ample emphasis on capacity development of its partners. Since its inception in the 1970s, IFPRI has had strong collaboration with Indian Agricultural Policy Research. This is evident from a rich set of published research from IFPRI researchers on India. This note highlights a few of the flagship activities undertaken during last year.

Estimating returns to research investments

IFPRI has conducted a study on estimating returns to public expenditure in Indian agricultural and its relationship with public investment and input subsidy. The research outputs provide insights about prioritizing public investments based on their contribution in agricultural growth and poverty reduction. Our studies have shown that investment in agriculture research pays high dividends in enhancing efficiency and reducing poverty. In addition to analysing the impact of public expenditure, we also analysed the changing composition of private investment in Indian agriculture and its relationship with public investment. The key findings under this activity include:

i. The rate of growth of private investment in agriculture has gained momentum from 2000s except in Odisha, Himachal Pradesh and Jammu & Kashmir;
ii. The increase in investment is concentrated in sectors such as land improvement, machinery-

implements, tractors, and livestock; and

iii. Private investment is facilitated by public investments in agriculture, irrigation and by input subsidies.

The outputs from this activity includes two IFPRI discussion papers and four research articles in peer-reviewed journals. A total of four newspaper articles have also been published to sensitize the policy makers and stakeholders.

Mapping adoption of improved varieties of cereals and horticulture crops

Adoption of improved agricultural technologies is an important pathway for increasing productivity and breaking the vicious circle of poverty in the developing countries. Technological innovations have played a prominent role in the agricultural growth of India. During 2017- 18, we conducted survey of about 30,540 farmers on varietal adoption surveys of cereal crops. The findings from surveys are very encouraging with respect to adoption of improved varieties. Output from this activity includes seven discussion papers. The key findings under this activity are below:

i. Highlights the positive impact of adoption of improved varieties / hybrids on a range of farm level outcomes—yield, profit, revenue, and the operational cost.

ii. Farmer's decision to adopt improved variety is strongly related to the adoption choice of social network members.

iii. Huge potential for innovators to serve as the focal point of the source of information for the farmers to diffuse the technology in a speedily manner.

iv. To boost the diffusion of technology, strengthening extension services, and encouraging farmer's interaction in Krishi Vigyan Kendra as well as in Agricultural Fairs/ Exhibitions is critical.

v. The household-level differences explain 69 % of the variation in the area under modern varieties of paddy, 53 % in the case of wheat and 37 percent in the case of maize.

vi. Adoption study is useful to research organizations to develop appropriate research programs and projects to promote adoption of newer varieties.

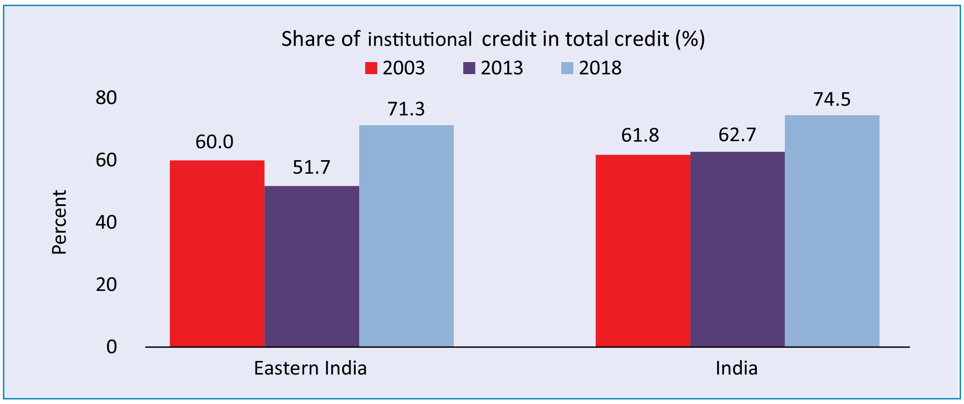
IFPRI is now focusing on the adoption and impact of modern varieties of selected horticultural crops. In consultation with Deputy Director General (Horticulture), a set of horticultural crops—Banana, Brinjal, Onion, Potato and Tomato—have been selected for the study. In 2019, varietal adoption surveys of horticulture crops were conducted in six states and in 2020 the survey is being conducted in seven states.

Constraints to green revolution in eastern India

Financial inclusion

Eastern India is lagging in agriculture sector as compared to other parts of India. The region is bestowed with best of resources, but agricultural performance has been poor despite government commitments. In 2018-19, the primary surveys were conducted to assess the impact of credit on rice and wheat productivity and rural households' income. Around 5000 farm households and 400 bank functionaries were interviewed from Bihar, Eastern Uttar Pradesh, Jharkhand, Odisha and West Bengal. The access to institutional credit in eastern India has the potential to increase:

i. rice and wheat yield by 11.9 and 11.0 percent, respectively; and



ii. household income by about 19 percent.

However, access to credit affects recipients heterogeneously which means differential approaches for different categories rather than a "one-size-fits-all" approach.

Rural non-farm employment

The importance of rural non-farm employment (RNFE) has witness accelerated growth over time. The same trend was witness in eastern India. Our study shows that diversification towards RNFE increase rural household income and reduce rural poverty. However, the impact depends on the type of engagement in RNFE. For instance, the participation in regular salaried job in non-farm sector increases the household income by 50 percent while the self-employed in RNFE increases household income by 16 percent. However, casual labourers engaged in non-farm activity continue to be vulnerable.

Output from the activity includes three research papers, one discussion paper and three newspaper opinion pieces.

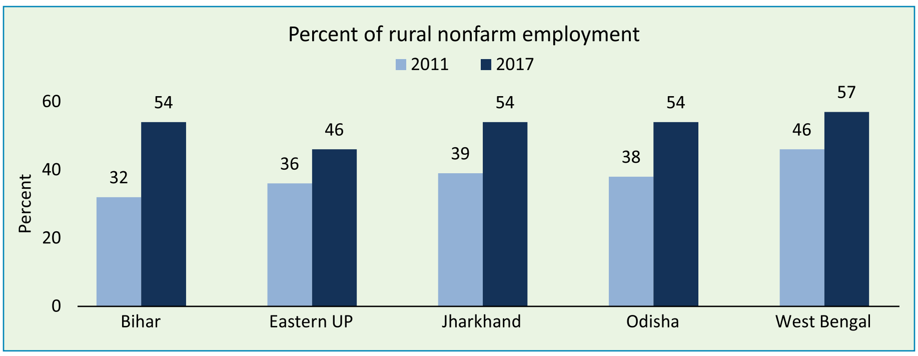
Impact of KVKs on farm households' economic welfare

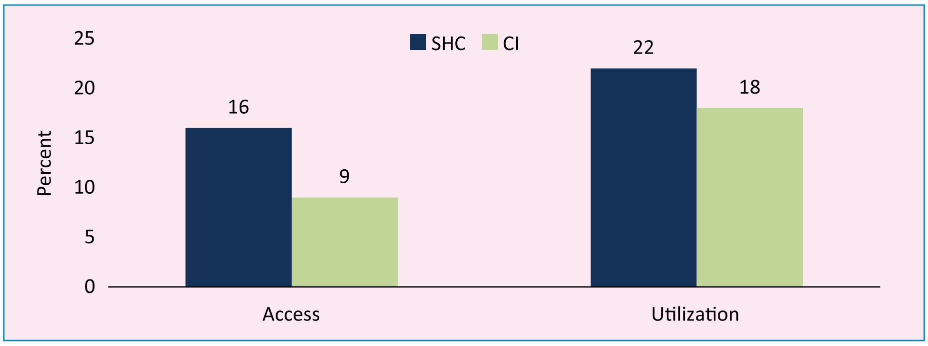
There is a large network of Krishi Vigyan Kendras (KVKs) across the country with primary mandate of technology assessment and demonstration. These are also engaged in quality seed production and distribution, frontline extension activities, identifying and documenting farm innovations and converge with ongoing schemes and programs of national importance. Despite their widespread presence and multi-faceted roles, policy makers often question their relevance and efficacy. IFPRI undertook comprehensive study on measuring impact of KVK activities and their processes in improving wellbeing of farmers. The study on impact of KVKs was completed and the report was jointly published as ICAR-IFPRI discussion paper. We found a significant positive impact of KVK on farmers' economic welfare and the benefit-cost ratio for expenditure in KVKs is 8 to 12, implying that in KVK an expenditure of Rs 1 yields at least Rs 8, which is a significant return.

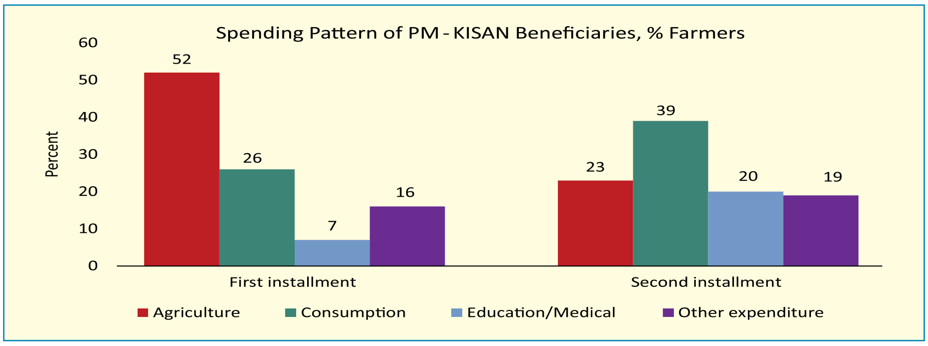
To supplement the macro level impact, IFPRI conducted a survey on KVKs in 2019 in Uttar Pradesh. The impact indicators were broadened to include the role of KVKs in disseminating Soil Health Card (SHC) and adoption of crop insurance. In addition, the survey also focused on the role of Pradhan Mantri Kisan Samman Nidhi (PM-Kisan) on KVK beneficiaries. A total of three joint discussion papers were published under this activity.

The study on SHC and crop insurance found positive impact on access to SHC for farmers and its utilization for better nutrient and fertilizer management and significant impact of KVKs on access of crop insurance. For improving efficacy, the result shows a positive impact for SHC. From policy perspective, the importance of KVKs are quite salient for improving the implementation and efficacy of agricultural schemes. Therefore, there is a need to expand the scope of KVKs through expanding its operation focused on the agricultural schemes.

PM-Kisan scheme aims to provide income support to farmers for easing their liquidity needs to facilitate timely access to inputs. This study examines the targeting accuracy and correlates of spending pattern of farmers. The findings from PM-Kisan study highlighted the following: (a) scheme reached to one-third farmers in first three months itself of its implementation, (b) significantly helped those who are relatively more dependent on agriculture and have poor access to credit and (c) stimulated the KVKs impact for the adoption of modern cultivars.







Farmers Producer Organizations (FPOs)

IFPRI initiated a study to understand the condition for the success of Farmer Producer Organizations (FPOs) in India. Field surveys have been carried out in two states—Bihar and Maharashtra—which focused on understanding the heterogeneity in the evolution and functioning of FPOs at the grass root level. FPOs have emerged as an important institutional mechanism to enhance farmers' access to markets, deal with challenges of product aggregation, and minimizing the transaction costs in accessing markets. The Government of India has been placing increased emphasis on expanding the network of FPOs. The study has been completed and a policy note has been prepared. One research paper and newspaper article has also been published on this theme.

The positive impact of FPOs are a) adoption of technologies, b) uptake of good agricultural practices, c) increase in productivity and gross income, d) reduction in cost of production, e) other benefits are like new information on cheaper inputs, better capacity to deal with risks of pest attacks and collapse in market prices *etc*. However, there are some challenges poses to FPOs are a) limited extend of technology adoption, b) high cost of technology, c) limited attraction through product differentiation, d) dynamism in leadership and e) lack of proper monitoring and evaluation.

Bio-fortified staples

IFPRI has conducted a study on exploring opportunities for introducing biofortified staples in diets of poor in Bihar and Odisha. The findings reveal the following**:**

a) replacement of ordinary variety of wheat with the zinc- and iron-rich variety WB 02 is likely to increase zinc intake by 31.3 percent and iron intake by about 33.3 percent.

b) replacement of ordinary variety of rice with the zinc-rich variety DRR Dhan is likely to increase zinc intake by about 61.4 percent.

Outputs from this activity includes three white papers and two newspaper articles.

Capacity building and policy communication

IFPRI organizes several capacity-building workshops in collaboration with ICAR and State Agricultural Universities (SAUs). IFPRI also facilitates and supports participation of scientists from ICAR institutes and State Agricultural Universities in international conferences and seminars.

In 2019, five such training programs in partnership with ICAR institutes and state agricultural universities were conducted and about 150 participants were trained. These include:

i. Impact Assessment of Agriculture and Rural Development Programs in Lucknow
ii. Impact Evaluation of Agricultural Research and Extension in ICAR-IARI
iii. Training program on the International Model for Policy Analysis of Agricultural Commodities and Trade (IMPACT) in ICAR-NIAP
iv. Workshop on Quantitative Techniques for Impact Assessment in PAU, Ludhiana
v. Online training on simulation modelling.

Similarly, four policy communication activities were organized this year, which include (i) social transfers to revitalize rural India, (ii) mapping the adoption of improved cultivars of major horticultural crops and assessing their impact in India, (iii) loan waiving versus income support schemes: challenges and the way forward and (iv) panel discussion on direct benefit transfer (DBT) of agricultural subsidies.

Workshop on Quantitative Techniques for Impact Assessment in PAU, Ludhiana

Training on the International Model for Policy Analysis of Agricultural Commodities and Trade (IMPACT) in ICAR-NIAP

International Livestock Research Institute (ILRI)

The International Livestock Research Institute (ILRI) works with partners worldwide to enhance the roles that livestock play in food security and poverty alleviation, principally in Africa and Asia. The outcomes of these research partnerships help people in developing countries to keep their farm animals alive and productive to increase and sustain their livelihood and farm productivity, find profitable markets for their animal products, and reduce the risk of livestock-related diseases. Supporting the many small-scale producers, processors, sellers and consumers of animal-source foods in low-income countries, ILRI works with partners to change practices, provide evidence to decision-makers and develop capacities in smallholder livestock development.

ILRI's corporate strategy articulates three strategic objectives and the underpinning five critical success factors that will be addressed to achieve the institute's mission: 'To improve food and nutritional security and to reduce poverty in developing countries through research for efficient, safe and sustainable use of livestock – ensuring better lives through livestock'. The recently completed science strategy further articulates the key elements of the critical success factor 'getting the science right', which includes different research areas that need to be addressed by the institute's research to different degrees depending on the trajectory in question. The science strategy also highlights the importance of ILRI's regional programs in implementing its research and ensuring that impact pathways are realised in local and regional contexts, whilst delivering global public goods.

ILRI is a CGIAR Research Centre which undertakes multi-partner 'CGIAR Research Programs' (CRPs) and these set the scope, direction, institutional partnerships and opportunities for ILRI research in India. In last several years, ILRI has successfully implemented a number of collaborative projects in the region including Cereal System Initiative South Asia (CSISA), Enhancing livelihoods through livestock knowledge systems (ELKS), National Agricultural Innovation Project (NAIP), Milk India Tanzania (MilkIT) project, Farm Animal Genetics Resources (FAnGR), India Mozambique Goat (IMGoat) project, Climate change, Agriculture and Food Security (CCAFS) etc. and set a positive track record as a scientifically sound, honest, sincere, responsive and flexible research institute that is good to work with.

In the region, ILRI has demonstrated the use of its knowledge and skills in conducting multi-disciplinary research on livestock-based livelihood, fodder innovation, zoonosis and food safety, participatory epidemiology, disease economics, informal milk market improvement, value chain assessment, research and identification of policy intervention and advocacy to complement the strong technical research capacities among the NARS especially in India. ILRI's research goes much beyond livestock technologies and based on ILRI's prevailing strengths and experience, ILRI complements NARS expertise by conducting research in the fields of food safety and zoonosis, gender, climate change, feed and fodder innovation, biotechnology, economic assessment of livestock systems, epidemiological studies, genetic studies and policy facilitation.

ILRI focusses on pro-poor livestock development policy which is very relevant for this part of the world. It develops, tests and pilots' interventions that are affordable, acceptable and accessible to the poor livestock keepers. Other research systems including many national systems have a broader mandate to cover the whole agricultural or livestock sector and therefore, often do not differentiate sufficiently the needs of poor smallholder livestock keepers from larger commercially oriented farmers.

ILRI's arguments and examples set by it in the field on pro-poor livestock development (for instance under NAIP or ELKS project, AIP) are well appreciated by policy makers and donor agencies. For last several years, ILRI has been implementing projects in partnership with local R&D organizations and has been trying to build their capacity by jointly designing and implementing projects. This is being done to strengthen capacity of local partners to ensure sustainability of ILRI's initiative even after closure of the project.

The Food Safety Zoonosis team at ILRI has previously been working with improving milk hygiene in Assam and has been successful in increasing awareness among farmers about diseases and the importance of hygienic practices. In addition, the intervention has been shown to increase milk yield and reduce mastitis.

The Policies, Institutions and Livelihoods program has previously worked on dairy systems in Bihar, Gujarat and Assam. This includes policy related issues in Bihar and the need to address the policy incoherence in the small holder dairy sector through organization of a multi-stakeholder policy working group which focuses on ways of addressing policy gaps, enhances capacities for policy implementation and facilitates policy learning.

As a global research institute, ILRI can bring global knowledge to address local problems. ILRI has access to and understanding of global livestock knowledge and technologies and therefore, it can create a platform for knowledge sharing and cross learning within and between regions.

The work plan for ICAR-ILRI collaborative projects for the period 2019-2022 was finalized and was approved by ICAR. Four scientists from ICAR institutes and one scientist from ICAR Headquarters visited ILRI, Nairobi during 2019 under Scientist exchange visit.

Assessment of the economic impact of priority animal diseases and the cost-effectiveness of their control strategies in India

The project envisages to quantify the direct and indirect impact of priority animal diseases in India and provide the insights of economic and non-economic effects. The project focus on three important priority animal diseases *viz*, PPR, HS and Brucellosis. In the initial years the focus is on PPR in small ruminants and further would be on HS and Brucellosis. Despite the impact on production parameters the project considers the disease effect on decisions made by other actors in the entire value chain through systems dynamic modelling approach.

Compilation of region and season-wise PPR incidence data (based upon official GOI data) has been completed. A workshop on conducting participatory sessions to collect and triangulate data from various stakeholders for Systems Dynamics Model building was organized by ILRI (24-26 July 2019). Sampling protocol finalized in terms of identification and classification of risk districts in the selected states using sheep and goat PPR outbreak data. As per the work plan, West Bengal, Rajasthan, Uttar Pradesh, Andhra Pradesh and Karnataka will be selected as study states. The survey instruments for various value chain actors in the PPR value chain were developed, field pilot tested and refined. The main survey to assess the impact of PPR has been imitated in Anantapur, Andhra Pradesh and Bareilly, Uttar Pradesh.

Improvement of basal feed resources through multi-dimensional crop improvement and application of spin-off technologies from 2nd generation biofuel

The collaboration with ICAR-NIANP, CSIR-IICT and Nagarjuna Fertilisers on deconstruction of ligno-cellulose biomass resulted in generation of evidence on the impact of steam explosion (SE) and two chemical combination treatments (2-CCT) on rice straw. The true in vitro organic matter digestibility of rice straw could be increased by about 34.9% units, turning crop residues essentially into concentrates using 2-CCT treatment while Steam Explosion treatment increased the same by 21.1% units. Long term *in vivo* observations by ILRI using total mixed rations (TMR) consisting to about 70% of rice straw suggest that both the treatments have significant impact on the total weight gain in sheep. In this work ICAR support was used to experiment application of the above two technologies and design engineering options and business plans that allows embedding of the technologies in decentralized private enterprises. Further, a feed resource mapping exercise was carried out in association with NIANP to understand the demand and availability of feed resources in all the states at district level. A structural study to identify the treatment combination that can yield highest energy is in progress. The entire work will be continued by installing a pilot plant with one ton per day capacity to generate data required for commissioning commercial plants by trying with different straws/stovers, species of animals (dairy, meat), engineering options (time, temperature, pressure, chemicals etc.) and processor costs including costs of recycling residues (lignin, water) to make sure that there is '0' discharge and the operation is environmentally friendly.

Rice straw samples of 390 released varieties and 101 mapping population from National Rice Research Institute, Cuttack were investigated for their fodder quality parameters such as nitrogen, neutral (NDF) and acid detergent fibres (ADF), acid detergent lignin (ADL), silica, metabolizable energy (ME) and *in vitro* organic matter digestibility (IVOMD). It was found that *Tanmayee,* one of the 390 cultivars, has high digestibility (46.2%) compared to others and among the 101-mapping population the line BA 115, though has highest digestibility (43.1%), BA 36 has high N (0.88%) with digestibility (42.5%) closer to BA 115.

In collaboration with Indian Institute of Millet Research, Hyderabad, more than 300 sorghum stover samples from two seasons in two locations were analysed for their fodder quality. Analysis done across locations in the AHT-GS trial showed that there is no significant difference among the entries in Nitrogen and acid detergent lignin but there was significant difference in the other traits (NDF, ADF, ME, IVOMD, GY, SY). Whereas in the AVT-GS and IAVHT-SS trials significant difference was found for all the traits in both entries and locations. It was also found that there was no correlation between stover quality traits and yields in all the trials.

Genome wide association study in Indigenous poultry breeds/varieties

Chicken play an important role in livestock sector contributing livelihood security in the form of poultry meat and egg to the rural people. Indigenous poultry farming provides a viable opportunity for the rural population to ensure food security, self-employment and improved livelihoods while contributing to the national economic growth. Free-range poultry farming is easy to establish, they are more prolific and unproblematic to rear on small plots of land and are more genetically diverse, well adapted, and more resistant to local pests and diseases. However, this sector is also subject to some constraints which lower the productivity of traditional chicken. The native poultry represent a valuable resource for livestock development due to their extensive genetic diversity which allows for rearing of poultry under varied environmental conditions. The indigenous chicken therefore exhibits a large genetic pool from which genes of interest can be exploited to provide a basis for genetic improvement and diversification to produce breeds that are adapted to varied conditions for the benefit of farmers in developing countries.

Traditional selection during last many decades was practiced improving the performance of birds, but the rate of genetic progress was not satisfactory and most of the times due to lower variability, selection was not effective to improve the performance. Due to continuous selection for body weights or egg production, other un-desired traits such as higher muscle fat, low adaptability, lesser immunity/fitness etc. have been indirectly selected and included in the population, which makes the birds more vulnerable to the diseases. To minimize all these undesired effects, genome wide marker assisted selection play crucial role in native as well as high performing poultry population. Although high density chicken array (600K) is commercially available containing SNPs information mostly from exotic/commercial chicken lines, but this chip lacks the SNPs data of most of the Indigenous native chicken breeds. So, there is an urgent need for developing a high-density chip containing SNPs information specific to the Indigenous native chicken breeds that will be used for selecting the elite native germplasm of India and other countries. Thus, searching the whole genome for better quality birds may not only improve productivity of birds but also nullify the un-intentional inclusion of undesired traits during selecting the elite parents, which may devise the concerted and systematic mechanism to augment performance of birds at a very faster rate than the traditional/conventional selection alone.

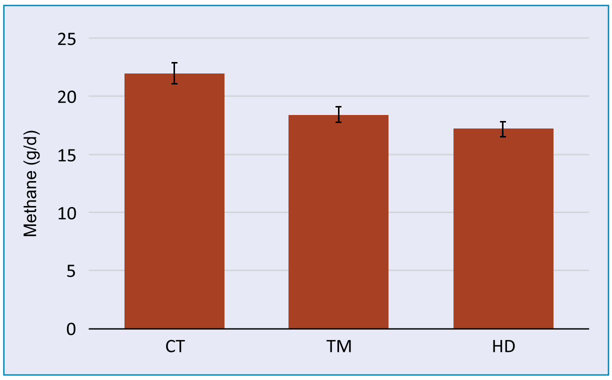
In this regard, a research project on "Genome wide association study in Indigenous poultry breeds/ varieties" was launched at ICAR-Directorate of Poultry Research, Rajendranagar, Hyderabad, India on 29th August 2019 in presence of Dr. H. Rahman, Regional Representative, South Asia, ILRI; Dr. R.N. Chatterjee, Director, ICAR-DPR; PI and Co-PIs from ICAR-DPR and Scientists of ICAR-DPR. The major objectives of the project were whole genome sequencing (10x coverage) of 14 native chicken breeds including high yielding improved and adapted exotic chicken lines, develop SNP chips and validate genomic selection with this SNP chip.

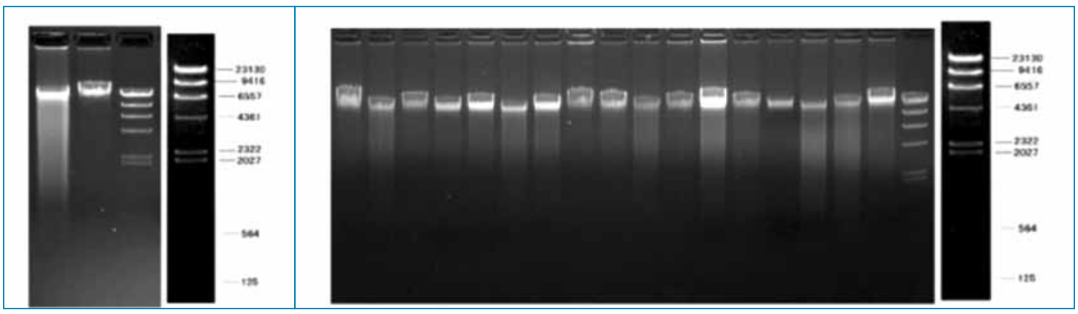
A total of 7 chicken breeds [Native chicken breeds- Aseel, Ghagus, Nicobari, Kadaknath, Hansli and tropically adapted chicken breeds - PB-1 (a broiler type line) and IWH White Leghorn layer chicken] were included in the study during the year 2019 and 7 more native breeds will be analysed in the year 2020. A total of 10 birds (5 males and 5 females) from each breed were included in the study and consequently, a total of 70 birds were considered for whole genome sequencing. The birds were selected randomly for this study. All 70 genomic DNA samples were sequenced with 10x coverage at Illumina NovaSeq platform. The raw read of the samples varied from 7.3 to 262 million. The raw Q20 score was more than 95.8 while Q30 score was more than 91.2 indicating the good quality sequence data of the samples generated from the sequencing platform. The raw data are being analysed with bioinformatic tools for detection of SNPs of individual samples. DNA quality of 70 samples (checked by 1% agarose gel electrophoresis) used for whole genome sequencing

Research Project on methane emission and its mitigation

During the reporting period, an *in vivo* study to ascertain the impact of anti-methanogenic product (*Harit Dhara*) supplementation was carried out in eighteen sheep (Avg. BW 30.3 kg). Animals in control (CT), positive control (TM) and test group (HD) were fed on a basal diet comprising finger millet straw and concentrate in 50:50. Both the anti-methanogenic agents tamarind seed husk and *Harit Dhara* were supplemented at a level of 5% of basal diet. After preliminary feeding of one month, the methane measurement and nutrient digestibility trials were conducted to examine the impact of supplementation on feed intake, methane emission and nutrient digestibility. Results from the study did not reveal any significant ($p>0.05$) impact of *Harit Dhara* supplementation on feed intake.

Similarly, the fibre digestibility (NDF & ADF) was among the control and test groups and did not vary ($p>0.05$) with the supplementation of *Harit Dhara* in present study. Enteric methane emission (g/d) measured using sulfur hexafluoride technique revealed a significant reduction ($p<0.05$) of ~22% as compared to the control was reported in *Harit Dhara* supplementation group of sheep, which is depicted in the figure. Data revealed a significant ($p<0.05$) reduction in total rumen protozoa, *Entodiniomorphs* and *Holotrichs* with the supplementation of anti-methanogenic supplement. *Holotrichs* appeared most vulnerable to the supplementation of *Harit Dhara* in present experiment.





Effect of Harit Dhara supplementation on enteric methane emission (g/d)

IVRI, Izatnagar has carried out a study to compare the enteric methane emission among indigenous and crossbred cattle and buffaloes fed on a similar diet comprising wheat straw and concentrate-based diet (70:30). Enteric methane emission in all the three species was measured using respiration chambers. There was no difference in the intake and nutrient digestibility among the buffaloes, indigenous (*Tharparkar*) and crossbred cattle. Similarly, the enteric methane emission was also similar in indigenous (165 L/d), crossbred (182 L/d) and buffaloes (177 L/d). Likewise, no difference in the feed intake, rumen pH, ammonia nitrogen, rumen protozoa and volatile fatty acid production was recorded in present study.

Dr. John Goopy, Research Scientist, ILRI visited the NIANP during 16-20 October 2019. During the visit, he delivered a talk on "Reducing Enteric Methane Emissions - Why We do Not Know More? A Perspective on 90 Years of Research" and interacted with scientists. Dr. Goopy and Scientists from NIANP jointly finalized the site and modalities for the construction of building, purchase and installation of Respiration Chambers for small ruminants at NIANP, Bengaluru.

International Maize and Wheat Improvement Center (CIMMYT)

Headquartered in Mexico, the International Maize and Wheat Improvement Center (known by its Spanish acronym 'CIMMYT'), established in 1966, works to reduce poverty and hunger by sustainably increasing the productivity of maize and wheat-based farming systems in Asia, Africa and Latin America. The ICAR-CIMMYT partnership in agricultural research is one of the longest and most productive in the world with a rich history of more than five decades. The collaboration started with the visit of Nobel Laureate Dr. Norman E. Borlaug to India in 1963 for ushering in "Green Revolution" in active partnership with the Government of India. In 2011, Borlaug Institute for South Asia (BISA), a joint initiative of CIMMYT and Government of India (ICAR), was established to address food, nutrition, environment and livelihood security in South Asia. CIMMYT, and BISA, have currently more than 150 staff in India operating from 14 sites. CGIAR Research Programs (CRPs) on Maize and Wheat agri-food systems and Climate Change, Agriculture and Food Security (CCAFS) are the corner stone of the ICAR–CIMMYT collaborative work plan 2018-2022.

In just four short years after Dr. Borlaug's first visit, the India-CIMMYT partnership doubled India's wheat harvest to 20 million tons and the nation reached self- sufficiency in wheat. The success continued and in 2019, India harvested a record 101.2 million tons of wheat. CIMMYT's Wheat Improvement Program in Mexico targets 60 m ha, about half of which is in India. During 2010-2019, more than 70 CIMMYT germplasm derived wheat varieties were released with 44 being direct release in different parts of India. The first two biofortified (grain Zinc rich) wheat varieties were also released from CIMMYT developed lines. Each year more than 100 lines were promoted to various national and state trials.

In maize, CIMMYT focused on the development of climate resilient maize hybrids and also Quality Protein Maize (QPM) that have competitive yields under optimal conditions and superior yields under abiotic and biotic stresses. During last decade a series new stress-resilient maize germplasm tolerant to drought, waterlogging and heat stress were developed and shared with national program as early and advanced generation lines, apart from elite hybrids, which were licenced to Indian maize program partners for official release and deployment. About nine QPM hybrids were developed in the last decade with extensive use of CIMMYT's maize germplasm. Germplasm resistant to Turcicum leaf blight (TLB), downy mildew, and bacterial leaf and sheath blight were also developed and distributed to the national maize program.

Conservation agriculture based sustainable intensification practices promoted by CIMMYT have achieved large scale adoption; these include zero tillage, direct seeded rice, precision land levelling, residue management, precision input management and mechanization and climate smart agriculture (CSA).

Since 1969, more than 360 Indian visiting scientists and nearly 90 trainees have been hosted at CIMMYT. Between 1969 and 2019, more than 2,500 Indian scientists improved their knowledge and skills through various capacity building activities with CIMMYT. A short (2 weeks) advance international course on conservation agriculture was introduced in India in year 2010. Since 2017, a long term (10 months) training of wheat breeders/pathologists at Mexico (for wheat breeding) and Bolivia (for wheat Blast research), has been introduced.

The progress of work plan activities implemented during the year 2019-20 have been summarized below:

Bread wheat improvement

The project focuses on breeding and testing of more productive wheat germplasm that combines a range of other necessary traits to enhance productivity and acceptance to farmers, industry and consumers. The major results are given below:

- Eight varieties of diverse parentage selected from previous international trials and nurseries were either identified or released for cultivation by national partners in 2019.

Variety Name	Parentage	Institute
DBW 222 (Karan Narendra)	KACHU/SAUAL/8/ ATTILA*2/PBW65/6/ PVN//CAR422/ANA/5/ BOW/CROW//BUC/ PVN/3/YR/4/TRAP#1/7/ ATTILA/2*PASTOR	IIWBR, Karnal
NIAW 3170	SKOLL/ROLF07	Niphad
HI 1628	FRET2*2/4/SNI/TRAP#1/3/ KAUZ*2/TRAP//KAUZ/5/ PFAU/WEAVER// BRAMBLING	IARI, Indore
HD 3249	PBW343*2/KUKUNA// SRTU/3/PBW343*2/ KHVAKI	IARI, Delhi
DBW 252	PFAU/MILAN/5/CHEN/ AEGILOPS SQUARROSA (TAUS)//BCN/3/VEE#7/ BOW/4/PASTOR	IIWBR, Karnal
HI 1621	W15.92/4/PASTOR// HXL7573/2*BAU/3/WBLL1	IARI, Indore
HUW711	MAYIL#4(=T. DICOCCON CI9309/ AE.SQUARROSA (409)// MUTUS/3/2*MUTUS)	BHU
VL Gehun 967	BAVIS#1(=SHARP/3/PRL/ SARA//TSI/VEE#5/5/VEE/ LIRA//BOW/3/BCN/4/ KAUZ)	Vivekanand Laboratory

- About 216 sets of International Trials and Nurseries from Mexico were grown by partner institutions in 2018-19 season. Multisite yield performance in India identified superior yielding, rust resistant lines for further testing. By seed multiplication and preparation of new international trials and nurseries a total of 195 sets provided to partners in India for growing in current season 2019-20 (Fig. 6). About 60% and 80% lines in the trials and nurseries had high to adequate resistance to Ug99 race group and yellow rust races present in India, respectively.

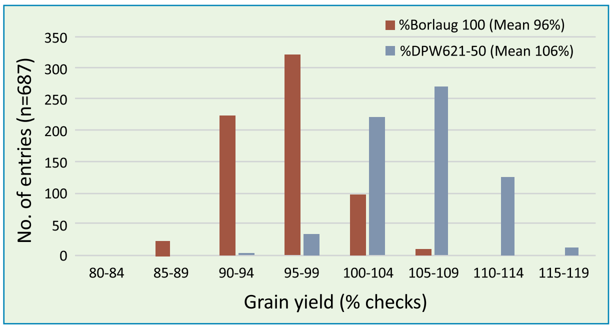


Fig. 6. Grain yield performance of 687 bread wheat entries under optimum irrigation (mean of three trials, Cd. Obregon 2017/18 & 2018/19) and included in various nurseries and trials in 2020

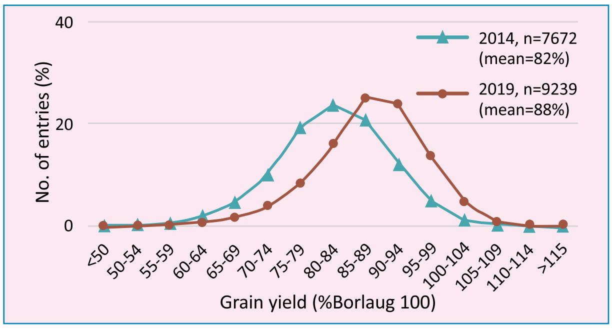


Fig. 7. Grain yield distribution for cohorts of 7672 wheat lines tested in 2013-14 season (baseline) and a new cohort of 9239 lines tested 5 years later in 2018-19 season at Ciudad Obregon, Mexico under optimally irrigated environment.

- Breeding cycles and phenotyping for enhanced yield potential, heat and drought tolerance, resistance to Ug99 stem and other rusts done at three locations in Mexico (Cd. Obregon, Toluca and El Batan), two in Kenya (Njoro-off- and main-seasons) and India (IIWBR-Karnal & BISA-Ludhiana). The grain yield trial at Cd. Obregon, led to identification of more than 500 superior, new bread wheat lines. The mean grain yield of wheat lines tested in 2018-19 cohort increased by 6% compared to lines tested in 2013-14 cohort, indicating at least 1% annual genetic gain (Fig. 7).
- About 300 high yielding lines with heat and drought tolerance identified through multi-year field phenotyping at Cd. Obregon, Mexico under managed environments.
- Grain quality analysis for 1,330 elite lines, selected from 1st year yield trials identified lines with good quality characteristics including high protein content (Fig. 8).

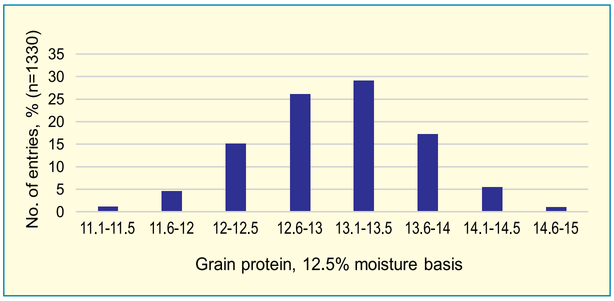


Fig. 8. Grain potein content of 1,330 entries retained from 1st year yield trials (Obregon 2018-19)

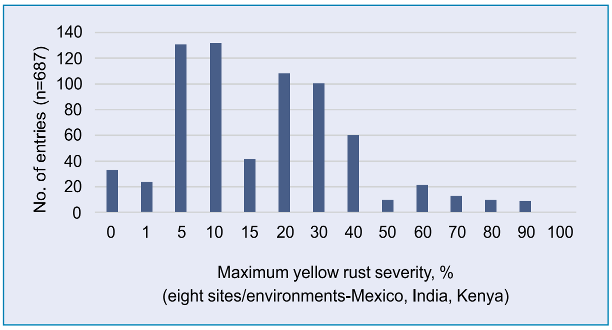


Fig. 9. Highest recorded yellow rust severity for wheat lines tested in Mexico (Toluca 2018, Celaya 2018-19), Kenya (Njoro 2018-off & main, 2019-off & main), and India (Ludhiana and Karnal 2018-19

- Although yellow rust fungus continues to evolve and migrate rapidly around the globe, use of diverse resistance in breeding combined with phenotyping and selection in Mexico, Kenya and India is helping to identify superior yielding, resistant lines in all three continents in adequate frequency (Fig. 9). All best lines were shared with Indian collaborators in the crop season 2018-19 and 2019-20.

Wheat Blast Research

During 2019, two sets of Indian materials were evaluated - 1) 100 Indian elite germplasm (named as IND100) at Jashore in Bangladesh, and Quirusillas and Okinawa in Bolivia; and 2) a new panel containing 353 wheat lines from India (IND353) evaluated at Jashore, Bangladesh. In each location, the materials were planted in two sowing dates, to expose them to wider variation of environments; inoculations were carried out and misting provided to increase the chance of heavy WB infection.

Blast screening for the 100 wheat lines from India

Of 100 lines, 34 were 2NS while remaining 66 were of non-2NS. Several lines showed consistently good resistance to blast, most of which were of 2NS; but still a few non-2NS lines showed moderate level of resistance. Ever since the 2017-18 season in Jashore, a few non-2NS lines have exhibited good resistance, like HD 2204 (IND 26), PBW 773 (IND 73), WH 1218 (IND 92) and HI 1622 (IND 45); additionally, DBW 39 (IND 99) didn't show good resistance at first but later exhibited better resistance.

Blast screening for the 2018 Indian 353 panel

The 2018, Indian 353 panel showed a clear bimodal distribution. Molecular data for 2NS translocation indicated that 97 of the 353 lines carried the 2NS translocation, accounting for 27.5% of the entire panel. Similar to the IND 100 panel, most 2NS lines showed good blast resistance and vice versa; but many outliers could be observed, especially for the 2NS group (Fig. 10).

Durum wheat improvement

As reported in previous years, results of the durum breeding program at CIMMYT during 2019 indicate that this project continues to identify new germplasm with high relevance to the Central and Peninsular Zones of India. We continue to identify many lines with very high yield potential in our trials based at the CENEB Obregon station (Fig. 11). Thanks to our abiotic stress tolerance testing capacity, we are able to identify, a number of lines that combined yield potential with good performance under drought and heat conditions, many of them with the earliness and kernel weights needed for the target environments in India.

- The focus on abiotic stress tolerance in CIMMYTs crossing program remained strong and our breeding pipeline is filled with highly relevant populations from previous crosses that should maintain a good stream of useful new lines for years to come.

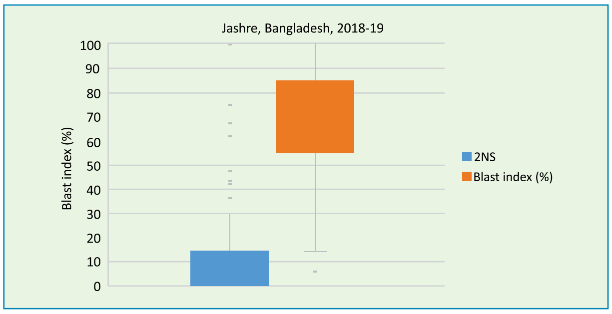


Fig. 10. Boxplot chart showing the phenotypic effects of 2NS in the 2018 India 353 panel

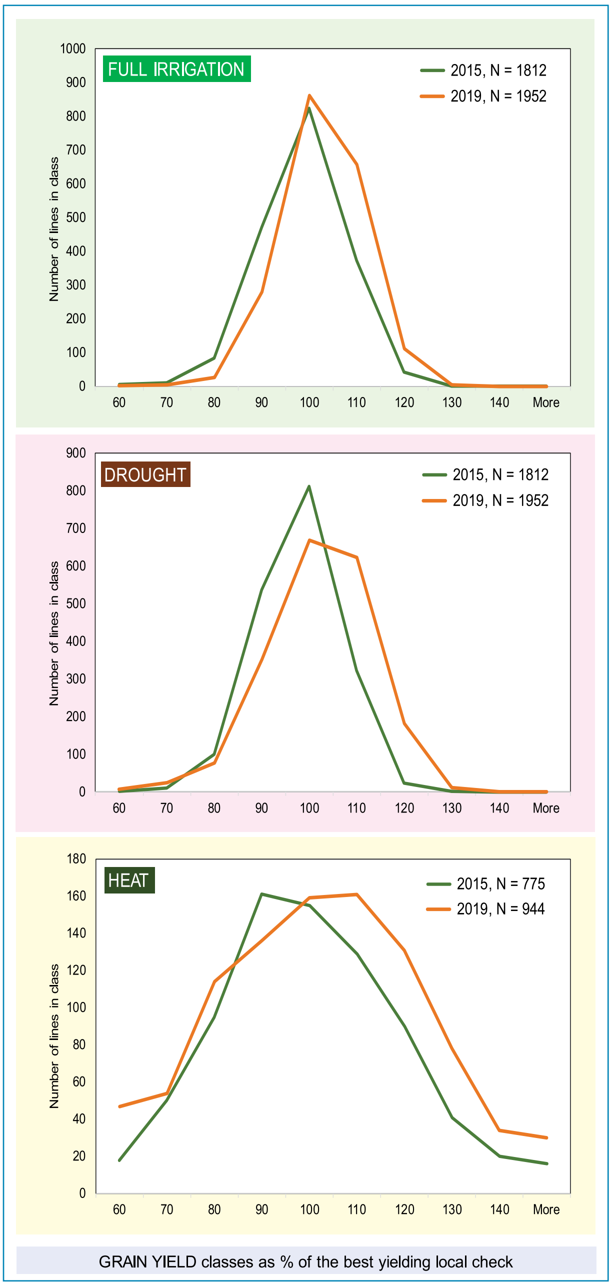


Fig. 11. Distribution of grain yield in advance durum wheat lines tested in 2015 and 2019 crop season

- Grain characteristics evaluation and quality evaluation confirmed that, as in past years, the frequency of lines with overall good quality attributes is high among the material tested recently.
- Based on the results of 2019 and those obtained in the previous 2 years, we have selected 45 improved advanced lines for the 52nd International Durum Yield Nursery (52nd IDYN) to be distributed to Indian collaborators in 2020.

We have also selected 132 candidate lines for seed increase in Mexicali 2019-20, from which we will select the 45 lines to be included in the 53Rd IDYN to be distributed in 2021.

Stress-Resilient Maize for Rainfed Kharif Season

In view of the importance of stress tolerance in rainfed Kharif maize, a new activity for phenotyping of abiotic stresses during the rainfed *Kharif* season, was formulated in collaboration ICAR-IIMR and three AICRP centres located at strategic locations.

Establishing precision phenotyping sites & phenotyping network for drought, waterlogging and heat stresses

- Three suitable locations for establishing precision phenotyping for drought, heat and water-logging stresses were identified.
- Key equipment including soil moisture profiles probe and weather station were installed and master data-sheet for capturing daily weather data and depleting moisture at different soil profile during experiment was made available to each center.
- Data-logger with Field-log made available to three AICRP centers for digital data-capture in the phenotyping trials.
- Training on various tools and system, including digital data capture and quantitative management of stress intensity with uniformity of drought stress based on growing degree days (GDD), and depleting soil moisture recorded on volumetric basis organized.
- Managed drought stress trials including a total 266 released/pipelines hybrids from IIMR/ AICRP and CIMMYT were planted during December 2019 at Kolhapur, Godhra and Hyderabad.

Identification of potential germplasm sources for abiotic stress tolerance and heterotic classification of ICAR-IIMR and AICMIP inbred lines through delineation of combining abilities

- DNA samples were collected from a panel of 752 lines available with AICRP and a panel of 658 lines from CIMMYT selected for waterlogging/drought/ heat/combination stress tolerance for the validation of the DArTAG platform. Genotyping is in progress.

Managed drought stress trials at Hyderabad, Godhra and Kolhapur during Rabi 2019-20.

- A sub-set of 193 lines from the IIMR/AICMIP panel were crossed to two testers each from CIMMYT and ICAR-IIMR testers in Design II.

Identification of commercially viable CIMMYT and ICAR-IIMR hybrids

- Selected stress-resilient high-yielding hybrids across location were identified. These will be evaluated though specifically designed rainfed trials though AICRP network to identify stress-resilient hybrids for *Kharif*.

Conservation agriculture

Long-term basic and strategic process-based research on conservation agriculture and their participatory validation in major cereal based systems in key geographies were carried-out to generate science-based evidence. Key outputs are listed below:

- A meta-analysis using 9,686 paired site-year comparisons representing different indicators of cropping system performance suggest significant benefits when CA component practices are implemented either separately or in tandem. For example, zero tillage with residue retention had a mean yield advantage of 5.8%, water use efficiency higher by 12.6%, increase in net economic return by 25.9%, and a reduction of 12-33% in global warming potential, with more favourable responses on loamy soils and in maize-wheat systems (Fig. 12).

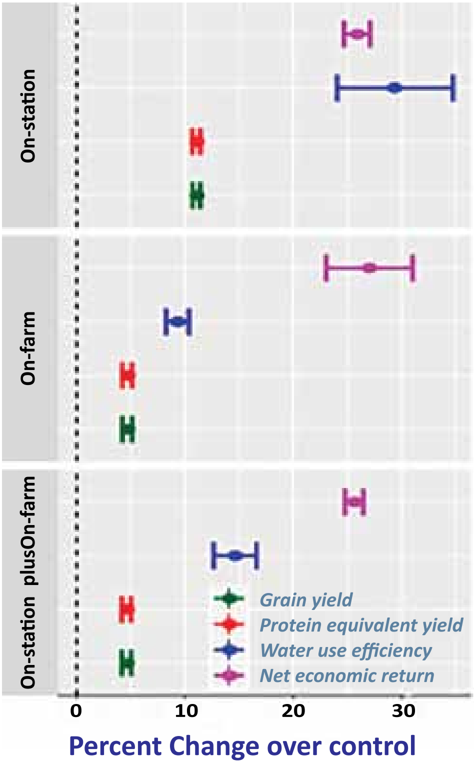


Fig. 12. Comparison of CA for key performance indicators

- Based on the strategic research on Food-Energy-Water (FEW) nexus in collaboration with PAU, two State recommendation on subsurface drip irrigation under CA in rice -wheat and maize-wheat systems have been made for their scaling in Punjab
- Meta-genomic studies under long-term CA in cereal based systems were conducted to

understand the diversity and richness of soil fungi at phylum and family taxonomic level. Higher Shannon diversity index was found in CA based maize based compared to rice-based systems. Maximum types of fungal species were recorded under partial CA based management due to increased food supply to microbes. Ascomycota was a dominating (69-95%) phyla across the management but was recorded higher in CA based rice systems whereas, Zygomycota having symbiosis with plants, was dominating in CA based maize systems.

- Basic studies on N and water dynamics (soil water balance and root water uptake) under CA + sub-surface drip (SSD) fertigation in maize/ rice in rotation with wheat, SSD was found to save 50.8% water under zero till rice (ZTR) than puddled transplanted rice (PTR). Study using Hydrus 2D model suggests that the proportion of cumulative root water uptake to total applied water was significantly higher (25.7%) in ZTR+SSD, followed by ZTR (17.9%) and lowest (13.8%) in PTR.
- Validation of an algorithm for Remote Sensing based approach for assessing adoption of conservation agriculture in the rice-wheat systems of western IGP using intensive ground truthing suggests nearly 20% of the adoption of no-till wheat in north-west India and can serve as a tool for rapid adoption tracking of CA.

Gendered preferences for wheat varietal traits in central India

Inability of varietal development system to address the heterogenous farmer preferences is a crucial impediment for rapid varietal turnover. A study was done to examines the potential differences in farmer preferences for wheat varietal traits with respect to gender and other socioeconomic attributes. The steps involved, and the results are given below:

- Selected the central Indian state of Madhya Pradesh as the study area, and the surveys are done in three districts – Jabalpur, Damoh, and Mandla.
- A preliminary ranking analysis indicated that farmers (n = 120) provide quality attributes the highest, the quantity attributes next, and the risk attributes the lowest ranks (Fig. 13).
- Based on the preliminary ranking of attributes, a choice experiment was designed and conducted among 420 farm-households belonging to 18 villages. Five varietal attributes – heat-stress tolerance, chapatti quality, lodging tolerance, potential yield and seed price – were included in the design.
- Female respondents had stronger preference for both chapatti quality and yield potential than male respondents. While both men and women tend to have positive preference for production risk-ameliorating, female respondents have relatively smaller coefficient estimates for heat-stress tolerance.
- Men are willing to accept a higher seed price for getting risk-ameliorating attributes, while women tend to maximize utility derived from a decrease of seed price and reduction of risk-ameliorating attributes.
- Significant inter-caste heterogeneity exists.
- These results underscore the importance of investing in gender-responsive varietal improvement programs to achieve efficient wheat seed value chains and inclusive and sustainable wheat farming systems.

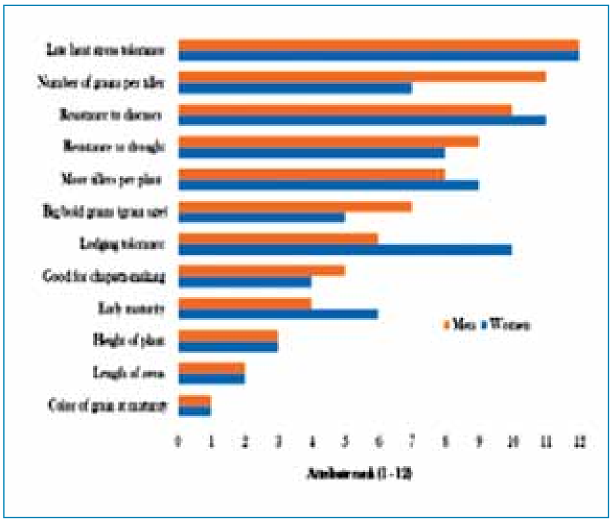


Fig. 13. Ranking of wheat varietal attributes (n = 120)

Capacity building activities

- Two young scientists from India spent 10 months in CIMMYT, Mexico and also visited Okinawa, Bolivia. Their training involved wheat breeding and pathology with emphasis on wheat blast. They participated in wheat breeding and pathology experiments conducted in El Batan, Toluca, Agua Frias and Obregon, Mexico as well as Bolivia.

- An international training on wheat blast disease screening and surveillance was organized at the Regional Agricultural Research Station, Jashore, Bangladesh from 19th to 28th February 2019. Four Indian participants attended this training.
- Three senior Indian scientists visited CIMMYT research station in Obregon.
- An advanced Course on Conservation Agriculture was organized. In addition, eleven students and five research interns have worked/completed their research in various aspects of CA based systems and generated new scientific insights.
- Two Indian scientists attended the stem rust training course in Kenya.
- Ten scientists from India were provided partial or full funding to participate in the 1st International Wheat Congress in Saskatoon, Canada.
- One scientist sponsored to attend the International conference of Wheat Diversity and Human health, Istanbul, Turkey.
- Around 200 young scientists and other stakeholders trained on issues such as wheat and maize breeding, farming systems, conservation agriculture, climate smart agriculture etc.

International Potato Center (CIP)

The International Potato Center (CIP) is a non-profit research-for-development organization with a focus on potato, sweet potato and Andean roots and tubers. The organization is mandated to delivers innovative science-based solutions to enhance access to affordable nutritious food, foster inclusive sustainable business and employment growth, and drive the climate resilience of root and tuber agri-food systems. CIP has its headquartered in Lima, Peru, CIP and has research presence in more than 20 countries in Africa, Asia and Latin America. CIP's vision is to work for a healthy, inclusive and resilient world through root and tuber systems.

CIP is a CGIAR research center, a global research partnership for a food-secure future. CGIAR science is dedicated to reducing poverty, enhancing food and nutrition security, and improving natural resources and ecosystem services. Its research is carried out by 15 CGIAR centers in close collaboration with hundreds of partners, including national and regional research institutes, civil society organizations, academia, development organizations and the private sector.

CIP has supplied over 1200 accessions (advanced clones, parents and trues seed families for clonal selection) of diversified potato groups to India to develop new varieties through breeding or to be released as locally adapted varieties. Eight potato varieties have been developed and released by CPRI using CIP clone as one of the parents. Two of the processing varieties developed by using CIP as male parents are occupying over 100,000 ha area in country and has opened gates for processing industries. In 2017, a CIP clone 397065.28 was released in India as Kufri Lima. This is an early maturity, heat tolerant and virus resistant variety. Farmers are expected to get 20% higher yield and profit by planting one month earlier than other varieties. Early planting means farmers will be able to sell their produce at a premium price before market is flooded with harvest of other varieties. This variety is expected to cover over 100,000 ha area in the next few years.

In collaboration with CTCRI, CIP has exchanged the elite germplasm that were procured from CIP-Lima. In 2018, CIP provided 20,000 orange flesh sweet

Fig. 14. Evaluation of CIP Clones under different Agro-Ecologies

potato true seeds to Central Tuber Crops Research Institute (CTCRI). So far, 480 hybrid clones have been selected for further evaluation (Fig. 14). Over the years, CIP has trained large number of Indian scientists in CIP-Lima or other regional centers on different innovative technologies such as aeroponic for seed production, marker assisted selection, study and exchange visit on GIS and crop modeling, TPS production technology and capacity building on developing biofortified varieties.

In 2019, CIP supplied 118 advanced potato clones: 21 heat tolerant and low tropical viruses resistant, 57 bio-fortified tetraploid clone rich in iron and zinc, resistant to late blight and major viruses, and 40 diploid clones for breeding purpose to develop varieties preferred by farmers, processors and consumers. The materials are currently multiplied for multilocation testing. Our objective is to release five locally adapted table and processing quality varieties in the next 5-7 years.

CIP clone 397006.18 was recommended for variety release for arid and semi-arid agro-ecologies of Gujarat, Rajasthan, Madhya Pradesh and Chhattisgarh to grow potato in 25-30% less water without effecting tuber yield significantly (Fig. 15). It is short-duration variety with 20% dry matter and good keeping quality. Farmers will not have to invest for seed every year and can use for 2-3 generations as it is resistant to viruses. Another bio-fortified potato variety - Yusi Maap (CIP clone 3g27g7.22) was notified in India based on its release and notification in Bhutan. There are several other short-duration CIP clones with both biotic and abiotic resistance and high dry matter of years.

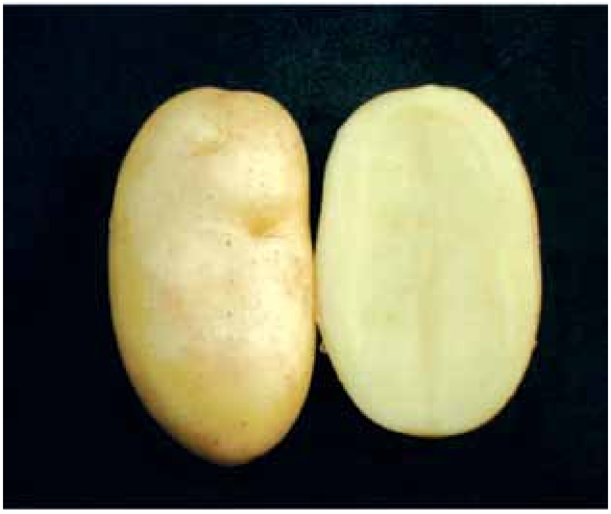


Fig. 15. CIP clone 397006.18 reccomended for release in 2019

CIP advance clone '304351.109' – which has red skin and is an early maturing variety (70-day maturity after planting) selected and yielding 40.91

Fig. 16. CIP clone 397006.18 reccomended for release in 2019

t/ha (marketable) and 43.02 t/ha (total) showed superiority by margin of 11% over best control other red variety (Fig. 16). This clone possessed 20% tuber dry matter and exhibited excellent keeping quality. The clone is resistance to viruses and moderately tolerant to late blight. Farmers and consumers both like red skin potatoes in Bihar, West Bengal, Odisha, North Eastern States and Jammu & Kashmir. There is great demand from the listed States to have new red skin variety as the exiting varieties exhibit poor yield trait. Earlier planting gives farmers the ability to sell their potatoes at a premium price. Early harvests give time to farmers to plant an additional winter crop to enhance their income. Release of this variety will enhance 30-40 productivity of North Eastern States and is expected to improve farmers' income by over 40%.

In 2019, CIP introduced a low cost apical rooted cutting technology to produce mini tubers as an alternative to highly capital intensive aeroponics (Fig. 17). This is now widely adopted in Vietnam and Africa. We have worked closely with CPRI to conduct economic viability of this technology in CPRI's Shillong center. In addition, we have set up two facilities that include tissue culture, poly house and net house to product mini tubers from tissue culture plantlets. The cost of one mini tuber would be about one rupee in apical rooted cuttings as compared to 6-8 rupees in aeroponics. Potato Technology Center in Haryana has also adopted this technology to produce mini tubers of Kufri Lima and other popular varieties.

In addition, CIP introduced low cost temporary net house technology in West Bengal, Karnataka, Maharashtra and Assam to initiate sustainable quality seed production. Production of healthy locally produced seed will reduce 40% seed cost and enhance farmer's income by 50% through enhanced yield compared to seed imported from other states. Three farmer clubs in North Bengal were selected for testing and upscaling the low-cost net house technologies at farm-level. Quality seeds were produced at three location in six temporary net houses of each 1350 m^2 Total cost of cultivation for 6 units was Rs. 3,60,000, gross sale was Rs. 13,95,000 and average profit per unit of 1350 m^2 was Rs. 1,72,500. ATMA and Pradhanmantri Krishi Sinchayee Yojna is upscaling this technology in North Bengal by supporting farmer's clubs in making more net houses (Fig. 18).

The SFLF model is a participatory and innovative bottoms up informal model where the farmers organize themselves into groups and synchronize their operations by virtually converting their small landholdings into a large field. This model enables small and marginal farmers to achieve bargaining power and economics of scale by strengthening backward and forward integration along the supply chain, lowering costs, and improving efficiency by synchronizing and harmonizing selected key operations (such as: land preparation, planting, and harvest).

Fig. 17. Mini Tubers Production using Apical Rooted Cuttings Technology Facility

Fig. 18. Decentralization of Potato Seed System in West Bengal

CIP piloted the SFLF model in 12 locations of Odisha (Fig. 19) and in 3 locations of Assam (Fig. 20). Through this model CIP has demonstrated the benefit of collective efforts in farming operations (Table 7). While the model emphasizes on bringing the small and marginal farmers together, at the same time it opens doors for better availability of inputs (seed, machines, fertilizer and other chemicals) through backward linkage to input suppliers. The potatoes framers from Odisha and Assam, participating in this model shared that for the first time they saw, learned and practiced mechanization for the potato crop – the initiative introduced mechanized potato planters and diggers in all the pilot locations. The initiative got overwhelmed response from farmers in both the states. Farmers participating in this farming model, have claimed that their productivity has doubled, and profit has increased three to four times.

Capacity Building

- Two weeks training for a CPRI scientist on the bio-fortification programme in CIP-Lima.
- Two weeks training program (Fig. 21) for a CPRI scientist on hybrid diploid potato from true seed in CIP-Lima.
- Organized visit of two scientists from Assam to attend World Potato Congress in Cusco, Peru and discuss research programs with CIP scientists in Lima.
- Organized a learning visit for scientists from Haryana and Assam to visit temporary net houses seed multiplication in Dhaka, Bangladesh.
- Organized a learning visit of Scientists from the University of Horticulture Science, Bagalkot, Karnataka to visit apical rooted cuttings seed production in Dalat, Vietnam.

Table 7: SFLF pilots implemented in 2019

	Total Districts	Villages	Total Number of Participating Farmers	Variety Introduced
Assam	3 districts Sonitpur Darrang Goalpara	3 Villages	105	Kufri Jyoti (table variety) Lady Rosetta (processing variety)
Odisha	4 districts Puri Jagatsinghpur Kendrapada Cuttack	12 villages	500	Kufri Jyoti (table variety)

Fig. 19. SFLF fields and farmer from Chenua & Saharadiyo Village, Odisha

Fig. 20. SFLF fields at Gingia village, Assam

- Organized a weeklong training on apical rooted cuttings for scientists from CPRI and state agriculture universities in Bangalore.
- Sponsored a scientist from CPRI to participate in CIP led conference on Euro Blight in Beijing, China.
- More than 500 persons including extension workers of Department of Horticulture and farmers trained on best potato production including seed production. Also organized exposure learning visits of potato stakeholders among potato growing states.

Fig. 21. Training on diploid hybridization on potato and on Biofortification in CIP-Lima

International Rice Research Institute (IRRI)

The International Rice Research Institute (IRRI), a member of the Consortium of the Consultative Group on International Agricultural Research (CGIAR) was established on 9th December, 1959 with the headquarters at Los Banos, Republic of the Philippines. IRRI is a world leader in rice research. It has direct presence in the 17 rice growing countries in Asia and Africa. IRRI technologies are being used by > 65 countries. Over more than six decades of operation, IRRI has amassed a unique portfolio of research products and intellectual assets on different aspects of rice systems, which remain as public goods.

Ever since its establishment, IRRI has had a close relationship with Indian agricultural research institutions/ universities. India was one of the signatories to IRRI's Charter when it was established. Senior Indian scientists and government officials have served almost continuously on IRRI's Board of Trustees since its establishment. Indian scientists at IRRI have contributed significantly to IRRI's success in using cutting-edge science to help bring food security, economic growth, and environmental protection to the world through their dedicated research and administrative efforts. Dr. M.S. Swaminathan, the first World Food Prize Laureate in 1987, served as IRRI's fourth director general during 1982-88. Dr. G.S. Khush, a rice breeder and 1996 World Food Prize laureate worked for 34 years at IRRI and made most outstanding countless contributions to keep the Green Revolution in rice production on right path. Over the years, more than 50 Indians have distinguishingly served/ serving IRRI.

IRRI collaborative work with ICAR institutes and State Agricultural Universities (SAUs) in India has

immense contribution to the development of the rice sector. Nearly half of total high yielding varieties of rice released in India over the past 60 years have used IRRI's germplasm in the varietal development. Nearly one-fourths of India's rice genetic improvement accounted for IRRI's germplasm during the period, 1966-2015 contributing to around 15% of total rice area accounted for IRRI's germplasm.

Having contributed immensely to enhancing food security in India and the region over the last five decades, through a Cabinet decision of the Government of India, IRRI recently established a South Asia Regional Centre (ISARC) at Varanasi, Uttar Pradesh, which was inaugurated by the Hon. Prime Minister Narendra Modi in December 2018. ISARC is working with ICAR, Department of Agriculture, Co-operation and Farmers' Welfare and SAUs in India as well as with Institutions in other countries of South Asia and Africa to enhance grain quality, nutrition, climate resilience, rice-based products development, value chain development and capacity building including strengthening of South-South collaboration initiative of ICAR.

IRRI is the lead center of the Global Rice Science Partnerships and Rice Agri-food System Research Program RICE - CGIAR Research Programs (CRP). IRRI and India have been successfully collaborating for almost six decades. India has been actively involved in IRRI's priority setting, strategic planning, scientific advising, and implementation of research in the region. The synergy of partnership resulted in development of high yielding rice varieties, 400 improved rice varieties tolerant to biotic/abiotic stresses suited to various rice environments, hybrid rice varieties bred through government and private sector programs, improved crop and nutrient management practices including conservation agriculture in rice-wheat systems and improved post-harvest technologies for improved sustainability and productivity. The free exchange of genetic material at both the national and international levels through IRRI's

International Network of Genetic Evaluation of Rice or INGER allowed testing and breeding under different rice ecologies and agro-climatic regions. Salient achievements emanated out of India-IRRI collaboration include:

- Conservation and exchange of rice germplasm: Out of 1,27,000 rice germplasm at IRRI's gene bank more than 17,000 are from India. Many of these have contributed immensely as door to rice breeding programs, such as Pokkali for salinity tolerance, N 22 for drought and heat tolerance, FR13A for submergence tolerance, and *Oryza nivara* for resistance to grassy stunt virus.
- Delivery of new varieties, practices, and technologies: The success of the partnership between India and IRRI began with the introduction of the high-yielding rice variety IR 8, dubbed miracle rice, which helped save India from a massive famine in the 1970s. This was only the beginning of a partnership that has led to development of more than 400 improved rice varieties that have resistance to pests-diseases and abiotic stresses, streamlined rice production practices, and extensive information exchange with Indian scientists and capacity building.
- Breeding of stress-proof rice: India was the first country to obtain the submergence-tolerant trait bred into local mega-varieties, through collaborative programs with IRRI. Many single- and multiple stress-tolerant lines (flash flood, stagnant flood, drought, salinity, *etc.*) introduced by IRRI in India are now being cultivated widely by the farmers. These varieties are helping enhance and stabilize rice productivity under the ever-changing climate in the region.
- Improved roll-out of hybrid rice: Hybrid rice research made a significant advance, thanks to partnership between India and IRRI. With IRRI's collaborative work with ICAR, India now ranks second only to China in commercial production of hybrid rice.
- Built capacity: 1,589 Indian researchers have so far participated in education and training programs at IRRI. Indian scholars who have undergone training and conducted research at IRRI include 123 PhDs, 24 M Scientists, 13 interns, 10 research fellows, and 138 on-the-job trainees. More than 1,000 Indian scientists also attended short-term courses run by IRRI.

The results of this collaboration have been outstanding, setting an example in international research collaboration. India now has an extensive partnership with IRRI in which around 250 institutions/organizations all over India are collaborating with IRRI. The work progress during the last one year through ICAR-IRRI partnership has been summarized below:

New Rice Varieties

Gene Editing: For gene editing with grain number1a (gn1a)-knockout, edited lines showed with higher total grain number leading to higher yield in comparison to wild type (WT) without any increase in 1000 grain weight. The T1 plants have been harvested and sequenced to identify the mutation (Fig. 22). Panicle architecture imaging technique employed. Breeding lines with different yield potential phenotyped to unravel the interrelationship between several yield traits. The same set of breeding lines is being genotyped, which will be used to identify key candidates influencing yield components of panicle traits using systems-genetics. The figure 16 displays the experiment on phenotyping being visited by IRRI and ICAR scientists at Patna.

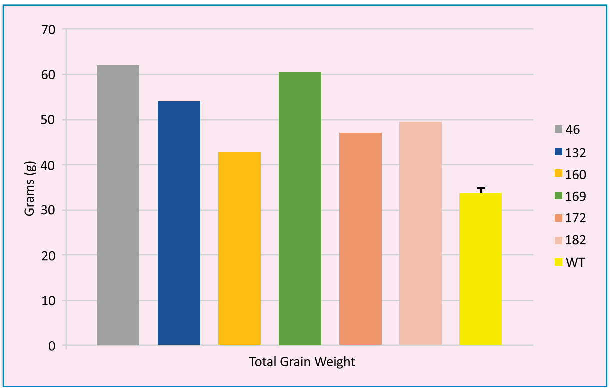


Fig. 22. Total grain yield of lines with Gn1a gene as compared to wild type (WT)

Epigenetic Regulation for Abiotic Stress Tolerance: The Guanine Deaminase (OsGDA1) gene knockout and over-expression lines were tested for drought tolerance and a clear relationship of negative regulation established, like the negative regulation of root architecture. Latest results provide definitive evidence for negative regulation of the root traits under stress by the epigenome modifying gene OsGDA1. The knockout (KO) and the over expression lines (average of three independent homozygous, Single-copy transgenic lines) show opposite effect, more clearly on root length than in xylem area.

Trait Mapping for Grain Yield, Disease, Insect Resistance: 3K panel subset was phenotyped for yield and 13 marker yield and yield related traits association (MTAs) established and superior haplotypes for important yield related component traits identified. Phenotyping of the subset of 3k panel for two seasons for blast revealed 12 significant MTAs for blast resistance. Haplotype analysis underway. Phenotyping of 3K panel subset for BB revealed 9 significant MTAs. Haplotype analysis is underway. For low GI, low GI- good texture lines characterized for yield. Low GI, intermediate GI lines subjected to transcriptome analysis and gene regulatory network derived to identify key candidate genes. At IIRR, Hyderabad- 8 lines with low GI tested in multilocation trial.

Insect-Pest and Disease Forecasting and Decision Support System: For epidemiology and management of rice false smut, promising donors for false smut resistance from 3k panel ARC10317, Baran Boro, IR 77384-12-35-3-12-1 were identified and are being used in resistance breeding this season. Work is under way on identification of QTLs for false smut resistance. SNP on chromosome 3 has been found associated with false smut traits. Molecular characterization of the collected *Ustilaginoidea virens* isolates using multi- locus sequence typing (MLST) is under progress. The work on whole genome sequencing of one false smut isolate, UV-4 (using Ilumina and Nanopore) has been initiated. Collection, establishment and maintenance of false smut isolates collected from different parts of the country in progress.

For Bacterial Blight, using genomic and phenotypic information on a large set of Xoo strains, stable molecular markers systems that can distinguish races have been developed. Using field experiments, real-time surveillance of races demonstrated. The markers have been transferred to a commercial platform, allowing other users to benefit from this technology.

For blast, in 2017, a two-step method was developed by combining PCR amplification using resistant-haplotype specific primers and sequencing of PCR amplicon for the precise diagnosis of known R genes in 50 elite rice varieties. The frequency of putatively functional Pi2/9 alleles is as low as 16%. Based on the survey of deployed R genes, we recommend prioritizing the introgression of R gene/alleles at the Pi2/9 locus and the Pikh gene at the Pik locus in the blast resistance breeding programs.

Heavy Metal Excluders for Enhanced Rice Grain Safety: Low Arsenic Rice

Multi-locational trial of 60 lines including traditional landraces and stress tolerant lines initiated in boro season for screening for tolerance/exclusion at Nadia (Low soil arsenic), Mustafabaad (Moderate soil arsenic), 24 Pargana (High soil arsenic) and Purulia (no soil arsenic control).

For Bio-actives for Healthier Rice, method development for simultaneous quantification of 41 bioactive compounds including phenolics, flavonoids, anthocyanins, tocopherol and tocotrienol is in progress using LC-MS/MS. Hosted a National Food Science Symposium from 26th to 27th December 2019 with a focus on Nutritional quality value addition of rice and rice-based food products to foster collaborations.

Applied Breeding, Multilocation Testing

A set 390 lines of estimation set 2 (ES002) were evaluated for important yield traits at IRRI, South Asia Hub (IRRI-SAH), Hyderabad. A set of 58 lines from Irrigated core panel (ICP) were multiplied and evaluated for yield attributing traits along with disease screening. ES003 and Irrigated core panel (ICP) lines are currently grown in MLT. 300 lines of Rainfed core panel 1.0 (RCP 1.0) were evaluated for yield and related components.

Phenotyping of 58 lines of global rice array (GRA) completed. Seeds of RCP 1.0 were distributed among the NARES partners. IET27958 (CR 4161-4-IR14L-572) was promoted to advanced varietal trial-I (AVT1) under aerobic situation. Out of 15 lines shared under drought breeding network (DBN) -three lines were promoted to advanced yield trial. More than 200 multiple stress tolerant lines developed and identified for multilocation evaluation in 2020 kharif season for transplanted situation (Table 8). Similarly, more than 30 lines identified for better adaptability to direct seeded situation with tolerance to different stresses.

Table 8: Multiple stress tolerant lines developed under collaborative program between IRRI and national institutes in India

Recipient	Institute	Genes/ QTLs	No. of Lines	Gene combinations	Status
Improve Swarna-Sub1	IRRI	11	32	*qDTY1.1+qDTY3.1+Xa4+xa5+xa13+Xa21+Bph3+ Bph17+Pi9+Gm4+Gm8*	MLT
Lalat	IRRI	6	40	*qDTY1.1+qDTY3.1+qDTY12.1+Xa4+Xa21+Pi9*	MLT
Naveen	IRRI	6	31	*qDTY1.1+qDTY2.2+qDTY4.1+Xa21+Pi9+Gm8*	MLT
Sahbhagi dhan	IRRI	6	14	*qDTY1.1+qDTY3.1+Xa21+Pi9+qCTS4a+qCTS11*	MLT
Krishna Hamsa	*IIRR*	6	8	xa13+Xa21+Pi54+Pi2+Bph20+Bph21	MLT
WGL14	*IIRR*	10	6	*Xa21+Pi1+Pi54+Pi2+Bph3+Bph17+Gm4+Gm8+ qDTY3.1+qDTY1.1*	MLT
PR 116	*PAU*	4	5	*xa13+Xa38+Bph20+Bph21*	MLT
PR 121	*PAU*	4	-	*qDTY3.1+qDTY12.1+Bph20+Bph21*	MLT
CO 43	*TNAU*	6	13	*qDTY3.1+qDTY12.1+Bph20+ Bph22+Sub1+Saltol*	Gen Adv
CR1009-Sub1	*TNAU*	7	32	*Sub1+qDTY12.1+saltal+Bph20+xa5+xa13+Xa21*	Gen Adv
Safri17	*IGKV*	6	51	*xa13+Xa21+sd1+pi1+pi2+Gm8*	MLT
Dubraj	*IGKV*	6	16	*xa13+Xa21+pi1+pi2+sd1+Gm4*	MLT

A workshop was held at IRRI South Asia Regional Centre (ISARC), Varanasi with participants from different institutes in India on December 23-24 to select centres for evaluation and the next step. In 2019, IET 25640 (RCPR 22-IR84899-B-183-20-1-1-1 has been released and notified in the name of "Swarna Shakti Dhan" by CVRC, during 83rd CVRC meeting held on 4th October 2019. The variety has been recommended for the state of Bihar, Jharkhand, Odisha, Chhattisgarh, Haryana, Gujarat, and Maharashtra. IET27958 (CR 4161-4-IR14L-572) promoted to AVT1-Aerobic. 6 entries nominated to IVT-Biofortification for high Zn and 8 entries nominated to IVT-Aerobic (from STRASA-DBN)

Climate Smart Management Practices

Climate Smart Management for Stress Prone Environment: Development of crop and nutrient management practices for recently released stress tolerant varieties (drought/flood/salinity/ sodicity/ anaerobic germination) was undertaken. It has been established that under salinity, higher K dose- 60 kg/ha promotes for better K+/Na+ homeostasis. 25% cost saving on fertilizers through microbial inoculants (25% RDF replaced with Halo Azo + Halo PSB + Halo Zn) has been identified. For water management, 56% irrigation water saving in surface drip- 0.73 kg/m3 IWP. Straw mulch was found better than black plastic (13% & 3% higher IWP at 8 & 6 dS/m, respectively).

Rice-Fallow: Pulse cluster demonstrations with improved cultivation practices were conducted in 23 districts covering 2528.27 hectare (ha) area during rabi 2018-19 and 2500 ha in rabi 2019-20; Green gram: VIRAT (IPM 205-7), Sikha (IPM 410-3), IPM 2-14, IPM 02-3, MH-421; Black gram: PU-31, VBN-8 and Azad. Adaptive trials conducted with improved pulse cultivars covering ~210 ha in stress prone districts during 2018-19 and 2019-20. Multi-Institutional Trials with collaborations of CGIAR organizations (CIP, ICARDA, ICRISAT and IRRI as lead) in Rice-Fallow targeting with five different crops were conducted (Table 9).

Direct Seeded Rice (DSR) Consortium

DSR consortium is engaged to identify risk-reducing practices for successful establishment of DSR, identify rice varieties suitable for DSR for different environments, develop integrated weed management options in DSR, evaluate the performance of drip irrigation system in DSR-based cropping systems and evaluate DSR performance in different cropping system in different environment. At ISARC, Varanasi, Drip irrigation DSR reduced irrigation water application by 75 to 85% compared to surface flood irrigation method in DSR or puddled transplanted rice with similar yields.

Table 9: Illustrates details of experiments by different CGIAR centres conducted in 2019.

Institutions	Activities in district	Area	Demo crop	Previous cropping
IRRI	I-Concept, OUAT & NRRI	7 Ha	Pulse crop, Vegetables	Rice-fallow/Rice-pulse
CIP	Puri, Koraput and Mayurbhanj	7 Ha	Sweet Potato	Rice-fallow
ICARDA	Kheonjar	2 Ha	Pulse crop	Rice-fallow/Rice-pulse
ICRISAT	Kalahandi, Nuapada, Nabrangpur	22 Ha in each district	Pigeon Pea / Check Pea	Rice-fallow/Rice-pulse
WVC	Koraput & Puri (I-concept)	2 Ha	Vegetables, heat tolerant/pulses	Rice-fallow/Rice-pulse

Accelerating Impact and Equity

Digital Extension: Final version of SeedCast launched in 26 districts of Odisha in close coordination with Department of Agriculture (DoA) and Odisha State Seed Corporation (OSSC). 3239 dealers oriented, and 2963 dealers indented demand for Kharif 2020. Out of 150+ varieties demanded, first 58 varieties constitute 99% of total demand. A total demand of 58,862 tons registered against previous year's sale of 27,500 ton by OSSC.

Rice Doctor user testing was done with DoA in the districts of Puri, Nayagarh, Jagatsinghpur and Cuttack and with Odisha Livelihoods Mission (OLM) in the districts of Nayagarh and Sundergarh and post graduate students of Odisha University of Agriculture and Technology (OUAT). Content write shop was conducted with support from National Rice Research Institute (NRRI), OUAT, DoA to validate and finalize the content for Rice Doctor Odisha. Dissemination of Rice Doctor Odisha is in progress with DoA and farmers. Planning to integrate Rice Doctor Odisha into ongoing government programs *viz*., e-pest surveillance and Fasal Suraksha Abhyan. For the Rice Crop Manager, 45 Head to Head trials to test the rainfed component of RCM, 15 on- farm trials to test the weed management component of RCM established with NRRI, 3 on- station experiments on productivity and resource use efficiency in different cropping systems established with OUAT, 15 on-farm trials on zinc management, 4 Ph.D. students involved in strategic research from OUAT, BHU, BAU & Amity University.

Rice Value Chain, Value Addition and Post-Harvest Management

Under the IRRI initiative, KVK-Khordha wih ICAR-CIFA worked on the designing the validation trail of Solar Bubble Dryer and other innovations. Association with OUAT was made by collaborating the validation of Solar Bubble Dryer systematically with defined parameters. The Grain safe prototype developed by IRRI for hermetic storage and solar drying of paddy in one operation was set up at RARS, AAU, Titabar. One ton of paddy seed was placed inside the Grain safe and initial moisture content of the paddy seed (var. Shraboni) was recorded 16-17.5%. One post Graduate M.Sc. (Agri) student, has been entrusted for taking periodical observations of the seed stored. Super bag trial was planned in Cuttack at farmer's field as well as at KVK, Santhpur to see the quality of paddy and other parameters. Similarly, in collaboration with OUAT, rice is stored in super bag to check the cooking quality, insect control and other quality parameter. Both trials are going on and the result will come after 4 months.

Integrated Solutions for Risk Management

Socially Acceptable Comprehensive Crop Insurance: In collaboration with CIWA, IRRI provided support to two group-based women enterprise activities through the NGOs SWAD and Pragathi. Capacity Building of 20 women farmer leaders on production and access to quality seeds completed; Seed system interface meeting of women members from 20 different groups with seed dealers, vendors, DOA and OSSC officials conducted; Demonstration of scientific seed storage practices using "IRRI superbag" conducted. Work initiated to establish mobile rice processing mill at Koraputhelping 2000 women farmers growing aromatic paddy in 1000 acres.

Adarsh Dharmagarh women farmers Services producer company limited (ADWFSPCL) is registered as an FPC and has mobilized 1751 women members. It is registered under OSSOPCA as seed producing agency for both rice and pulses; Rice seed production undertaken successfully in 73 ha (involving 145 women farmers); and pulse seed production in 25 ha involving 40 women farmers is on-going; 80 women farmers participated in Quality Rice seed production training in Kharif 2019, and training on pulse seed production is on- going for the FPC members.

Quality Rice Seed Production training completed in Kharif 2019 in different districts of Odisha covering 120 women farmers. For crop insurance, process Transparency, insurance unit as village or individual plot, and market risk coverage are the most preferred attributes. Awareness program significantly improved the choice of crop insurance (from 15% to 78%). Classroom based training is better, but digital approach is also significantly improved insurance choice. 70% farmers preferred bundles product to stand alone insurance or STRV.

Capacity Development

Four scientists, two each from NRRI, Cuttack and two from IIRR were selected for four months training program at IRRI in the area selected by the ICAR institutes. The training covered IoT-based decision support systems for water management, Genome editing and mapping of grain nutritional properties.

Field Monitoring of Varietal Development at ICAR Research Complex for Eastern Region, Patna

Project Workshop on Development of multiple stress tolerance and DSR molecular breeding held at ISARC during 23-24 December 2019

Rice Science for a Better World
IRRI Team (Dr. Matthew Morell, DG IRRI; Dr Arvind Kumar, IRRI India Representative & Dr. Nafees Meah, IRRI S. Asia Representative) meets with Dr. Trilochan Mohapatra (DG, ICAR)

International Water Management Institute (IWMI)

IWMI works with a vision `a water-secure world' and has its offices in 13 countries and a global network of scientists operating in more than 30 countries. For over three decades, IWMI's research results have led to changes in water management that have contributed to social and economic development. With its headquarters in Colombo, Sri Lanka and offices in Delhi and Anand in India, IWMI has been working on the issues related to water and agriculture for over two decades in India. IWMI-TATA Water Policy Program (ITP), Anand has been addressing the issues in water institutions, policy, governance and management for close to about 20 years. ITP has operated as a 'irrigation-agriculture-poverty' think tank. Our researchers work in close collaboration with national and state governments and contribute to water resources planning, management, and policies. The international quality and relevance of IWMI research was acknowledged by the awards of the 2011 Crystal Drop Award and 2012 Stockholm Water Prize.

IWMI's mission is to provide water solutions for sustainable, climate-resilient development. IWMI targets water and land management challenges faced by poor communities in developing countries, and through this contributes towards the achievement of the Sustainable Development Goals (SDGs) of reducing poverty and hunger and maintaining a sustainable environment. IWMI is leading the CGIAR Research Program (CRP) on Water, Land and Ecosystems (WLE) and partnering with other CRPs including Climate Change, Agricultural Food Security (CCAFS). IWMI in India is hosted by the Indian Council of Agricultural Research (ICAR)/ Department of Agricultural Research and Education (DARE). It partners with numerous national and state level bodies, such as the Indian Council of Agricultural Research (ICAR), Department of Water Resources, River Development and Ganga Rejuvenation and various civil society organizations, donors, foundations and the private sector. Funding partners include governments, foundations, multilateral organizations and the private sector.

Together with our partners, we combine research with data to build and enhance knowledge, information services and products, strengthen capacity, convene dialogue and deliver actionable policy analysis to support the implementation of solutions for water management. IWMI works through collaborative research with many partners in the country, and targets policymakers, development agencies, farmers and private sector organizations.

Over the years IWMI has been regularly contributing to water management, water resources policies and planning, water-energy-food nexus, solar irrigation, water risks monitoring and management-floods and droughts, and water productivity to name the few. IWMI research in the past has contributed towards achieving the millennium development goals and presently working to support the sustainable developmental goals. IWMI's research in India has had a significant impact on water policy. Innovative science and evidence-based solutions were provided for emerging national priorities. These includes river basin management, sustainable groundwater management, climate change and adaptations, improvement of water use efficiency, business models for waste and wastewater management, urban and peri-urban farming.

IWMI has contributed to different river basin management aspects addressing water security and agriculture. The IWMI-TATA Water policy program (ITP) undertook extensive research on the groundwater energy nexus and identified practical ways to unlock the issues through Jyotigram Yojana scheme in Gujarat. This has become a flagship program and implemented in several states of India. The Planning Commission hailed

Gujarat's Jyotigram scheme as a huge success and recommended replication across the country. In West Bengal, IWMI research has helped in improving groundwater access for smallholder farmers to make groundwater use profitable through amendment of GW pumping act.

IWMI has also worked on the micro irrigation adaptation through awareness programs on maintenance of the system and scheduling of irrigation. This led to the reduction in water abstractions and increased yield up to 40 percent in southern states of India. Policy guidelines was also developed in the promotion and improvement of micro irrigation in Tamil Nadu state. Developed database for different river basins (Krishna, Ganga, and Brahmaputra) in India and map of the irrigated areas. The maps are available in IWMI website for research reference and policy advocacy.

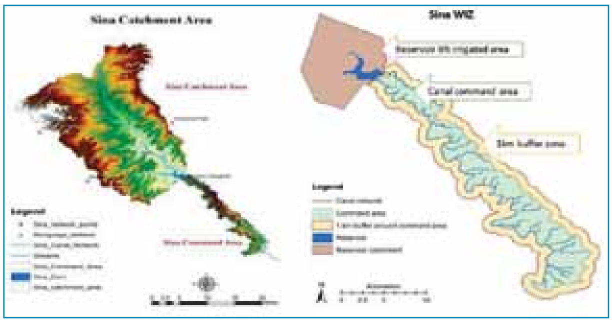
IWMI has implemented and promoted various water saving initiatives viz., direct seeding of rice, alternate wetting and drying of rice and Mechanized transplantation of rice in Andhra Pradesh and Telangana states in coordination with State Agricultural Universities for climate change adaptation.

Recently, Prime Minister Krishi Sinchaayee Yojana (PMKSY) was analysed under ITP and its results shared through policy consultations with key stakeholders to present alternative formulation that prioritized the 112 districts that are most irrigation deprived (less than 30% irrigated holdings) and where groundwater development is less than 70%. Taking cognizance of this policy research, Water Resources Ministry, Government of India developed a special groundwater irrigation development program, PMKSY-Groundwater to add 2.1 million ha of new irrigated areas in 96 most irrigation deprived districts.

The work plan activities during the last one year have been summarized below:

Enhancing Economic Water Productivity in Irrigation Canal Commands

IWMI in partnership with the ICAR-Indian Institute of Water Management (IIWM), and AICRP IWM Mahatma Pule Krishi Vidyapeeth (MPKV), in a joint pilot project in Sina medium irrigation canal system demonstrated a new concept of water influence zone (WIZ), through direct use of canal irrigation and indirect use of return flows through groundwater or conjunctive irrigation, which is important and often may be larger than the designed command area. The performance analysis of the system comprises of water accounting, benchmarking indicators, and the water cost curves to support the decision support system for identifying potential financially viable strategies for enhancing water productivity, i.e., the value per unit of irrigation consumptive water use (CWU) expressed in INR/m^3. Increasing economic water productivity (INR/m3) is a better strategy for water scarce systems. The analysis raises the following important issues for policy planning: i) refocus assessment of actual irrigated area and investment for bridging the gap between IPU and IPC in the command area to the WIZ, ii) focus on conjunctive irrigation in the WIZ in rabi season which is not possible without groundwater recharged from return flows, and iii) introducing cropping pattern which increase EWP. The Irrigation Department, Government of Maharashtra has approached IWMI for undertaking a similar study in the *'Yedgaon Dam Reservoir and Canal System'.* This is an outcome of a potential opportunity for further upscaling and an evidence of uptake.



Underground Transfer of Floods for Irrigation (UTFI)

Underground Transfer of Flood for Irrigation (UTFI), piloted jointly with ICAR-CSSRI in Rampur district of U P for ground water recharge and reducing floods has been completed in 2019 and pilot site handed over to local Gram Panchayat and Administration for future operations. Over three years of pilot testing, volumes ranging from 26,000 to 62,000 m^3 were recharged each year over durations ranging from 62 to 85 days and this would be enough to irrigate 8 to 18 hectares of rabi season crop. Efforts were concentrated on upscaling in UTFI in high potential districts of U.P. As part of this process, on 8th January ICAR-CSSRI organised a state level "Consultations on scaling out UTFI" where Hon'ble Agriculture Minister of Uttar Pradesh graced the consultations as the Chief Guest. The UTFI has also been referred as one of the adaptation options in 2019 UN Water Policy Brief on Climate Change and identified as one of the UNESCO case studies on successful managed aquifer recharge (MAR).

Index Based Flood Insurance (IBFI) and Post Flood Management

IWMI, jointly with ICAR- IIWM, Bhubaneswar and ICAR Research Complex for Eastern Region, Patna and with the support from CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS) and the CGIAR Research Program on Water, Land and Ecosystem (WLE) and the support of State government partners in Bihar have been working to develop flood index insurance that can accurately predict yield loss of smallholder farmers using satellite and public data – thus reducing the transactional costs of providing insurance and making insurance for smallholders a viable product. The IBFI has now been tested for the past three years (2017–2019), covering 1,550 households of which 950 HH with a total insurance of INR 1,500,000 covering more than 15 villages in Gaighat and Katra block in Muzaffarpur district. Insurance claim pay outs to eligible farmers were made in formal ceremonies by Hon'ble Union Minister of Agriculture and Farmers Welfare in 2018 and by Hon'ble Union Minister of Animal Husbandry and Fishery in 2020. It is also important to note that during the 2019 flood insurance pay-out, it promoted a total of 45% women beneficiaries through gender-responsive insurance literacy and advocacy and capacity building among local communities.

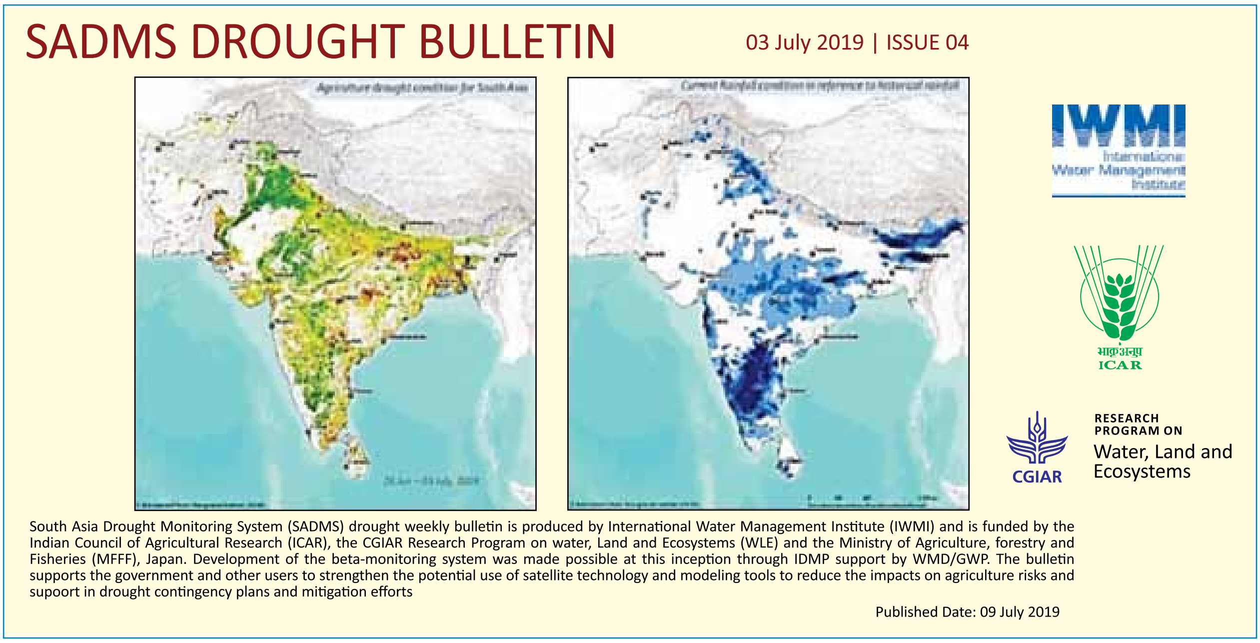
In conjunction with IBFI, post-flood management plan to promote agriculture resilience was also piloted in selected flood affected areas of Muzaffarpur and the results have been encouraging with enhancement in benefit: cost ratio from 1.55 to 2.92. Moving forward, a new project on "Bundling Innovative Risk Management Technologies to Improve Smallholder Livelihoods in South Asia (BICSA)" has been initiated during 2019 by bundling insurance with stress tolerant seeds and advisory and post disaster recovery. BICSA was piloted in 2019 for kharif and rabi with 754 households in Muzaffarpur and Gaya districts, Bihar.

Drought Monitoring, Planning and Management

IWMI is Jointly bringing out district wise weekly drought bulletins using South Asia Drought Monitoring System (SADMS) in collaboration with ICAR-Central Research Institute on Dryland Agriculture (CRIDA) for kharif and Rabi seasons and sharing with Central and State Authorities including IMD website. Drought information and products have been in particular shared with Karnataka, Tamil Nadu, Andhra Pradesh and Telangana for Kharif and Rabi seasons for drought monitoring. ICAR-CRIDA has also validated this in six districts and is piloting use of this information in drought contingency planning. This information is also used to support drought contingency plans for states in Tamil Nadu, Andhra Pradesh, Karnataka and Telangana to mitigate drought risks. IWMI-ICAR joint work on "Drought Surveillance System for South Asia: Climate and Food Security Outlook" has been adjudged for the Geospatial World Excellence Awards 2020.

Climate-Resilient Agriculture

A new project "Strengthening Capacity in India for Scaling-up Climate-Smart Agriculture Technologies, Practices and Services" jointly



SADMS DROUGHT BULLETIN

03 July 2019 | ISSUE 04

South Asia Drought Monitoring System (SADMS) drought weekly bulletin is produced by International Water Management Institute (IWMI) and is funded by the Indian Council of Agricultural Research (ICAR), the CGIAR Research Program on water, Land and Ecosystems (WLE) and the Ministry of Agriculture, forestry and Fisheries (MFFF), Japan. Development of the beta-monitoring system was made possible at this inception through IDMP support by WMD/GWP. The bulletin supports the government and other users to strengthen the potential use of satellite technology and modeling tools to reduce the impacts on agriculture risks and supoort in drought contingency plans and mitigation efforts

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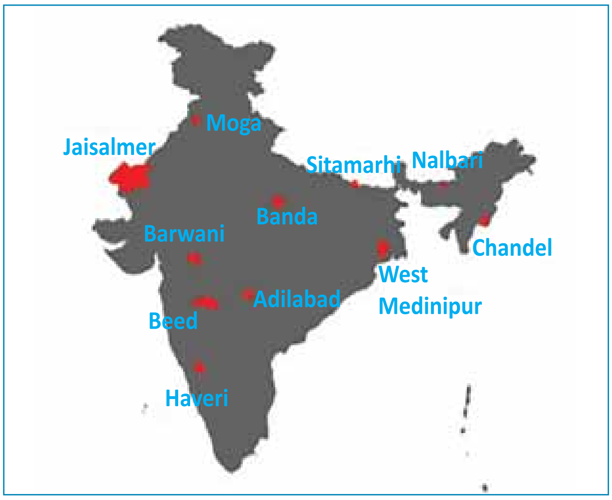
developed by ICAR, IWMI and CCAFS started in 2019. The project aims to contribute towards a national strategy for synthesizing cumulative knowledge, experiences and learnings gained by ICAR, CCAFS and CG Centre's Programs in climate risk management to guide investments being made by the government and donors in scaling out climate resilient agricultural practices and technologies at the developmental scale in India.

Core team including members from ICAR, CRIDA, ATARI, IWMI and CCAFS has been created which jointly discussed preparation of a framework and detailed action plan for preparing district climate Resilient Agriculture plan. As part of the project, 11 vulnerable districts were selected, one from each ATARI zones for building capacity and piloting district climate resilient agriculture plan. In 2019, 3 Core project group meetings with partners and 3



workshops with 11 selected KVK's, ATARI's were organized. Further to that, 11 stakeholders' meetings at selected KVK districts were organized by local KVKs to inventorize and prioritize climate smart agriculture interventions. Risk and vulnerability analysis of 11 selected districts was also undertaken. Outlines of the district climate resilient agriculture plan was finalized and preparation of report for pilot district has been in progress.

RESILIENCE: The overall goal of the RESILIENCE project is to improve agricultural productivity and the adaptive capacity and livelihoods of smallholders to climate and economic changes, by building resilience and strengthening the market value chains in the states of Odisha and Assam in India. IWMI, as one of the partners, carried out socio-economic vulnerability assessment and agro-ecosystem mapping (in partnership with ICAR-NRRI in Odisha) to assess smallholder vulnerability in face of climate change and identify suitable climate smart agriculture (CSA) technologies. In total 1627 households were surveyed with sample size of 825 in Odisha and 802 in Assam (partnership with AAU, Jorhat and MSSRF). Socio-economic vulnerability analysis was carried out to analyse the most suitable interventions that can reduce the vulnerability.

IWMI has also started field pilots in collaboration with ICAR-NRRI to test integrated water resource management practices and improving water-use efficiency at two pilot sites in Cuttack District. Drip irrigation, soil moisture-based irrigation using chameleon Sensors and alternated-wetting and dry (AWD) have been setup for both demonstration and evaluation of water productive. As part of project, IWMI will also provide flood and drought monitoring for advisory services in the pilot areas.

Climate-Smart Solarization of India's Irrigation Economy

IWMI is partnering with International Solar Alliance (ISA); Indian Council for Agricultural Research (ICAR); World Bank; Tata Trusts; CGIAR Research Program on Water, Land and Ecosystems (WLE); CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS); Swiss Agency for Development and Cooperation (SDC); Gesellschaft für Internationale Zusammenarbeit (GIZ); Aga Khan Rural Support Programme, India (AKRSP-I); Collectives for Integrated Livelihood Initiatives (CInI); Gujarat Energy Research and Management Institute (GERMI); and Gujarat Urja Vikas Nigam Limited (GUVNL) in this important area of solar irrigation.

A Policy Consultation on Solar Irrigation-Solarization of Agriculture- risks and opportunities was jointly organized by ICAR-ISA-IWMI on 26th June 2019, at NASC Complex, New Delhi. IWMI and ICAR-CAZRI made presentations at the IWMI-ICAR Special Thematic Session on "Solarization of Agriculture" arranged by ISA at the 22nd ISA SUN Meet in Delhi on 22nd August and this provided an excellent opportunity to share our experiences with other member countries of ISA. In December 2019, IWMI partnered with the World Bank and NITI Aayog to co-organize a policy consultation on Energy-Water-Agriculture Nexus in New Delhi. IWMI's SPaRC (Solar Power as Remunerative Crop) pilot in Dhundi attracted a lot of media and policy attention and inspired the Government of Gujarat's *Suryashakti Kisan Yojana* (SKY)– for promoting grid-connected solar pumps. As part of SKY, more than 3,500 farmers have already been solarized. With support from SDC, IWMI has organized farmers in ten SKY feeders into feeder-level solar cooperatives and another six such cooperatives are currently awaiting formal registration. IWMI-SDC Regional Project on "Solar Irrigation for Agricultural Resilience in South Asia" (SoLAR-SA) was approved and initiated in December 2019, and groundwater sustainability study is an important component of this project.

Community Irrigation Management

Our impact assessment study of the "West Bengal Accelerated Development of Minor Irrigation (WBADMI) Project" based on instruments of household sample survey, FGDs, KII, field visits and application of RS and GIS tools has demonstrated increase in cropping intensity, cropped area especially in Rabi season, increased irrigated area, and crop diversification in Bankura, Birbhum, Purulia and Paschim Medinipur. The results suggest the advantage of community based irrigation management and value addition through integrating this with agricultural support services. This demonstrates that creating functional WUAs and value addition through providing agricultural support services is critical for increased agricultural production and livelihood generation.

Workshops, Consultations and Outreach

- About 10 Workshops, consultation meetings, seminar and capacity building events were organized in partnership with ICAR.

- IWMI –ICAR organised a joint session on 'How Research is Contributing to Water, Food and Nutrition Security' at the 3rd World Irrigation forum in Bali on 3rd September, 2019
- IWMI together with ICAR – Indian Institute of Water Management (IIWM), Bhubaneswar organized a workshop on Economic Water Productivity and Irrigation Benchmarking using OIBS/SAMS tool in Maharashtra on June 7th, 2019
- ICAR-IIWM– IWMI co-organized together with SAARC a short course on water management at Bhubaneswar.
- IWMI provided DKMA- ICAR with a IBFI Photo story to be shared online for the website
- Two success stories have been shared with DKMA for being uploaded on the ICAR website– IBFI and UTFI

World Agroforestry (ICRAF)

World Agroforestry (ICRAF) is closely working with ICAR institutes under NRM Division in the domain of Agroforestry and allied aspects to compliment the overall aims and goals of ICAR; and to enhance livelihoods of farmers. As part of the ICAR-ICRAF Work Plan 2016-2020 and based on the priority areas decided during the last ICAR-CG Meeting for 2019-20, the salient achievements for the year 2019 are summarized below.

MIR Spectroscopy based assessment of soil health for rapid assessment of important soil parameters that can be used in the soil health card scheme

Ongoing MIR Spectroscopy based assessment of soil health continued to improve the models used in MIR spectroscopy to predict soil properties in Alfisols, and to establish suitable prediction models for estimation of additional soil properties in both Alfisols and Inceptisols. Results obtained during 2019, using Mid-infrared (MIR) technology further confirmed good prediction results for six soil properties viz. pH, Electrical Conductivity (EC), Organic Carbon (OC), Sand, Silt and Clay in Alfisol. These results were also confirmed by the Soil Physics Laboratory, IARI, New Delhi. A fresh set of 448 samples of Inceptisols collected from different locations in the Indo-Gangetic plain were analysed for pH, EC, and Av-P, by both the MIR and wet chemistry methods. IISS-ICRAF team is working to develop/ refine the prediction models for Inceptisols. The progress of work on MIR was reviewed on 17th December 2019 at ICAR-IISS, Bhopal in the presence of scientists from ICAR-IISS, Bhopal; IARI New Delhi; and ICRAF (New Delhi and Nairobi). Based on the 4 years' Spectroscopy data obtained by IISS-ICRAF & its reconfirmation at IARI, MIR spectroscopy is ready for large scale use to effectively analyse pH, Soil Organic Carbon, EC, Sand, Silt, Clay, and (indirectly) nitrogen in Alfisol

ADG (Soil & Water Management), ICAR HQ reviewed the progress of work through ICAR-IISS-ICRAF collaborative project on use of Infrared Spectroscopy in Soil Health Assessment at ICAR-IISS, Bhopal on 29 May 2019.

Joint Progress Monitoring of the Collaborative Project on "Assessment of important soil properties of India using Mid-Infrared Spectroscopy" at ICAR-IISS, Bhopal on 17 December 2019.

of India which covers 20 % of the geographical area of the country. MIR technology can also be used to analyse Soil Organic Carbon and pH in Inceptisols. Work to standardize the models for other soil type will continue in 2020.

Efforts to develop small-smart-mobile equipment to measure soil health

ICRAF with partners has developed a prototype of handheld-portable device for on the spot analysis of soil properties. The instrument is in advanced stage of development, and the first prototype is expected to be available for testing in India during 2020. ICAR-IISS and ICRAF teams agreed to do a pilot testing when the equipment is available during 2020.

Publication of guidelines for production of quality planting material of Agroforestry species, and to designate a certification agency for the quality planting material for agroforestry species

Lack of availability of quality planting material (QPM); and absence of a guideline to produce and certify QPM production are major prohibitive factors for expansion of agroforestry / Trees outside Forest (TOF). Therefore, it was agreed that ICAR-ICRAF will jointly develop a QPM guidelines in collaboration with relevant stakeholders. The guideline was completed during 2018-2019, and after approval of the draft during ICAR-CGIAR meeting, it has been jointly published by ICAR-ICRAF. One hundred copies of the book were circulated to various ICAR institutions, SAUs, Government Ministries, Departments, and the line departments of the state Governments.

Regarding the certification method and certifying agency for the QPM, ADG-Agroforestry led the discussions with the Director-CAFRI & PC AICRPAF, ICAR-NRM Division, and Additional Secretary DoACFW & Director SMAF to designate a certification agency for agroforestry species. The National Bamboo Mission has already taken this up through the Technical Committee No.1, where ICAR is represented by the Deputy Director General (NRM). Therefore, it is appropriate that DoACFW will use the institutional framework finalized under Restructured NBM to designate a certification agency for QPM for agroforestry species which would include scientists of Institutes of ICAR.

Joint ICAR-CAFRI and ICRAF efforts to harmonize the terminology, definitions and techniques used to map Trees outside Forest)/agroforestry

There are significant differences on mapping of agroforestry done by various institutions. Therefore, it was decided during 2018 to harmonize the terminology, definitions and techniques used to do such mapping. Accordingly, several rounds of discussions and exchange of information/literature was held with the Members of the Focused Group onRS&GIS of Expert Committee constituted by the MoEF&CC to develop strategy to increase green/tree cover outside recorded forest areas (Tree Outside Forest, TOF). After consulting relevant stakeholders, a draft document was prepared covering harmonized terminology, definitions, and techniques used to map TOF/ agroforestry, and was shared with ICAR-Natural Resource Management division; ICAR-CAFRI; Centres of AICRP on Agroforestry; World Agroforestry (ICRAF); Ministry of Agriculture & Farmers Welfare (MoAFW; GOI), Ministry of Environment, Forests and Climate Change (MoEF&CC; GOI), and its various institutions; FSI, NRSC and Members of the Focused Group of Expert Committee constituted by the MoEF&CC on strategy to increase green/ tree cover outside recorded forest areas. The ICAR-ICRAF book entitled "Mapping Agroforestry and Trees Outside Forest" was formally launched virtually by Dr Trilochan Mohapatra, Secretary DARE & Director General, ICAR during the ICAR-CGIAR Annual Review Meeting held on 4 May 2020. The publication is available on ICRAF website: http://www.worldagroforestry.org/publication/mapping-agroforestry-and-trees-outside-forest

Developing consensus among stakeholders using uniform definitions, terms, and technology to map agroforestry /trees outside forests

All the relevant stakeholders jointly reached on the consensus for developing common techniques on mapping and delineation of agroforestry area/ TOF in India. The agreed methodology and terminology are documented in the ICAR-ICRAF book entitled "*Mapping Agroforestry and Trees Outside Forest*". The stakeholders are expected to use it uniformly. The publication is available online: http://www.worldagroforestry.org/publication/mapping-agroforestry-and-trees-outside-forest

Estimation and mapping of area under specific agroforestry tree species (Poplar) through remote sensing and GIS

ICAR-CAFRI and ICRAF are working to develop technology/spectral library to successfully map individual tree species using Geo-informatics. Through this ongoing project, using satellite data of different resolution, poplar plantations were mapped in 3 states. For state level mapping, Sentinal-2 satellite data (spatial resolution 10 m) was used, while for district level mapping, high resolution LISS-4 data (spatial resolution 5.8 m) was employed. State level Poplar mapping using Sentinel-2 data was completed in Uttar Pradesh, Uttrakhand, and Bihar. Mapped areas were verified through ground truthing as well. In addition, district wise mapping of poplar in Punjab was completed using high resolution data (LISS-IV). To complete district wise mapping of Poplar in Punjab, high-resolution data (LISS-IV) was procured from National Remote Sensing Centre (NRSC).

State level Poplar area maps along with statistics for three states were generated. The digital image interpretation techniques with sub-pixel classification method was used to generate prefield maps of Poplar in Punjab. The final district-wise Poplar area maps in the districts having significant area under poplar were developed with high mapping accuracy.

Estimated Poplar area was highest in Hoshiarpur district (10573 ha), which is 53.9 per cent of the agroforestry area of the district (Fig. 23). Poplar based agroforestry systems accounted for more than 50 per cent of total agroforestry area in Rupnagar, Pathankot and Hoshiarpur districts. Area under Poplar in Kapurthala, Jalandhar and Tarn Taran districts has been estimated to be 1814.23 ha, 1694.56 ha and 2162.49 ha, respectively. Agroforestry and Poplar area in 12 districts of

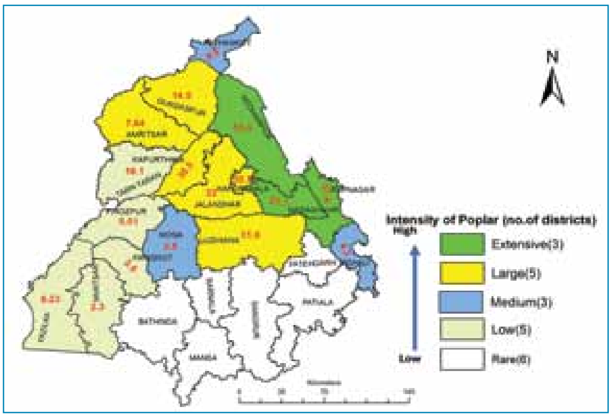


Fig. 23. Map of Punjab showing district-wise poplar intensity and percentage in Punjab

Punjab come out to be 145822 ha and 38989.59 ha, respectively. Poplar area accounted for about 26.7 percent of the agroforestry area in these districts. Poplar mapping at state level with Sentinel-2A data indicates Poplar occupies an area of about 0.276 million ha (5.63% of total geographical area). Accuracy of these estimations are about 81%.

ICRAF to initiate (medium/long term) training programs for ICAR scientists at Nairobi or at its other regional/ country programs

Based on recommendation, ICRAF initiated a medium-term training program on "Tree Genomic Research", and one ICAR scientist successfully attended this co-learning capacity development program at ICRAF Nairobi.

ICRAF should take forward the idea of initiating tree genomics in collaboration with NRCPB, NBPGR, CAFRI & other institutions

ICRAF worked with different stakeholders for taking forward the suggestion on initiating tree genomics research in India. A one-day meeting to discuss Tree Genomic Research Initiative was organized on 25th Sept. 2019 under the chairmanship of Dr T. Mohapatra, Secretory DARE & DG ICAR. Various scientists and officials from DBT, DST, ACIAR, ICRISAT, ICRAF and ICAR Institutions participated & contributed. It was decided to promote convergence, cooperation, and alignment among stakeholders leading to establishment of a consortia partners representing ICAR, ICFRE, CSIR and other institutions/ organizations with strength in tree-genomics. Collection of information on collection/ availability of Agroforestry species germplasm and existing facilities and expertise at the involved institutions is in progress. Based on the information received a draft paper on Status of Tree Genomics was circulated among the stakeholders and finalized. Members of the Consortium have nominated a nodal person and a lead scientist who would be directly contributing to this initiative. An e-consultation was to identify some of the priority agroforestry species, and to develop a road map for further action. Based on the importance of neem for production of neem coated urea, and its medicinal, pesticidal, and other domestic uses; neem emerged as one of the most potential species to initiate the genomic work.

Discussion on the Tree Genomic Research Initiative under ICAR-ICRAF Collaborative Work Plan, held at NASC Complex, Pusa on 25th September 2019.

Improvement of tribal livelihood through lac agroforestry

Work progressed on Lac-based agroforestry interventions initiated jointly by ICAR-IINRG-ICRAF on farmer's field in three districts of Jharkhand viz. Ranchi, Khuthi and Saraikela-Kharsanwa. Farmers were provided more than 7000 lac host saplings of *Flemingia semialata*, *Calliandra* and Ber. Capacity development activities like farmers' field school (1); demonstrations (18), field days (3), Kisan Gosthi, farmers' field school and diagnostic & crop monitoring visits (38.) were conducted in collaboration with partners. Impact will require some more time for trees to grow.

ICRAF is also implementing a large project with 5000 farmers in full partnership with ICAR-CAFRI, NRRI, and CAZRI in Odisha. Project is funded by Odisha Government.

ICRAF closely worked with ICAR institutes on various aspects of agriculture research and development in India, and it's out scaling in other Asian and African countries. Following are some of the activities undertaken during 2019.

- ICRAF is jointly working with ICAR-CAFRI to out scale its agroforestry-NRM based water conservation technology in 2 districts of Odisha. Full recognition and visibility to ICAR-CAFRI is ensured at each and every step of the implementation.
- ICRAF and the National Institute of Agricultural Extension Management (MANAGE) in collaboration with Indian Council of Agriculture Research (ICAR); ICAR- Central Agroforestry Research Institute, Jhansi; Forest Collage & Research Institute, Mettupalayam, TNAU, Tamil Nadu organized an International Training Program on "Agroforestry" under FTF ITT Program from 10 -24 October 2019 for middle level policy makers and agricultural professionals from five Asian and five African countries. The 26 participants were from Sri Lanka (5), Bangladesh (2), Botswana (1), Cambodia (1), Kenya (1), Malawi (2), Nepal (7), Myanmar (4), Tanzania (1) and Uganda (2).
- During December 2019, ICRAF in collaboration with Ministry of Agriculture of Vietnam organized an Agroforestry Policy dialog for Viet Nam at Hanoi where scientist from ICAR-CAFRI participated and shared the Indian expertise on agroforestry technologies and agroforestry policy.
- ICRAF in collaboration with CAZRI implementing a pilot on agrivoltaic-agroforestry

Participants from ten countries in Africa and Asia of the International training, "Agroforestry: Policy, Practice and Impact" organized by ICRAF-ICAR-FCRI during 10-24 October 2019 system in Odisha where CAZRI scientists are taking the lead.

Capacity building

As part of capacity building activities under ICAR-ICRAF Work Plan following initiatives were taken in collaboration with ICAR institutes

- Five scientists represented ICAR at the 4th World Congress on Agroforestry during 18-24 May 2019 held at Montpellier, France.
- One scientist represented ICAR at the Regional Agroforestry Conference held at Kathmandu, July 2019.
- One scientist from CAFRI represented ICAR at the High-Level Consultation on "Need, Role, and Potential of Agroforestry Policy" held in Hanoi, Vietnam during 18-19 December 2019.
- Odisha State Government officials attended 3 Study tours at ICAR-CAFRI
- CAFRI is part of the Monitoring & Evaluation team of the Govt. of Odisha for implementation of Odisha agroforestry project.

Return on investment information

Benefits through agroforestry are enormous but challenging to calculate a financial value for each one. The most robust benefit is the production of more than 70% timber required by the country through agroforestry which is valued at more than Rs. 14,000 crores annually. This otherwise, would have been imported. ICAR-ICRAF's joint work has significantly contributed towards this.

Agroforestry has contributed to the increased green cover of India (ISFR, 2017) which in turn provides environmental benefits (addition of oxygen and removal of carbon from the atmosphere). Both these actions are priceless and hard to put a value in Rupees. Based on an assessment, the average rate of return on investment in agroforestry in terms of Cost: Benefit ratio varies from 1: 2.4 to 5.02.

ICAR-ICRAF collaboration complemented and added value to ongoing research priorities of natural resource management in the country. It resulted in developing the techniques for use of geo-informatics in mapping agroforestry at national and sub-national level, formulation and approval of National Agroforestry Policy-2014, monitoring hub for tree-crop contributions to SDGs at multiple levels, and capacity development through nine international trainings on Carbon Finance Market, Carbon Stock Assessment, Carbon Trading Options, Climate-smart agroforestry options, Geospatial technologies, Design of Agroforestry experiments, Ecosystem services, Meta-analysis, Agroforestry Policy, Practice and Impact benefitting more than 100 participants. With ICRAF initiating a medium-term training program on "Tree Genomic Research" this year one ICAR scientist got benefitted through this co-learning capacity development program at ICRAF Nairobi.

ICAR-ICRAF has immensely contributed for much required national level guidelines and certification standards for planting material. Agroforestry mapping technique developed will help in species identification, and the MIR Spectroscopy based assessment of soil health can be used for rapid assessment of important soil parameters.

Farmers practicing diversified agroforestry system (trees planted in pulses/oilseeds) in Odisha

With the collaboration, the profile and visibility of ICAR institutions is highlighted in the region, and globally. The best example is ICAR-ICRAF's India experience on agroforestry policy resulted in launching of National Agroforestry Policy in Nepal, and the ASEAN Guidelines for Agroforestry Development. ICAR-ICRAF joint publications on Agroforestry are receiving global attention as indicated by the Visits/downloads, reads statistics in the region and globally.

World Fish

WorldFish is an international, non-profit research organization that works to reduce hunger, malnutrition and poverty across Africa, Asia and the Pacific. With a 45-year track record of leading science, WorldFish generates scientific evidence and innovations for the inclusive and sustainable development of aquaculture and fisheries, making fish and aquatic foods a path towards shared prosperity, inclusive growth and healthy and resilient livelihoods. WorldFish is part of the CGIAR, the world's largest agricultural innovation network, whose mission is to end hunger by 2030 through science to transform food, land and water systems under threat of climate change. Within CGIAR and the wider global agenda of agricultural research for development, WorldFish has a unique research mandate focusing on the role and contribution of aquatic foods and aquatic food systems to the global food systems transformation towards healthier and resilient diets. Our research shapes and supports progress on multiple Sustainable Development Goals (SDGs), with a mission focus on SDG2: Zero Hunger and a special focus on SDG14: Life Below Water. WorldFish is dedicated to making fish and other aquatic foods a key component of the transformation of global food systems, contributing to addressing poverty, hunger and malnutrition among the millions of people who depend on aquatic foods in low- and middle-income countries throughout Africa, Asia and the Pacific. The CGIAR Research Program on Fish Agri-Food Systems (FISH) is led by WorldFish.

ICAR and WorldFish research collaboration under CG Partnership began in 2018 although the broader framework for CGIAR existed in 1996. The work plan activities for this partnership were to (a) facilitate in-depth scientific interactions between 3 research programs of WorldFish (Sustainable Aquaculture, Small Scale Fisheries, Value chains and Nutrition) and (b) Co-development of a five-year (2019-2023) work program. The 5-year joint research is designed as an evolving and dynamic research activity to harness the research potential of ICAR researchers and WorldFish and address topics of regional and global relevance. The research design and activities implemented in 2019 would set the stage for accomplishing the envisaged research outputs over the next 4 years leading to important outcomes and impacts. The following section provides the details of work done in 2019

The collaborative programmes are being implemented through three of the ICAR Institutes *viz*., Central Institute of Freshwater Aquaculture (CIFA), Bhubaneswar; Central Inland Fisheries Research Institute (CIFRI), Barrackpore; and Central Institute of Fisheries Technology (CIFT), Kochi; broadly in the three thematic areas as given below:

i. Life cycle and environmental foot print analysis of carp and pangassius farming systems in India including yield gap analysis and on farm performance evaluation of genetically improved varieties (e.g. rohu and freshwater prawn),
ii. Productivity enhancement from inland wetlands and flood plains, and
iii. Fish consumption patterns of rural and urban consumers and development of specific fish products for the first 1,000 days of life – pregnant and lactating women and young children 6-24 months of age.

In the process of implementation of the work plan, the following interaction meetings were held for initiating the collaboration:

- Theory of Change Workshop during 16-18 July 2018 at CIFA, Bhubaneswar.
- Series of scientific exchange visits in October 2018 for the research teams from CIFA to WorldFish Penang, CIFT to WorldFish Cambodia and CIFRI to WorldFish Bangladesh.
- Two-days ICAR-WorldFish Research Strategy Synthesis Workshop in WorldFish, Penang during 26-27 November 2018.

Sustainable Aquaculture

- Conducted a Workshop on Life Cycle Analysis (LCA) during 20-22 January 2019 that includes of life cycle inventory analysis, defining system boundaries, methods of data collection and validation and use of LCA software for data analysis, impact assessment and interpretation of results.
- Completed Life Cycle Assessment (LCA) survey in Andhra Pradesh and West Bengal, after validating structured questionnaire for the LCA study of carp and striped catfish.
- Completed survey of existing practices for yield gap analysis of genetically improved varieties of *Jayanti* rohu and freshwater prawn. Collected data from 17 *Jayanti* rohu & 5 non-*Jayanti* rohu and 3 improved prawn hatcheries and 43 improved prawn farms, which are being analysed.
- Under the systematic selective breeding programme for Giant freshwater prawn, *Macrobrachium rosenbergii,* collected data from 3 prawn hatcheries, 30 prawn farms and 13 improved prawn farms for performance assessment of genetically improved freshwater prawn and so far, achieved 11 generations of selection.

Resilient small-scale fisheries

- Conducted workshop from 18-23 Feb 2019 in WorldFish, Penang as part of the WorldFish-FAO collaboration for creating multi-stakeholder information and communication alliance for support to small-scale fisheries (SSF) in Asia, which in turn can potentially link to global policy processes, including the Small-Scale Fisheries - Global Strategic Framework (SSF-GSF) of the FAO/UN.
- CIFRI and WorldFish Experts conducted 3-days training at CIFRI during 18-20 February 2019 to officers from Department of Fisheries, Odisha for mapping of aquatic resources in the state.
- Completed exploratory survey in eight wetlands of West Bengal and Assam for small scale fisheries development. Studies being undertaken on ecology, fisheries, socio-economics in *beels* in West Bengal and Assam, capacity building activities and governance.
- Demonstrated 1000 kg grass carp production in three pens of 0.5 ha area at Beledanga Wetland, West Bengal in 45 days the primary cooperative society.

Value Chains and Nutrition

- Conducted training and demonstration programme on preparation of 4 products such as Fish soup powder, Fish based snacks, Nutrimix and Fish chutney powder the states of Kerala, Odisha and Manipur.
- Studied the fish consumption patterns of rural consumers in the states of Meghalaya, Odisha, Karnataka and Kerala. Further studies on assessment of the effect of feeding fortified fish soup powder for 30 days to selected 25 adolescent girls in Meghalaya having less haemoglobin (<10 g) showed increase haemoglobin level from initial 6 g to 13 g.
- Promoting ICAR-CIFT technologies such as Solar dryer, refrigeration enabled Mobile Fish Vending Kiosk and Mini fish de-scaling machine through private sector partnership for supporting fish product development and increase fish consumption.

Three key activities planned as part of the 2019 work plan in February and March 2020 could not be conducted due to the global COVID-19 pandemic. The activities that was proposed to be taken up during early 2020 include:

1. Five-days Fish Genetics training program in Penang for CIFA Genetics Researchers planned in February 2020.
2. Fish supply/demand and fish futures workshop planned in CIFA, Bhubaneswar in March 2020.
3. Five-days visit of young researchers from CIFT to work with nutrition researchers in WorldFish to undertake data analysis and writing of fish consumption survey results.

Summary of Work Plan for the Calendar Year 2020

Institution/Program	Activity	Deliverables
ICAR-CIFA WorldFish (Sustainable Aquaculture)	Continue Life cycle studies and yield gap analysis work	Research paper on LCA of carp farming systems Research paper on on-farm performance of improved *Jayanti* Rohu
ICAR-CIFRI WorldFish (Resilient small-scale fisheries)	Continue work on productivity enhancement strategies from wetlands and flood plains	Research paper on role of improved governance and technical interventions on fish production from beels and associated nutritional outcomes for the community
CAR-CIFT WorldFish (value chains and nutrition)	Continue work on fish consumption patterns of rural and urban consumers and development of specific fish products for the first 1,000 days of life	Research paper on fish consumption patterns of rural and urban people and its nutritional implications Research paper on development and acceptance of novel fish products for first 1000 days of life

The joint research activities initiated in 2019 will be further developed under the 5-years joint research program (2019-2023) and is expected to contribute to increased productivity from sustainable aquaculture, better governance of inland water bodies and improved nutritional outcomes from capture and culture fisheries.

Annexure

Proceedings of the Review Meeting of ICAR-CGIAR Partnership (2019-20)

The Virtual Annual Review Meeting of the CGIAR Centres was held on May 4, 2020 under the Chairmanship of Secretary DARE & DG ICAR to review the progress of work in 2019 as per the approved work plans and to plan research activities for 2020. A total of 102 participants could join this virtual meeting, including Additional Secretary (DARE), DDGs, ADGs, Directors of various ICAR Institutes who are partners in the collaborative projects, officials of DARE, Country Representatives of CGIAR Centres and their colleagues.

Dr. T. Mohapatra, Secretary, DARE and DG, ICAR in his initial remarks highlighted the importance of ICAR-CGIAR collaborations citing some examples of success, in areas of germplasm exchange, capacity building of scientists, and the number of research projects, publications, policy documents, *etc*. He drew the attention of all to 'One CGIAR' initiative and urged all CG Centre representatives to prepare for the change. He placed on record the contribution of Dr. Peter Carberry, ex-DG, ICRISAT and extended a hearty welcome to the New DG, Dr. J d'A. Hughes, wishing her success during her tenure. DG, ICRISAT Dr. J. Hughes acknowledged the ICAR Partnership and called on the CG Centres to work together to benefit India.

Additional Secretary of DARE and Secretary of ICAR, Shri Sanjay Singh emphasized on factoring in unforeseen situations such as the current pandemic in all our research endeavours and using new IT solutions for enhanced efficiency in operations.

This briefing was followed by presentations. After each presentation, detailed discussions were held, and the action points emerged have been documented below:

(I) International Crops Research Institute Semi-Arid Tropics (ICRISAT)

i. Dr. Kiran Sharma gave a presentation on the projects on legumes and millets highlighting different aspects including variety development, molecular marker-assisted backcrossing, biparental/association mapping, molecular characterization and QTL based mapping, screening of breeding lines, insect resistance in pigeonpea and chickpea, and new breeding techniques including the deployment of CRISPR technology for gene editing.

ii. During 2019, 14 varieties and hybrids were released in India from the breeding materials developed through ICAR-ICRISAT collaborations. These include two machine harvestable varieties of chickpea, two high oleic varieties of groundnut, one high yielding and fusarium wilt resistant variety of pigeonpea, four biofortified hybrids of pearl millet, two multi-cut forage varieties of pearl millet and three multi-cut forage varieties of sorghum.

iii. There were 128 breeding lines (chickpea 75, pigeonpea 5, groundnut 16, sorghum 32) and 79 hybrids (pigeonpea 8, pearl millet 59, sorghum 12) developed through ICAR-ICRISAT collaborations in various AICRP trials during 2019.

iv. Apart from these, he mentioned that integrated farming systems have also been established in four districts of Maharashtra, Telangana and Andhra Pradesh. Dr Sharma presented the work plan for 2020-2021 that has been agreed with the ICAR partners.

After detailed discussion, the following action points were decided:

- ICRISAT to make efforts to widen the genetic base in groundnut and pigeonpea through pre-breeding and sharing of advanced breeding lines with the national partners.
- Knowledge-sharing (e.g. mapping panel) and partnership across the NARS to achieve faster progress in groundnut and legumes.

- Systematic approach for gene editing in crops was emphasized. Specifically, efforts be made towards CFTs of transgenic events of pigeonpea developed by ICRISAT.
- ICRISAT should prepare a yearly plan for capacity building of national partners in areas such as generation and use of genomic resources, data analytics, speed breading and genome editing.
- Millet-based research in partnership needs further strengthening, specifically on red grain and low tannin lines in sorghum and hybrids of pearl millet for dry areas of Rajasthan.
- The newly recruited scientists of ICAR to be attached to ICRISAT for training in order to take advantage of frontier areas of research in ICRISAT.

Overall, the progress made under ICAR-ICRISAT Partnership was observed satisfactory.

(II) International Maize and Wheat Improvement Centre (CIMMYT)

i. Dr. Arun Joshi presented the report and work plan for 2020, highlighting that 8 varieties were developed through ICAR-CIMMYT partnership. Dr. Joshi mentioned that screening of materials has already started in wheat blast research; 100 Indian varieties are being evaluated along with a new panel of 353 lines, which were tested in Bangladesh and Bolivia. Through this exercise, 25-50 lines have been estimated to be identified for blast resistance.

ii. Further, he stated that 200 durum germplasm lines have been shared for trials with ICAR to screen for drought and rust resistance; additionally, 752 lines are being tested for stress tolerance and the molecular mapping. In conservation agriculture, metagenomic studies under long-term conservation agriculture have been employed to understand the diversity and richness of Ascomycota and Zygomycot, which revealed that the former was dominant under conservation agriculture systems.

iii. Joint efforts were also highlighted on crop residue management in the north-west plains of India. In an effort to understand the socio-economic impact of wheat-based systems, the gender preference for wheat traits was narrated as one example. This study further revealed that the farmers preferred varieties majorly by colour and length, but heat stress tolerance and lodging susceptibility were also considered by a few farmers.

iv. CIMMYT gave special emphasis to the capacity building; 2 scientists (one from IIWBR and another IARI) completed 10 months Visiting Scientist program in wheat breeding and pathology in Mexico and Bolivia; One scientist from IARI attended the Stem Rust Training Course in Kenya in 2019; 2 scientists attended the International Training on Wheat Blast Disease Screening and Surveillance in Bangladesh; 2 dozen student interns during 2019 was a highlight.

The progress presentation was discussed, and the following points were decided:

- New variety development in wheat should target 10 t/ha yield potential along with thermal heat tolerance.
- New areas of research identified for future include bread wheat improvement, blast resistance, durum wheat improvement and quality in wheat.
- CIMMYT to consider quality of wheat by grading the existing varieties.
- In maize, rigorous precision phenotyping and heterotic grouping of germplasm was suggested
- CIMMYT to undertake socio-economic analysis of laser land leveling in the Indo-Gangetic plans.
- Productivity and nutritional aspects of maize, in particular Kharif maize, and more emphasis on biotic stresses and DH development were suggested for research partnership.
- CIMMYT to allocate adequate funding to maize portion in the work plan.
- CIMMYT to submit Feedback of the Capacity building activities of ICAR Scientists.

Over all, the progress made under ICAR-CIMMYT Partnership was found satisfactory.

(III) International Centre for Agricultural Research in Dry Areas (ICARDA)

i. Dr. Ashutosh gave an account on the 5 ongoing projects under the ICAR-ICARDA partnership on pulses, barley and wheat and climate resilient agriculture. Under the Food Legume Research Platform (FLRP), Amlaha, Madhya Pradesh, lentil was a flagship program.

ii. The joint research revealed, RVL-3 lentil variety to be best performing under zero tillage even in the drought hit zones of Madhya Pradesh. He stated that about 96 lines were selected at FLRP and shared with partner institutions for evaluation in 2019/20 crop season in diverse agro-ecological conditions.

iii. Two lentil varieties released, and 11 promising lines are in AICRP trials. One variety of barley was also released through this research partnership. 762 diverse genotypes from global collection of wheat durum panel was evaluated at FLRP and shared with IIWBR. In addition, 102 promising lines of grass pea, 145 lines of Kabuli chickpea, 25 lines of faba bean, 630 lines of barley and 72 lines of durum wheat lines have been shared with ICAR Institutions and SAUs. He highlighted the introduction of 4857 legume and cereal genetic materials in the country. Further, he confirmed the mapping of rice fallows of West Bengal).

iv. As a measure of alternative fodder resources, 67 varieties of cacti have also been introduced. In capacity building, the highlight is that 24 students are pursuing MSc/PhD and 7 young scientists visited Morroco and Lebanon from the Indian NARS.

Taking note of the progress made so far, the following activities have been suggested for 2020:

- Prioritized identification and deployment of climate-smart traits in pulses, wheat and barley
- Rice fallow mapping to be done in Assam and Tripura
- Promoting climate resilient and cost-effective technologies in the rainfed areas/rice fallows
- Strengthening partnership on fodder with ICAR-IVRI, ICAR-IGFRI and CAZRI on high biomass grass pea and spineless cactus
- Large-seeded Kabuli chickpea and early & high biomass lentil to be shared with ICAR-IIPR
- Bangladesh varieties, super-early lentil variety `Barimasur-9 to be tested in between two rice crops and Stemphylium blight resistant Barimasur-8 variety to be evaluated in the eastern Indian States.
- Dual-purpose low-toxin grasspea varieties to be promoted in relevant areas included Sunderbans.
- Sharing of tissue culture protocol with CAZRI for date-palm
- ICAR Institutes such as IIWBR, CAZRI, IIPR, IGFRI and others to take advantage of the promising materials from ICARDA

Over all, the progress made under ICAR-ICARDA Partnership was satisfactory.

(IV) International Rice Research Institute (IRRI)

Dr. Arvind Kumar presented a brief account on ICAR-IRRI Research partnership. Salient highlights included the following:

i. The new science for new variety with regard to roots traits, and trait discovery leading to identification of 9 significant MTAs for BB and 12 MTAs for blast.

ii. Three advanced rice lines after testing in AICRP have been identified and released.

iii. Through joint efforts, the diagnostic kit called `SWEET^{R}' has been developed to identify rice bacterial blight pathogen. 690 lines have already been entered into trials.

iv. Total of 163 kg of seeds were shared through INGER program. Efforts on climate smart management of rice systems, viable crop intensification and water management measures have been advocated; soil moisture map has also been developed for Odisha and Assam as part of the rice fallow work plan; Mass demonstration on pulses, digital extension through *digital apps* (such as Rice Crop Manager, SeedCast and RiceDoctor, which all have been linked to the common service centre CSC portal as well) and rice value chain are the other highlights. Integrated solutions to risk management linked to crop insurance was one of the successful awareness programs through these joint efforts.

The following points were suggested:

- The ongoing programs to be continued with great vigour and in active partnership with ICAR Institutes.
- Marking assisted breeding has been successful in rice. This needs to be accelerated for curbing complex traits. Special focus is essential by IRRI.
- The work on rice epigenetics be further extended in collaboration with NRRI, IASRI,

IARI, NIPB, and may be some others as well.

- Special emphasis to be given for strengthening of digital extension and development of rice value chain; IRRI to work in collaboration with NRRI and IIRR on defined points.
- IRRI to facilitate more human resource development (HRD) programs through this partnership in the areas of genomic selection, big data analysis, epigenome analysis, advanced rice quality analysis, and trait discovery.

The progress made under ICAR-IRRI Partnership was found satisfactory.

(V) International Water Management Institute (IWMI)

i. Dr. A.K. Sikka gave a consolidated account on ICAR-IWMI partnership. Under project `Enhancing economic water productivity in canal irrigation system', he explained the tradeoff between variability and supply, and need for policy interventions (such as a testimony from Pune district, Maharashtra) to increase resiliency.

ii. He mentioned that the upscaling underground taming of flood for irrigation (UTFI) program is a major success story that has been reflected in the UNESCO case studies.

iii. He also said that together with CRIDA, a South Asia Drought Monitoring System has been developed; the South Asia Drought Surveillance System fetched Geospatial Innovation Award in 2019.

The recognition for an output of this partnership was appreciated, along with a few points to consider for 2020-21, as below:

- IWMI to submit a note on UTFI and Innovation Award
- IWMI to jointly develop a comprehensive drought monitoring for a digital and dynamic district agricultural contingency plan and to launch a new project for drought portal.
- The solarization of Indian agriculture to be piloted in Jharkhand
- Under the CCAFS program, IWMI to assist in building the capacities of Indian scientists and address the climate resilience and agricultural risk management issues. The upscaling activities of NICRA villages warranted a framework for scaling it up through KVKs in the non-NICRA cluster areas and linked them to the developmental programs through ATMA and others alike.
- The poor irrigation efficiency is an issue in agriculture and therefore, a call has been given to utilize IWMI's expertise for canal automation and also in safe use of waste water for agriculture
- Use of drought indices and systematic upscaling successful models/tools/technologies will benchmark our partnership standard
- IWMI to involve horticulture and fisheries institutes of ICAR in the work plan, as appropriate

The overall progress under the ICAR-IWMI partnership was satisfactory.

(VI) World Agroforestry (ICRAF)

i. Dr. Javed Rizvi gave the presentation on the ICAR-ICRAF cooperation. One of the outputs of this collaboration was a publication titled `Mapping Agroforestry and Trees Outside Forests' based on multi-stakeholder consultation.

ii. The predication accuracy of MIR spectroscopy for different types of soils studied was found successful with alfisols as of now.

iii. Taking clue from these efforts on soil health, a prototype of the handheld soil analyzer has been developed.

iv. The guidelines to produce quality planting material of agroforestry species was a strategic outcome of the ICAR and ICRAF that has also been shared with all the States and stakeholders.

v. The geo-spatial techniques for mapping specific areas was used to identify the thermal response of different tree species in agroforestry systems, particularly in Punjab, Uttar Pradesh, Bihar and Uttarakhand. Eventually, poplar mapping is completed.

The following action points were decided after discussion to strengthen the partnership:

- The publication on Mapping Agroforestry is to be sent to all stakeholders.
- The area under agroforestry must be cleanly delineated covering all species and all states.
- The handheld soil analyzer must be tested and validated objectively for various soil health parameters.

- Explore a chip-based technology for real time monitoring the germplasm of important agroforestry species maintained in the field gene banks
- ICRAF to accelerate joint-launching of the tree genome project.
- A study in critical analysis of *Prosopis cineraraia* in Rajasthan needs to be undertaken in collaboration.
- Awareness and large-scale pilot to use MIR for SOC, pH, Clay, Silt, Sand in Alfisol and continue work to improve the prediction of properties in other soil types.
- ICRAF to involve horticultural institutes of ICAR also in the work plan, as appropriate.

Over all, the progress of work under ICAR-ICRAF Partnership was satisfactory.

(VII) International Food Policy Research Institute (IFPRI)

i. Dr. Anjani Kumar gave a presentation on the progress in research, policy and capacity building aspects. Estimating returns to research investments in agriculture, mapping adoption of improved varieties (both field and horticultural crops), constraints to green revolution in eastern India including agricultural marketing, and rural non-farm sector employment were major areas of focus in this partnership.

ii. While MSP emerged as a basic issue in the field crop procurement along with human outmigration, access to institutional credit did emerge as one major factor that adds to the farmers' income.

iii. ICAR and IFPRI together developed the Transparent Performance Indicators for the KVKs both at macro level (using NSSO data) and micro level (using KVK level data). Likewise, the joint assessment of farmer producer organization was highlighted, and the challenges thereof were discussed.

iv. It was also presented that a survey was also conducted to understand the preference of stakeholders about the direct benefit transfer; more than 70% beneficiaries supported this mode.

v. Dr. Anjani Kumar further highlighted that various levels of trainings have been considered for the Indian scientists and listed the five policy communications that emerged out of this partnership along with the several good research papers.

The progress of ICAR-IFRPI partnership research was discussed thoroughly and the following actions points emerged:

- Thrust to be given on strategic areas of research such as, efficiency of investments in R&E, agriculture-nutrition linkages, marketing, value chain and trade, agri-innovations and evaluation of ecosystem services.
- The new work plan (2020-2025), as signed recently needs to be thoroughly discussed with all the working partners for effective implementation.
- IFPRI to harness the meta data as available with ICAR including CERA for policy planning.
- A note on DBT appraisal is also to be provided to the Council by IFPRI for communicating it to the Government at various levels.
- IFPRI to work on developing a policy narrative on a chosen topic for appraisal to the Government of India; for example, adoption of improved varieties to enable green revolution in eastern India.
- ICAR Institutes to take cognizance of these reports being developed by IFPRI for the larger cause of the nation.

The overall progress made under ICAR-IFPRI Partnership was satisfactory.

(VIII) International Livestock Research Institute (ILRI)

i. Dr. H. Rahman presented the outcome of the ICAR-ILRI collaboration. The four projects that are being undertaken through ICAR partnership covered four priority areas: (i) animal disease economics, (ii) backyard poultry genomics, (iii) methane emission and its mitigation, and (iv) extension: feed and fodder.

ii. Dr. Rahman stated that the assessment of the impact of priority animal diseases (like PPR, Brucellosis and Hemorrhagic Septicemia (HS) has been undertaken under animal disease economics project). The analysis of PPR incidence in states of Andhra Pradesh, Karnataka, Uttar Pradesh, Rajasthan and West Bengal have been undertaken.

iii. Poultry genomics was another focus that facilitated sequencing of 70 birds leading to 2GB of data. In methane emission, anti-methanogenic feed supplements and rumen microbiome dynamics upon intake are being analyzed to mitigate GHG emission from the animal sector *per se*. One paddy variety Jalamani, the straw of which has been identified to have high digestibility, has therefore been recommended as a feed-fodder supplement in eastern India.

While ILRI is to work on the new theme areas identified for implementation from 2020 onwards, the following suggestions were made:

- Given the importance of the ongoing feed/fodder project, ILRI to consider continuing it in consultation with the nodal SMD.
- Thrust to be given on value chain and system dynamics, SNP chip development, breed specific molecular signature, enteric methane measurement on a long-term basis, engineering solutions for feed/fodder digestibility.
- It was opined that ILRI's capacity could further be harnessed for meta-analysis of AMR data being generated in the country.
- While appreciating the phenotypic information on various poultry breeds, ILRI to also consider upscaling it for pan-India application and management.
- ILRI to provide status paper on molecular signature research of indigenous backyard poultry germplasm available in the country.
- ILRI has been advised to have a relook into the ongoing projects to be taken up during 2020-21 and discuss with concerned SMD and Dr. J.K. Jena for any mid-term corrections.

The overall progress made so far in the ICAR-ILRI partnership was found satisfactory.

(IX) WorldFish (WF)

i. Dr. V. Chadag Mohan gave a presentation on the progress in the ICAR-WFC Work Plan. Most of the projects under this work plan are just about a year old, although the life cycle assessment for carp farming systems was initiated during January 2019.

ii. It was stated that the performance assessment of genetically improved Jyanthi Rohu is being done in collaboration with CIFA and CIFRI.

iii. Detailed baseline studies and situation analysis have been done for Beel fisheries management, one in Assam and another in West Bengal to help enhance benefits to the local communities. The beel work is being done in collaboration with CIFRI.

iv. It was highlighted that some fish-based products such as fish soup powder, fish-based snacks have also been developed through CIFT partnership for consideration under the 1000 days nutrition program. Their preference over the existing products and adoption in the societies is being studied.

These following points emerged during discussion for necessary action:

- Focused co-development of the programs in small-scale fisheries, sustainable aquaculture, value chains and nutrition, and allied technologies.
- WF to explore collaborative research on fish genomics and quantitative genetics
- WF-ICAR to jointly identify global and local successful models, undertake preference studies and product developments for the benefit of the country.
- The periodical monitoring by SMD was noted and reiterated to look at the work plan once again for any mid-course corrections.

The progress made so far was satisfactory.

(X) Bioversity International (BI)

i. Dr. J.C. Rana presented the progress of work. The collaboration dwelt on breeding for improved banana, ecosystem services and agro-biodiversity index, evaluation of germplasm, *etc*.

ii. For improved banana, 24 lines have been evaluated and eventually 2 varieties were released by the National System. In addition, 245 accessions are being conserved; out of which, 97 accessions have been characterized.

iii. Highlighting the expert consultation on agrobiodiversity indices and ecosystem services held in April 2019, the agrobiodiversity study conducted jointly in Karimnagar and West Godavari was elaborated.

iv. A detailed study in a 236-acre multi-varietal orchard revealed higher microorganisms and their enzymatic activities helped in soil health and so eventually determined the productivity of the orchard *per se*.

v. Evidently, the BI has come out with a soil health assessment framework and advisories thereof based on 6 indicators.

vi. Under the mainstreaming agrobiodiversity project, over 575 varieties have been tested; 1974 traditional varieties identified, and 19 community seed banks established. 15.5 quintals of seeds were distributed from these community seed banks to the needy farmers under covid situations. The presentation also highlighted the strength of India in the agrobiodiversity research. He further stated that all the ongoing programs and project would be continued in close collaboration with the ICAR Institutes and SMDs concerned.

After a thorough discussion, the following action points emerged:

- BI to provide a note on the two new varieties released
- BI to facilitate chip technology for germplasm assessment.
- Food chain analysis of pesticides, as one of the key parameters under ecosystem services needs to be included.
- BI has been advised to undertake geomapping of TR4 in partnership with ICAR institutions.
- BI was advised to have clarity on the administrative mechanism while transferring germplasm to UHS, Bagalkot. Director, NBPGR testified that all copies related to germplasm exchange is available. DDG (HS), however, opined that the territorial jurisdiction of available germplasm will be with IIHR.
- The BI was advised to work systematically and to have separate discussions with the SMDs concerned for.

Over all, the progress made by Bioversity International was satisfactory.

(XI) International Centre for Tropical Agriculture (CIAT)

i. Dr. V.P. Singh made efforts for progress presentation. Due to poor connectivity, the presentation could not be heard completely. Therefore, he was advised to share the presentation by email to ADG (IR).

ii. Director, ICAR-IIPR affirmed that about 1200 germplasm of common bean were shared by CIAT with IIPR, and if the Bio-fortified germplasm high in Cu, Fe and Zn could be shared with IIPR.

The following suggestions were made:

- Further, DG (ICAR) warranted CIAT to take up capacity building of ICAR scientists in digital agriculture on priority.
- In view of CIAT-Bioversity Alliance, our work plans with CIAT and Bioversity need to be re-examined. It is required to be realigned with the Alliance objectives and action plan for enhanced efficiency and faster progress.

(XII) International Potato Center (CIP)

i. Dr. S. Mohanty gave the presentation on the ICAR-CIP collaboration. A total of 119 potato clones were supplied to the Indian partners and import permits for 419 germplasm lines were enabled. He also underlined that the tropical virus resistant germplasm gave good results in the Indian soils and are being promoted.

ii. CIP clone 397006.18 and the biofortified `Yussi Map' has been recommended in 2018-19 for cultivation in hot-arid and hot sub-humid to humid conditions, respectively. Three more clones are presently in AICRP trials, he added.

iii. Further, 20000 orange flesh sweet potato seeds have been shared with Central Tuber Crops Research Institute (CTCRI) and being prepared for trials in 2020. For the first time, zero-tillage potato cultivation was successfully demonstrated in Assam and Odisha, adding value to the conservation agricultural practices. The "Small Farmer Large Field Model (SFLF)" was piloted in 15 locations in two states (Assam and Odisha). The results of these pilots showed an impressive yield increase – average of around 11 tons per acre. 700 farmers benefitted from these SFLF interventions.

iv. Apical root cuttings were reported to be successful in Odisha, Karnataka, Assam and Haryana; this standardized protocol is being shared with the states for mass multiplication. The ongoing works would continue in 2020 as well.

After careful discussions, the following suggestions have been made:

- CIP to facilitated import of elite clones including 57 biofortified clones for testing trials in India; 419 more lines are under importation and screened further.
- CIP to consider replicating the model potato village as in Gingia, Assam
- There would be shortage of fresh potatoes in the western countries as most companies would reopen only after lockdown due to covid-19. Therefore, it was agreed to have more seeds for export. Director, CPRI however affirmed that the export has already begun even during lockdown situations.

Over all, the progress made under ICAR-CIP Partnership was satisfactory.

This was followed by open discussion amongst ICAR and CG Partners who all expressed the importance and relevance of this partnership for the cause of Indian agriculture.

After a detailed deliberation, the following general action points were decided:

- It was agreed that 'taking it to field' is important to realize the impacts of outputs/results. This needs further discussion with concerned SMDs and DDG (Ext).
- The CG Centres should not work in *silos* in order to avoid duplicity and enhance impacts.
- The field visits would not be 'business as usual' because of COVID-19. Therefore, alternate pathways for work implementation needs to be considered. ICAR did underline the importance of a SOP/framework or protocol for field-based activities, as this is going to be a new normal.
- The products (virtual, documents, and others) emerging out of this ICAR-CGIAR partnership should be informed to DARE/ICAR periodically and are to be systematically promoted to realize the impact of this collaboration.
- With regard to One CGIAR initiative, further discussions would be required to develop a mechanism for CG Centres working in India. DG ICRISAT was requested to take the lead in consultation with all the other CG centres and draw a framework for action.
- Every CG Centre should inform every activity/ project that they perform within the country even beyond the Work Plan. (**Action: All CG Centres**)
- CG Centres involving KVKs should keep the DDG (Extension) informed and similarly the activity that has footprints of engineering and other disciplines to be informed to respective DDGs. (**Action: All CG Centres**)
- Every CG Centre is to provide all other funding sources for their work activities in India, as they are important to continue India's membership of the CG System Council. DARE and ADG (IR), ICAR should be kept informed of this periodically. (**Action: All CG Centres**)
- A brief ATR for the previous year action points be given during progress review meeting. (**Action: All CG Centres**)
- Opening of new centres/institutions by the CG Centres is discouraged. However, prior to proposing such centre opening to any Central Govt department or any State Govt., it needs discussion with DARE being the nodal administrative department for CGIAR matters as notified by the Govt. of India. (**Action: All CG Centres**)
- Capacity building of Indian scientists/ students through this partnership needs further strengthening (**Action: All CG Centres**)
- SMDs in ICAR HQ to undertake immediate assessment of the work plan, and suggest any mid-term corrections; SMDs to also periodically monitor the progress of the ICAR-CGIAR Partnership (**Action: All DDGs**)
- DDG (NRM) to be involved in monitoring process of ICAR-CGIAR Partnership across the SMDs (**Action: All DDGs**)

The meeting ended with a vote of thanks to the Chair and appreciation of participation despite COVID-19 limitations.

CGIAR

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