ANNUAL REPORT
2015-16

सत्यमेव जयते

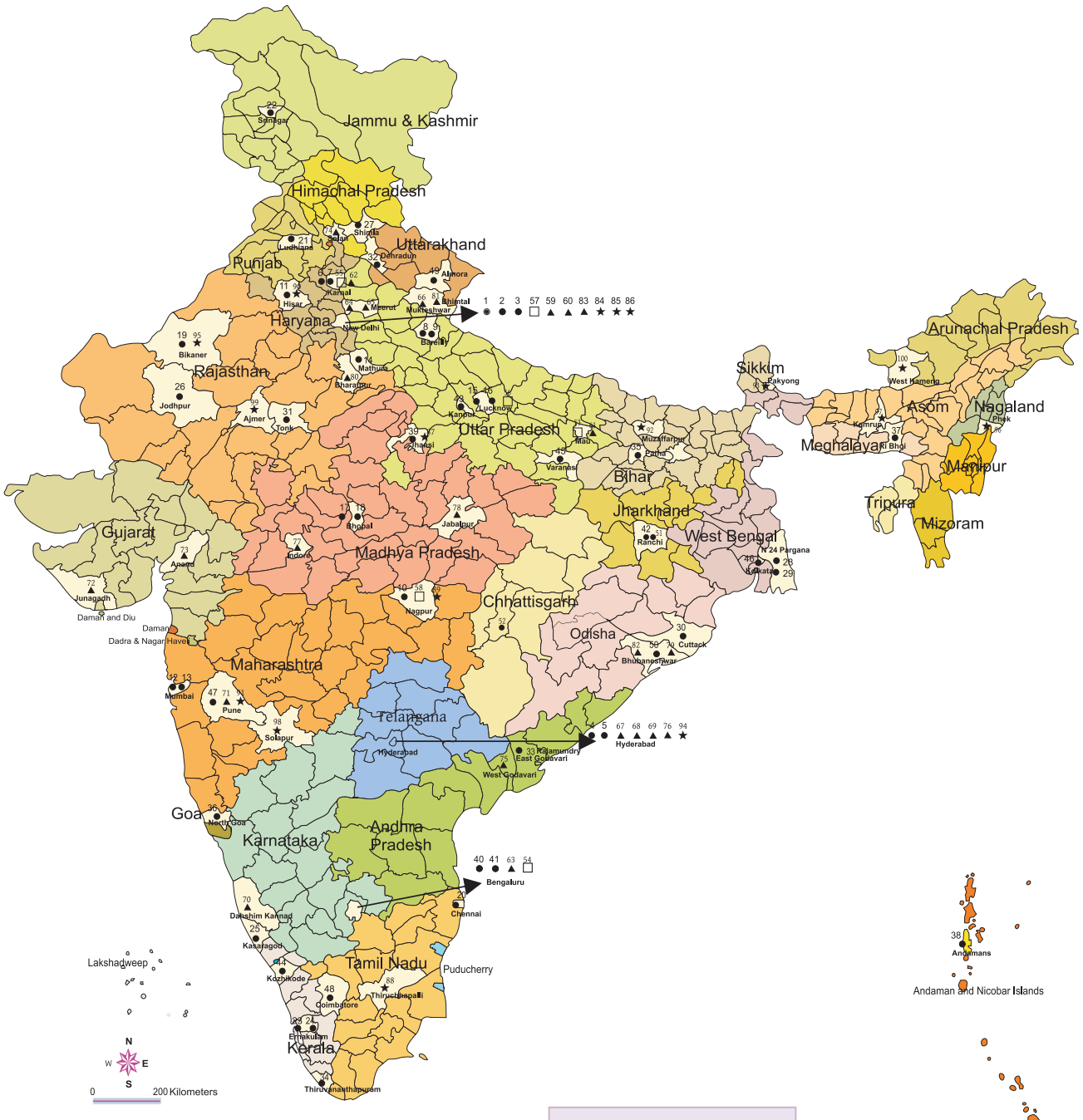
Department of Agricultural Research and Education
Ministry of Agriculture and Farmers Welfare
Government of India

भाकृअनुप
ICAR

Indian Council of Agricultural Research
New Delhi

INDIAN COUNCIL OF AGRICULTURAL RESEARCH

Institutes, Bureaux, Directorates and National Research Centres



● 65 Research Institutes ● 6 Bureaux ● 15 National Research Centres ● 15 Project Directorates

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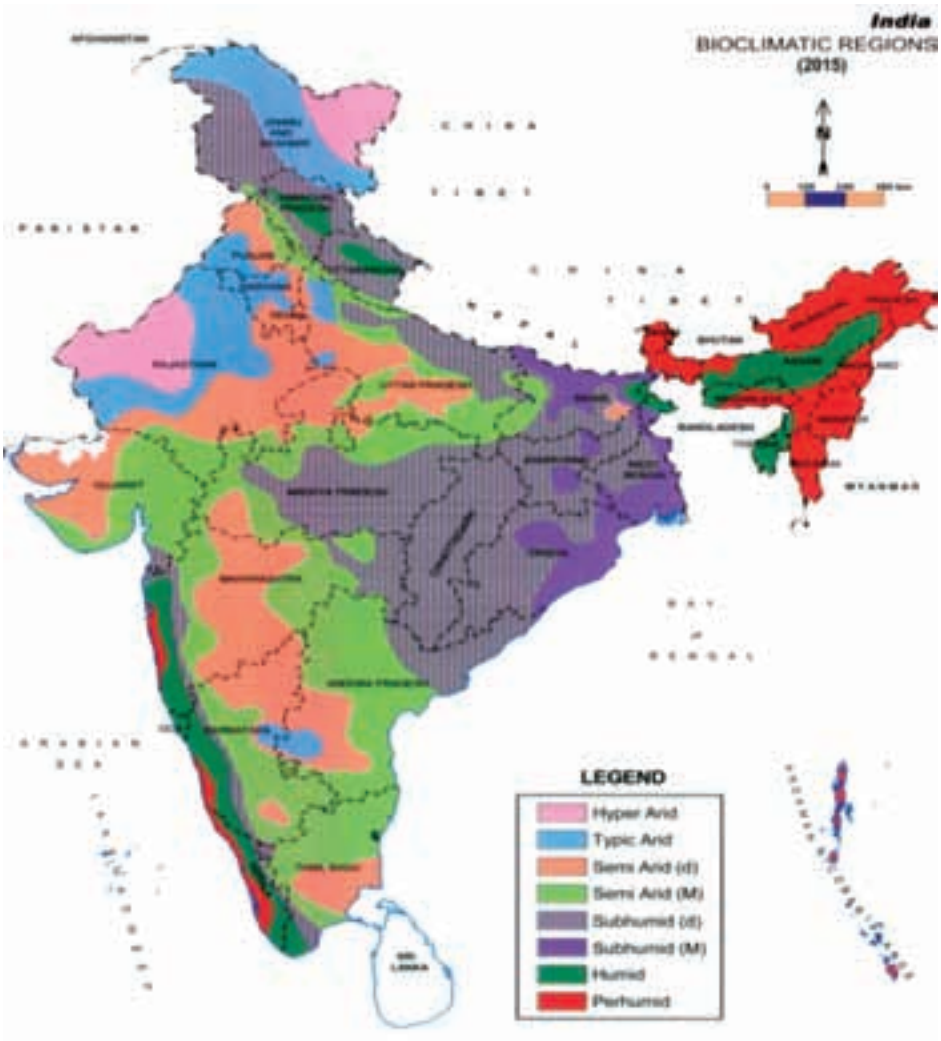
INDIA BIOCLIMATIC REGIONS 2015



Foreword

It is a matter of pleasure to present the *DARE-ICAR Annual Report-2015-16*, the second, as President of the ICAR Society. The Report embodies brief account of the progress, major achievements and new initiatives in agricultural research, education, extension undertaken by the institutions of our National Agricultural Research and Education System (NARES) under the aegis of Indian Council of Agricultural Research.

The 87th Foundation Day, Award ceremony and the National Conference of the Krishi Vigyan Kendras (KVKs) were held at Patna and the events were graced by Hon'ble Prime Minister of India as Chief Guest, for the second consecutive year. Hon'ble Prime Minister called upon agricultural scientists and planners to design second green revolution with new vision, dimensions and objectives to address the agricultural challenges in this modern era. On this occasion, the Hon'ble Prime Minister also launched Farmers FIRST, Student READY, ARYA, and *Mera Gaon Mera Gaurav*, unique initiatives of ICAR towards entrepreneurship development of agricultural graduates and improving technology dissemination.

Sustainable enhancements in productivity and quality of farm produce are a major objective of the Council. In this endeavour, our agricultural research institutes developed and released about 80 high-yielding varieties of cereals, oilseeds, pulses, forage, commercial and horticultural crops for cultivation in different agro-ecologies and produced about 978, 17,562, and 3,418 tonnes of breeder seed, foundation seed and planting material, respectively. A further boost to improving nutritional security came in form of a biofortified rice variety CR Dhan 310 that was commercialized for the Indo-Gangetic Plains. An improved location-specific breed of chicken 'Narmadanidhi' was developed. A step towards Blue Revolution was success in induced breeding of captive stocks of a popular fish, *Rita chrysea*, endemic to Mahanadi river, and milkfish (*Chanos chanos)*. For enhanced sustainability and profitability of different farming systems, need-based and region-specific mechanization and energy management technologies as tractor-operated check-basin former, Cottage-scale pilot plant for probiotic soy-cheese spread and soy milk powder were developed. Methods to prepare functional and nutraceutical food products like composite flour eggless cake, Multi-grain tortilla chips, Antioxidant- rich pasta from vegetables and buckwheat and Extruded snacks from broken walnut kernels were developed.

The processes for total utilization of commercially unmarketable pomegranate fruits into juice, wine, pomegranate seed oil, organic mouth wash and bio-colour from rind were standardized. The Agricultural Technology Information Centres in the country served as single window delivery systems by providing technology information, technology services and technology inputs to nearly five lakh farmers.

In order to nurture scientific talent, creativity, team work and innovations, the Council conferred 82 awards under 18 different categories; this includes not only the scientists and institutions but also farmers and agriculture journalists.

The Council undertook a major exercise to formulate Vision-2050 documents of all research institutes that is based on well articulated assessment of present and emerging agricultural scenario, new opportunities in the offing, research issues and strategy framework, relevant for the next three decades. Being sensitized about the contemporary and future needs of the agricultural research and development, the Council revisited the mandates of the research institutes.

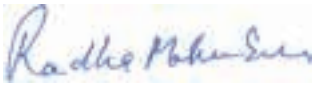
Two major proposals of the ICAR relating to Krishi Vigyan Kendras (KVKs) and Strengthening and Development of Higher Agricultural Education received approval of the Cabinet. Consequently, the number of scientific positions and cadre strength of KVK will be enhanced from 16 to 22. Three new agricultural Technology Application Research Institutes (ATARIs) will be established besides reorganization of ATARIs in terms of inclusion of States for better monitoring of KVKs. Foundation stone of a new IARI, Hazaribagh, Jharkhand was laid by Hon'ble Prime Minister. A National Research Centre for Integrated Agriculture at Pipra Kothi, East Champaran district (Bihar) is established to conduct research on the development of location specific integrated farming system models for diverse agro-ecological conditions, especially flood and wetland situation. Central Agricultural University, Imphal is being strengthened with six additional colleges for strengthening agricultural education in north eastern states.

The ICAR has carved a niche for itself in the international agricultural research community. In the year 2015, the Council hosted 23rd International Grassland Congress under the theme of 'Sustainable Use of Grassland and Range for Environmental Balance, Biodiversity and Fodder Production' wherein more than 500 scientists, farmers, NGOs and development officers from 47 countries participated. The UN General Assembly declared 2015 as the International Year of Soils (IYS) for raising awareness among the people on the importance of soil in sustaining life support

system on earth. Keeping this in view, the Council celebrated World Soil Day on 5 December 2015 in as many as 607 Krishi Vigyan Kendras and 80 ICAR institutions/Agricultural Universities across the country and nearly 2.5 lakh Soil Health Cards were distributed to famers on this occasion.

It is our constant endeavour to ensure that our farmers must get the maximum benefit of technological developments and to this effect Indian Council of Agricultural Research took an active part in the national *'Jai Kisan Jai Vigyan'* Week during 23-29 December 2015, observed for the first time, to commemorate the birth anniversary of former Prime Ministers Shri Atal Bihari Vajpayee and Late Shri Chaudhary Charan Singh, who made immense contribution for promoting use of science for the welfare of farmers.

Being aware that enhanced application of science, technology, information, knowledge, competent human resources and investments are going to be the key determinants of future growth and development, the Council and the National Agricultural Research and Education System at large, are determined to harness the advances of science for the welfare of society. I compliment the team DARE/ICAR for their untiring efforts and worthy contributions in agricultural R&D and hope that the information presented in the *DARE/ICAR Annual Report 2015-16* will prove to be useful information resource for all those working for development of Indian agriculture.



(RADHA MOHAN SINGH)
President
ICAR Society

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Indian Council of Agricultural Research

President, ICAR Society, and Union Minister of Agriculture and Farmers Welfare	:	**Shri Radha Mohan Singh**
Union Ministers of State for Agriculture and Farmers Welfare	:	**Dr Sanjeev Kumar Balyan**
	:	**Shri Mohan Bhai Kundariya**
Secretary (DARE) and Director General (ICAR)	:	**Dr S. Ayyappan**
Additional Secretary (DARE) and Financial Adviser (ICAR)	:	**Shri P.K. Pujari (Up to 3 June 2015)** **Mrs Seema Bahuguna (Additional Charge) (4 June 2015 to 9 August 2015)** **Shri Sunil Kumar Singh (Since 10 August 2015)**
Additional Secretary (DARE) and Secretary (ICAR)	:	**Shri R. Rajagopal (Up to 23 December 2015)** **Shri Chhabilendra Roul (Since 6 January 2016)**

The Mandate of the Indian Council of Agricultural Research

(i) To plan, undertake, aid, promote and coordinate education, research and its application in agriculture, agroforestry, animal husbandry, fisheries, home science and allied sciences.

(ii) To act as a clearing house of research and general information relating to agriculture, animal husbandry, home science and allied sciences, and fisheries through its publications and information system; and instituting and promoting transfer of technology programmes.

(iii) To provide, undertake and promote consultancy services in the fields of education, research, training and dissemination of information in agriculture, agroforestry, animal husbandry, fisheries, home science and allied sciences.

(iv) To look into the problems relating to broader areas of rural development concerning agriculture, including post-harvest technology by developing co-operative programmes with other organizations such as the Indian Council of Social Science Research, Council of Scientific and Industrial Research, Bhabha Atomic Research Centre and the universities.

(v) To do other things considered necessary to attain the objectives of the Society.

1. Overview

Keeping pace with the changing requirements of the Country's farm sector, ICAR Institutes developed a number of cost-effective technologies, techniques and products, not only to enhance the productivity of various crops and commodities, but also the quality of produce, for enabling remunerative agriculture. The partnerships within the National Agricultural Research and Education System (NARES) as well as outside, with several organizations were the hallmark of R&D efforts during the year. An overview of the salient achievements is presented here and the detailed accounts of activities/ achievements are presented in the specific sections devoted to each thematic area. It is my pleasure to present DARE/ICAR Annual Report 2015-16, in which multiple activities of agricultural research, education and extension are highlighted.

The 87th Foundation day of ICAR function held at Patna was graced by the Hon'ble Prime Minister for the second consecutive year. On this occasion, the Hon'ble Prime Minister launched several initiatives of ICAR, viz. Farmers FIRST, Student READY, Attracting Retaining Youth in Agriculture (ARYA), Agri-Tech Foresight Centre (ATFC) and *Mera Gaon, Mera Gaurav*, for building entrepreneurship amongst the agricultural graduates and improving technology delivery as well as knowledge empowerment of farmers. Hon'ble Prime Minister also laid Foundation Stone of IARI, Hazaribagh, Jharkhand, being the first such step in the country. Hon'ble Minister of Agriculture and Farmers Welfare laid the foundation stones of the Indian Institute of Agricultural Biotechnology (IIAB), Ranchi and National Research Centre on Integrated Farming at Motihari, Bihar. The other initiatives included launching of Consortia Research Programmes and Extra Mural Funding in the Council.

The ICAR in a major exercise, formulated the Vision-2050 documents and revised the mandates of all the institutes keeping in view the changing needs of agricultural research, human resources and technology dissemination *vis-à-vis* growing population and consequent increase in food demand, changing food consumption pattern, state of natural resources, climate change, commercialization of agriculture, global trade regime and a dynamic policy environment both, domestic as well as global. The nomenclature of several ICAR institutes was also revised.

During the year, several areas in the northern states were impacted by hailstorms that caused damage to ready-to-harvest wheat crop; the monsoon was delayed and on an average remained 14% deficient resulting in loss to rainfed farming in some parts of the country. Such unforeseen natural calamities bring out the vulnerability of the agriculture and also look to the agricultural research community to be proactive for building resilience to natural exigencies. Our institutions responded to the needs from time to time. The Overview presents brief account of salient achievements.

Soil and water productivity

Land resource inventory on 1:10,000 scale was prepared taking Landscape Ecological Unit (LEU) consisting of landforms, land use and slope as the base map while bio-climatic map of India was revised. Electronic atlas of water resources, developed for Odisha and Himachal Pradesh, is a useful tool for catch assessment and developing GIS based Decision Support System. The information will help planners to concentrate efforts, allocate resources and deploy manpower according to the distribution of fishery resources.

Bamboo plantation-based bio-engineering interventions were found promising for reclamation and productive utilization of major ravines namely, Mahi ravines at Vasad (Gujarat), Chambal ravines at Kota (Rajasthan), and Yamuna ravines at Agra (Uttar Pradesh). These interventions could absorb more than 80% of rainfall and reduce the soil and nutrient losses by 90 and 70%, respectively. Foliar sprays with various chemicals were evaluated to mitigate dry spells during crop growing season across diverse rainfed agro-ecologies. Plant growth promoting *Rhizobacteria* and *Arthrobacter* were isolated, characterized and field evaluated in vertisols of Madhya Pradesh; average yield of wheat due to actinomycetes inoculation was 16% higher over control. Shortlisted *Arthrobacter* isolates effectively improved yield of maize and soybean. A soil nitrogen test based fertilizer prediction model for targeted yield in Nagpur Mandarin was developed.

Integrated farming system (1 ha) model comprising cropping systems (0.52 ha) + horticulture (0.32 ha) + dairy including bio-gas and vermicompost unit (0.08 ha) + fish cum poultry (0.1 ha) + mushroom developed in western Himalayas, provided round the year improved production (21.52 tonnes REY (rice equivalent yield)/ year), profit (₹ 3.06 lakh/year) and employment (731 man days/year).

Climate change

The Cool Farm Tool model used to estimate emission of GHGs, integrates several globally determined empirical GHG quantification models. Using the tool, GHG fluxes (carbon-dioxide and methane), moisture and heat in the soil-plant-atmosphere systems were measured in rice-wheat rotation. Among the cropping systems, maize-wheat cropping registered highest

carbon management index. The cumulative seasonal methane emission was reduced by 75% in aerobic rice as compared to continuously flooded rice and the seasonal emissions were lower in slow-release N fertilizer.

Genetic resources

Genetic resources form the basis of qualitative and quantitative improvements in agriculture. The search for new genetic resources, floral and faunal, their documentation, conservation and utilization form a continuum. In this endeavour 29 explorations were undertaken in eight states and 1,454 accessions including 500 of wild species were collected; 383 Herbarium specimens were added to the National Herbarium of Cultivated Plants. In the National Gene Bank, 7,668 germplasm accessions of orthodox seed species were stored; 48 shoot tips/ meristems of different vegetatively propagated species were cryo-stored and 11 accessions were added to *in-vitro* storage for long-term storage. From 45 countries, 32,552 accessions were imported including international trial material. Thirty-six novel germplasm lines were registered.

A total of 1,503 indigenous and 195 exotic collections comprising fruits, vegetables, tuber crops, plantation crops and nuts, spices, medicinal and aromatic plants, ornamental crops and mushrooms were made from different sources. One *ber* accession (CIAH-Ber-S-15) for early maturity, one *bael* (CISH-B-18) for high fruit yield, four walnut accessions with higher nut and kernel weight, three almond accessions with more kernel recovery, two chili accessions (BS-20 and BS-79) with field tolerance to leaf curl, Dolichos Yellow Mosaic Virus tolerant accession of Indian bean (VRSEM 12) and turmeric (Acc. 849) with high yield were identified. Fifteen species of spiders belonging to six families were recorded and in a first of its kind study spider population in rainfed cotton agro-ecosystem of central India was documented.

Registration of seven new breeds of indigenous livestock during 2015 took the total number of registered indigenous breeds in the country to 151 (39 cattle; 13 buffalo; 24 goat; 40 sheep; 6 horses and ponies; 9 camel; 3 pig; 1 donkey; and 16 chicken). Belahi cattle, Gangatiri cattle, Pantja goat, Kachaikatty Black sheep, Kharai camel, AgondaGoan pig and Mewari chicken are the newly registered breeds. Molecular breed signatures of Gir, Sahiwal and Tharparkar were developed. The National Gene Bank at NBAGR now stores 129,174 frozen semen doses belonging to 44 breeds of cattle, buffalo, goat, sheep, camel, equine and yak. Screening of Frieswal bulls and bull calves for genetic diseases revealed a carrier prevalence percentage of 4.6 for BLAD (bovine leukocyte adhesion deficiency) in Frieswal bull calves, while no carriers were noticed for deficiency of uridine monophosphate synthase, bovine citrullinaemia. Four native chicken populations, PD-4 (Improved Aseel), Aseel, Ghagus and Nicobari fowl were conserved at the ICAR-Central Avian Research Institute.

Fish biodiversity was assessed in the basins of rivers Sharavathi, Valapattanam, Chaliyar, Chandragiri, and upper Mahanadi and in Torsha and Gandak rivers of Ganga-Brahmaputra basin.*Tor putitora* and *Cyprinion semiplotum*, the endangered species in IUCN list, were also recorded from Torsa river (West Bengal) and Balarampur. *Ailia coila, Nangra nangra, Puntius conchonius, Sicamugil cascasia* and *Botia lohachata, Eutropiichthys vacha, Ompok pabda,* which are respectively in the list of vulnerable and endangered category were found in Gandak river. A new fish species *Clarias serratobrachium* sp. nov. was discovered from the wetlands along Indo-Burma border.

Crop improvement

Development of improved varieties/hybrids of food crops and their cultivation are central to increased farm production and consequently national food and nutritional security. During the year high-yielding varieties of cereals (21), oilseeds (16), pulses (8), forage crops (6) and commercial crop (3) were released from our institutions for cultivation in different production ecologies of the country. Biofortified rice variety CR Dhan 310 was commercialized successfully in the Indo-Gangetic Plains belt and Swarna Shreya, a new rice variety for drought–prone conditions was released. To ensure a faster spread to farmers' fields, 978, 17,562, 12,847, 14,000, and 3,418 tonnes of breeder, foundation, certified, truthfully labelled seed and planting material, respectively, were produced. Further nearly, 2,026 lakh of planting material and tissue-cultured plants were produced.

Five different antioxidant genes, characterizing antioxidant defense system from two Indian maize inbred lines, were cloned and registered with Gene Bank as a part of the International Nucleotide Sequence Database Collaboration (INSDC). Insect bioassay of selected lines of chickpea and pigeonpea exhibited larval (*Helicoverpa armigera*) mortality in the range of 20-100%. Allele-mining of drought-responsive factors CcCDP, CcHyPRP and CAP2 gene was accomplished in selected set of chickpea and pigeonpea genotypes. Eleven stress induced miRNAs including those responsive to heat stress in pigeonpea were identified. First time whole genome and transcriptome sequencing of *Colletotrichum falcatum*, red-rot pathogen of sugarcane was reported. Genome sequence of psychro-tolerant bacteria *Staphylococcus xylosus* strain LSR_02N, isolated from the water (sediment) at the confluence of river Zanskar and Indus at Leh, Jammu and Kashmir, was deciphered. The complete genome sequence of *Virgibacillus* sp. bacterium revealed the presence of genes for osmo-regulation and oxidative stress tolerance. Genetic diversity analyses were done in rice (6,984), wild Oryza (48), barnyard millet (94), kodo millet (96), prosomillet (16), sponge-gourd (45), bread wheat (48), pearl millet (90) and giloe (24). Trait-specific markers were developed for terminal heat tolerance, HKT2:1 gene and rust and spot blotch resistance genes in wheat, yield-related genes in rice,

FAE1/ KCS1 gene in Indian mustard, transcription factor families in giloe, and abiotic stress tolerance in horsegram and pigeonpea.

Arka Udaya, mango hybrid with medium-size fruits, firm and deep yellow pulp; Arka Rashmi, guava hybrid with pink pulp; PDKV Baharacid lime with higher fruit yield; Kalpa Haritha, dual-purpose coconut for copra and tender nut; a hybrid cashew (H126) with jumbo nut; Bhima Safed, white onion with 22-25 tonnes/ha bulb yield during *kharif*, Arka Agni and ArkaAlankara, two male sterile marigold hybrids with higher fresh flower yield; Appangala 2, mosaic Virus (katte) resistant cardamom hybrid with 9.3 q/ha dry capsules yield and improved varieties of seed spices like fenugreek (AFg-4), ajwain (AA-93) and nigella (AN-20) having desired traits for yield etc. were developed and recommended for cultivation. Complete plantlets of Nagpur Mandarin and Sweet Orange were successfully regenerated from hybrid endosperm via somatic embryogenesis.

Nutrient management schedule for organic production of Grand Naine and Nendran banana; the technology for production of iron-fortified oyster mushrooms (*Hypsizygus ulmarius*); fertilizer adjustment equation for targeted yield (690–1140 kg/ha) of Appangala 1 and Green Gold varieties of cardamom and integrated nutrient management schedule with improved corm yield of turmeric variety Sudarsana, were developed. An integrated cropping system having coconut + cocoa + banana + pineapple with net income of ₹ 3.77 lakh/ha was developed and successfully demonstrated at Aliyarnagar, Tamil Nadu.

Livestock improvement

India has been holding the position of leading milk producing nation in the world for the last several years with sustainable increase in the annual milk production wherein the research developments played a crucial role. Studies showed that average first lactation 305 days milk yield of cows was 3,703.6±31.3 kg and average age at first calving was 1,036.6±10.2 days. Under Conservation and Genetic Improvement of Indigenous Cattle Breeds, the milk yield showed an increasing trend among the progenies of different sets, and average 305 days milk yield increased from 1,958 kg in first set to 2,604 kg in 10th set. Semen doses of Gir, Kankrej, Sahiwal were produced and utilized for insemination.Cloning of the only alive Wild-buffalo of Chhattisgarh has opened up new avenues of cloning technology application in conservation of endangered species. Prolific sheep strain GMM × P (Garole-Malpura-Malpura × Patanwadi) revealed a multiple birth of 50%. Under Mega Sheep Seed Project, flocks of Chottanagpuri, Mandya, Mecheri, Sonadi, and Malpura were built in their respective breeding tracts for production of superior seed stock and their breeding rams were distributed among farmers for improvement of indigenous sheep breeds. AICRP on Goat Improvement significantly affected conservation and improvement of goat genetic resources as it increased population of goats true-to-the breed and productivity amongst 13 descript breeds and three lesser known genetic resources. The implementation of goat husbandry technologies in famers' flock provided average employment ranging between 80 and 140 man days in a year; and income improved from 67 to 257 % of investment in Assam hill goat. The triple cross pigs ($D_{50}H_{25}G_{25}$) showed significantly higher body weight and pre-weaning and post-weaning growth rate.

Captive stocks of *Rita chrysea*, an indigenous catfish endemic to Mahanadi river, were successfully induced-bred in hatchery conditions. The fish has good consumer preference and market demand. Giant snakehead (*Channa marulius)* and milkfish (*Chanos chanos)* were also induced bred. Milkfish with its ability to grow with other fishes and shrimp and also being disease resistant is an ideal fish for polyculture.

Crop management

Endophytes, *Bacillus subtilis* REN51N and *B. firmus* J22N isolated from seed, root and stem of groundnut were effective in mitigating drought stress and enhancing growth and yield of the crop. *Bacillus aryabhattai* MDSR14 (JF792521) and arbuscular mycorhizal fungi significantly increased dry-matter accumulation, seed yield and phosphorus-use efficiency in soybean and maize intercropping. Application of ethrel, gibberelic acid (GA3) and cytokinin at critical growth stages of sugarcane in autumn planted crop enhanced plant population, tiller survival, number of millable canes and cane yield compared to control.

Stem-rot *(Sclerotium rolfsii)* tolerant genotype of groundnut (CS 19) showed higher constitutive level of pyrocatechol. Intercropping *bajra* with groundnut (3:1) supported lowest population of thrips, hoppers and aphids as compared to other intercrop combinations. Azadirachtin 1.5% @ 7.5 ml/L and standard check of monocrotophos 36 SL @ 1.2ml/L were effective for checking thrips. A detached leaf technique was standardized to screen castor genotypes against grey mold caused by *Botryotinia ricini*. Destruction of infested tomato plants and fruits, preservation of potential natural enemies like *Nesidiocoris tenuis*, *Necremnus* sp., *Orius* sp., and *Trichogramma* spp., mass trapping of male moths both in nursery and main field using nanomatrix, lure trap and use of biopesticides *(Bacillus thuringiensis*, *Beauveria bassiana)* and entomopathogenic nematodes proved promising in management of *Tuta absoluta*. A new invasive mealy bug, *Phenacoccus madeirensis* Green, known to occur in South American region, was recorded on cotton in severe form in Chamrajnagara (Karnataka) infesting 80% plants. For biocontrol, potential Gnat predator, *Diadiplosis hirticornis*, infesting invasive mealy bug, was documented. Unique association was observed between predator gnat and mealy bug. The predator can be easily mass produced in laboratory on pink mealy bug and utilized as a potential biocontrol agent.

An eco-friendly integrated pest management (IPM)

technology in rice was demonstrated successfully with farmers' participation mode over cluster of villages in Gautam Budh Nagar, Uttar Pradesh. Bio-acoustic gadgets equipped with alarm and distress calls of different animals when installed effectively warded off birds and wild animals from feeding on crops. Eco-friendly protocol for trapping melon-fly resulted in trapping 2.5 times more fruitfly, as compared to conventional trap. *Lepidiota mansueta,* a biennial species of white grub, is a severe endemic pest of multiple field crops in Majuli river island of Asom, and tribal people here relished cooked/ fried adults of *L. mansueta*. The beetles serve as the source of protein rich food, having nutritional and nutraceutical value. The seed cotton yield was 38% higher in open-pollinated plot and 17.5% higher in *Apis cerana* pollinated plots as compared to pollinator excluded plots.

The incidence of South American tomato leaf miner or tomato moth *(Tuta absoluta)* was documented around Bengaluru for the first time in India. The incidence of banana skipper, an invasive butterfly pest (*Erionota torus*) was recorded across Kerala in monsoon. Protocol for the detection of Tristeza virus in citrus aphids *(Aphids citricola)* was validated and real-time PCR protocol was developed for specific detection of *Phytophthora meadii* that causes fruit rot of arecanut.

Livestock management

With a view to economise the feeding cost, sugarcane mud was successfully incorporated up to 20% in concentrate mixture of growing calves without any adverse effect on growth of both, pre- and post-ruminant calves.Linseed oil feeding improved the omega-3 content of meat of birds, whereas conjugated linoleic acid (CLA) accumulation in meat significantly increased with increasing CLA level in the diet of broilers. Liposome proved to be a better alternative to egg yolk as buffalo bull semen extender. The adoption of accelerated lambing system in Malpura sheep produced 32.58% more lambs in comparison to one lamb in a year under conventional system. A real time PCR assay was developed for the diagnosis of *Brucella melitensis,* the most common abortion causing agent in small ruminants. A new vaccine was developed for protection against infectious bovine rhinotracheitis. Molecular diagnostics were developed for porcine circovirus 2, *Brucella* isolates and *Clostridium difficile.* Methicillin resistant *Staphylococcus aureus* (MRSA) was isolated and characterized from milk samples collected from bovine and caprine mastitis. The supplemental feeding of leaves of *Aegle marmelos* and *Murraya koenigii* augmented fertility in delayed pubertal heifers both at farm and field conditions. Equine infectious anaemia antibodies were not reported from surveyed animals in the country. Presence of MRSA in food-producing animals and retail meat are a cause of concern about exposure of humans through food chain. A PCR protocol for rapid detection of mithicillin-resistant *Staphylococcus aureus* (MRSA) from pigs was standardized for routine screening of pigs. Aqueous and methanolic extracts of *Nicotiana* spp. and *Zanthoxylum alatum* showed effective hirudinicidal activity. Risk path analysis of notifiable avian influenza (NA, HPNA1, LPNAI) was identified for the import of chicken, meat and by-product and also live birds. A lateral flow kit for the diagnosis of *Listeria* species was designed. Detailed phylogeny indicated role of migratory birds in the spread of H5N1 virus, although trade of poultry/poultry products cannot be ruled out. PCR assays for the detection of 17 prioritized exotic and emerging viruses were developed. FMD virus serotype O vaccine strain with enhanced thermo-stability was constructed using reverse genetic approach.

Fisheries management study on hilsa revealed that there is 40% over-exploitation of spawning stock biomass (SSB) and further increase in exploitation levels might cause serious decline in the fishery. About 20% reduction in fishing effort, restriction on use of small mesh sized gill nets and banning of fishing during breeding season may be implemented for restoring the hilsa stocks. In marine tropical fishes, otolith morphometric studies were standardized for species/ stock confirmation.

Mechanization and energy management

For enhanced productivity and profitability of different farming systems, need-based and region-specific mechanization and energy management technologies were developed. These include: tractor-operated check-basin former (96% saving on cost of operation over conventional manual method); planting system for small seeds (useful for small and marginal farmers of tribal areas to promote production and productivity of millets); tractor-operated small seed planter (saving of 50.4% in operation cost and 81.1% in labour requirement as compared to conventional method of onion cultivation); micro-controller-based variable rate granular fertilizer applicator (met closely the target fertilizer application rate for grid size of 8 m × 8 m); pineapple harvester, to mention a few. Bioreactor was developed for accelerated composting. Energy audit of biomass gasification based power plants (seven plants having total capacity 67.5 MW) in the Punjab State revealed that these plants can generate 10 billion units of electricity worth ₹ 6,000 crore every year. Coconut wood canoe of dimensions 9.0 m LOA 1.50 m BOA and 0.70 m depth was designed to accommodate eight to ten people and is suitable for gill net, seine net and hook and line operations.

Post-harvest management and value-addition

The post-production systems in agriculture sector faces huge losses estimated to range from around 4% for foodgrains to 18% for fruits and vegetables. Value-addition and preservation in post-harvest chain would help making greater and healthier food choices for the consumers throughout the year. Cottage-scale pilot plant for probiotic soy-cheese spread and soy milk

powder was developed. Probiotic soymilk powder exhibited antioxidant and antimicrobial properties. Heat treatment and ripening chamber for banana was developed to enhance the shelf-life of banana and for product safety.

An instrument, developed to measure electrical insulation of jute and allied fibre-based technical textiles, is useful for assessing suitability of fabric for electrical insulating products like gloves, jackets, floor covering etc. The process protocol for large-scale production of nano-cellulose from cotton linters was optimized. This product can be a potential candidate for use as reinforcing agents in polymeric composites, concretes, natural rubber composites; as rheology modifier in paints and as carrier for pesticides and micronutrients.

Biosynthetic pathway of aleuritic acid, one of the widely used compounds by perfumery industry, was reported for the first time. Application of fortified lac mud, a waste of lac-processing industry, proved a good nutrient source for vegetable and flower production. A natural nail polish formulation was developed based on the lac resin (a natural material), which besides being glossy, hard, smooth and durable is non-hazardous to health, and conforms to requirements of BIS standards (IS: 9245:1994). India is the largest producer of guar gum in the world. Carboxymethyl derivative (anionic) of guar gum was synthesized, which is useful in fabric printing, oil well fracturing, mud drilling and industrial applications and preparations as stabilizer, thickener and suspending agents.

An eco-friendly bio-treatment process was developed for production of paper from the lignocellulosic fibre produces. The paper produced has improved optical and physical properties and the process generated less pollutants. ZnO was selected as a suitable nano particle for jute textiles to impart flame retardancy. Flame-retardant nano-particles were synthesized chemically. A process for production of nano fibre mat from cellulose acetate (CA) was developed; this mat can be used as matrix for the development of nanosensors. Rotary knife roller gin, a high-capacity option, gave better fibre-spinning quality thus increasing profitability of ginning business and ensured timely processing of cotton. Methods to prepare functional and nutraceutical food products like composite flour eggless cake, Nutri-laddoo, Multi-grain tortilla chips, Antioxidant-rich pasta from vegetables and buckwheat, White ragi-malt based designer, and Extruded snacks from broken walnut kernels were developed.

Processes for total utilization of commercially unmarketable pomegranate fruits into juice, wine, pomegranate seed oil, organic mouth wash and bio-colour from rind was standardized. A combination of edible coating (pectin or PVA) and modified atmospheric packaging of minimally processed carrots extended its storage life up to 21 days at 8°C without significant deterioration in quality. The novel feature of the test, developed for detection of *Escherichia coli* in milk, is rapid detection within 15.0 ± 1.15 h as against 3-5 days protocol in conventional method. *Sous-vide* processing technology prolonged the shelf-life of chicken sausages to more than 90 days under refrigeration temperature compared to a shelf-life of only 20 days. An antidiabetic extract (ADe) product, Cadalmin™ with potential activity against type-II diabetes, was developed from a blend of marine macro algae.

Agricultural education

For maintaining and upgrading quality and relevance of higher agricultural education, financial and monitoring support was provided for Niche Area of Excellence (28), Experiential Learning Units (21 new), besides refurbishing and maintenance of educational structures, student and faculty amenities, course curricula revision/improvement, strengthening of libraries with ICT and modernization of teaching with multimedia learning resources. HRD programmes/ activities facilitated promotion and execution of ICAR sponsored schemes that include centralized admissions in UG/PG to reduce inbreeding, infuse merit and promote national integration; award and distribution of fellowships to attract talent and promote merit, admission of foreign students for globalization of agriculture education, capacity building of faculty through summer-winter schools and Centre of Advanced Faculty training, National Professorial Chairs and National Fellow Scheme for promotion of excellence, Emeritus Scientist Scheme as a structural method of utilizing skill bank of the outstanding superannuated professionals.

Social science

Study on crop planning for resource use efficiency and sustainability revealed that paddy, remains the most rewarding crop during *kharif* under market price situation, perhaps due to assured prices and higher yields. In *rabi* season, pea cultivation became more profitable than wheat in Punjab. A positive development was seen in reduction of disparity between a cultivator and non-agricultural worker after 2004-05 due to acceleration in agricultural growth and decline in the number of cultivators. Rural workforce that had increased by 50 million between 1993-94 and 2004-05, declined by seven million afterwards primarily due to exit of female workers from the agricultural works. Relatively faster growth in non-farm sectors, higher non-farm wages and improvements in literacy level of cultivators and agricultural labourers are some important factors responsible for the recent changes in employment.

During the reported period the GAP-India worked towards catalyzing the GAP activities in South Asia and link with partners in other countries to benefit and support gender equity actions in the region. Gender difference was observed as 13.04% girls were severely malnourished and 8.70% moderately undernourished in comparison to boys. The All India Co-ordinated Research Project (AICRP) on Home Science focused

on empowerment of women in agriculture and 23 technologies for mitigating drudgery of farm-women were developed/refined/tested at different centres. Eight technologies were ergonomically evaluated after field interventions. Technologies scaled up for introduction among Self-Help Group were harvest bags (basket), seed-cum-fertilizer bag, seed placement tube, head load managers, revolving milking stool and stand, *gopal khore, trishul* weeder and cotton picking apron.

Management Information System (MIS) and Financial Management System (FMS) (*http://icarerp.iasri.res.in*) were implemented in 108 ICAR institutions with more than 20,000 users; and nearly 10,000 personnel were trained on system. Online software was developed for easy accessibility and quick reference of polycross trials by the experimenters (*http://design.iasri.res.in/webpd*). First whole genome putative microsatellite DNA marker database (*http://webapp.cabgrid.res.in/sbmdb*) of sugar beet was developed for bioenergy and industrial applications.

Information, communication and publicity services

In a partnership with AgroInnovate India Ltd., a company of DARE/ICAR, the DKMA participated in the Global R&D Summit 2014 which was organized by Federation of Indian Chambers of Commerce and Industry (FICCI) wherein some of the cutting edge technologies, products and solutions of ICAR Institutes were exhibited to key customers, business buyers, investors, scientific community and media at large. The DKMA participated in an International Workshop on 'Development of Communication strategies for adoption of Agri-Biotechnology in Asia' in Thailand. The DKMA has signed an MoU with Project Director, The Essential Electronics Agricultural Library commonly known as TEEAL (An International Project from Cornell University, USA) for providing information on agriculture and allied sciences to the researchers working at places where the internet is patchy through TEEAL.

In order to strengthen 'Farmer FIRST', research work from across Institutes was disseminated through *The Indian Journal of Agricultural Sciences, The Indian Journal of Animal Sciences*. Besides, 24 journals of related professional/academic societies are also posted on the ICAR web site, visible globally in sync with open access policy of the ICAR.The *ICAR Reporter, ICAR Mail, ICAR Chiththi* (Hindi), *Agbiotech Digest, INDIA-ASEAN News on Agriculture and Forestry* were also published. Popular form of agri-information was carried in the *Indian Farming, Indian Horticulture, Kheti, Phal Phool* along with some special issues.

Towards strengthening the programme 'Student READY', a new project was launched in which authors were invited to write textbooks for the undergraduate students. Besides DKMA brings out a new publication on every third day. About 32,000 pages covering nearly 250 publications were published during the reported period. Press conferences, publicity material to press and exhibitions were also compliance by the DKMA for showcasing ICAR technologies on different occasions of national and international events across the country. Special trainings were organized to strengthen the capacity building programmed in interest of the scientists.

Technology assessment, refinement and transfer

The processes of Technology assessment and refinement are as important as the technology generation prior to transfer at the field level. During the reported period, 2,652 technology interventions were assessed across 4,003 locations by laying out 27,008 trials on the farmers' fields. Women specific income generation technologies (205) related to technological empowerment of rural women were assessed at 394 locations covering 2,917 trials under the thematic areas. Technological interventions (39) in 43 locations were refined through 398 trials on livestock, poultry and fisheries under the thematic areas, viz. disease management, feed and fodder management, nutrition management and production and management. During the reported period 98,624 Field-line demonstrations covering 52,326 ha were organized. Of these 90,974 (92%) demonstrations covering 47,001 ha were on crops. During reported period, 1.96 lakh q seeds of improved varieties and hybrids of different crops were produced and provided to 3.28 lakh farmers. In all, 228.75 lakh quality planting materials of elite species of different crops were produced and provided to 18.38 lakh farmers. Bio-agents, bio-pesticides, bio-fertilizers, vermin-compost, mineral mixture etc. were produced and supplied to the extent of 16,406 q benefiting 9.39 lakh farmers. Kisan mobile advisory (KMA), an initiative by the ICAR, sent 93,949 short text messages, 14,788 voice messages and 1,180 both SMS and voice messages to benefit 223.94 lakh farmers on various aspects of agriculture based on input provided by 557 KVKs.

Under the sub theme-Technology Demonstrations and Dissemination for Climate Resilient Agriculture, about 100 KVKs carried out demonstrations on natural resource management (6,968 ha), crop production technologies (4,450 ha) and on fodder and feed production (682.18 ha). About 17,315 animals/birds belonging to 3,092 farmers got benefited from the demonstrations related to livestock and fisheries. The Zonal Project Directorates upgraded the knowledge and skills of 3,182 staff of KVKs by arranging 76 capacity development programmes. The Agricultural Technology Information Centres (48) in the country served as single window delivery systems by providing technology information, technology services and technology inputs to 4.99 lakh farmers who visited the ATICs.

Research for tribal and hill regions

Eleven varieties of maize and 10 varieties of French bean were screened under organic farming in NEH Region. Under *jhum* improvement programme, ramie crop was introduced in Garo hills. *Labeo pungusia*, a

threatened and commercially high valued fish, was induced bred for the first time. This is an important breakthrough for aquaculture and conservation of threatened fishes of North East region. At Tripura centre, rice-fish-pig-tuber crop based integrated farming system (IFS) was found suitable farming model for marginal farmers of Tripura under rainfed ecology.

In Central Island region 12 varieties of crops—rice (2), amaranthus (2), poi (1), mung (3) and noni (4)—were developed and released for the benefits of Island farmers. In Island region, germplasms (57) were collected from different parts of Andaman and Nicobar Islands. Three varieties CIARI Mung 1, CIARI Mung 2 and CIARI Mung 3 were released. Other accomplishments in the islands included first record of shovel nosed lobster, *Thenus unimaculatus* from Andaman and Nicobar Islands; of rice land race Aath Number Dhan, and captive breeding of skunk clawn fish.

In Nagaland, vaccine bank for free supply of different vaccines for livestock and poultry to the beneficiaries directly or through KVKs and State Department was set up under Tribal Sub-Plan. Other tribal sub plan programmes included water transfer through gravity fed HDPE pipe line and integrated watershed development with the help of tribal community.

National Agricultural Science Fund

The National Agricultural Science Fund, established to support basic and strategic research in agriculture, beside supporting, reviewing, monitoring and evaluation of the ongoing projects also initiated funding of new projects which were in the process of evaluation. During the year 2015-16, the NASF delivered five patents and 38 technologies. Some of the important projects are: Phenomics of moisture deficit and low temperature in rice-double herbicide tolerant transgenic rice for weed management; development of transgenic pigeonpea and chickpea; dominant nuclear male sterility system in rice for hybrid seed production; development of genetically engineered vaccines against poultry viral disease; adaptive mechanism and capture breeding in hilsa; green fishing systems for the tropical seas, defense genes of tiger shrimp against bacteria and white spot syndrome virus besides several others.

Intellectual property portfolio management

Patent applications (49) from 25 research institutes were filed taking cumulative figures to 980 applications from 69 ICAR institutes. Indian Patent Office granted three patents: IN266213, for development and use of rubber disc with soft rubber layers as material for self-grooving roller in roller ginning machines; IN266707, zinc chloride pre-treatment of micro-crystalline cellulose for preparation of nano-cellulose by homogenization process; and IN266905, method for maximum percent recovery and detection of organo-chlorine and organophosphorus pesticides together from brackish water/coastal water, taking ICAR's cumulative number of granted patents to 170. ICAR institutes (23) filed 94 copyrights. Till date, 21 applications trademark have been granted registration. For applications filed earlier, 167 varieties (149 extant and 18 new) were granted registration certificates during this period.

Partnership and Linkages

Memoranda of Understandings were signed between ICAR and Auburn University (USA); University Court of the University of Edinburgh, Scotland (United Kingdom); Eastern Africa Statistical Training Centre (Tanzania), and Seychelles Agricultural Agency (Seychelles). The Work Plan was signed between ICAR and International Livestock Research Institute, Kenya. Memorandum of Agreement was signed between ICAR and Ministry of External Affairs, Government of India for setting up of an 'Advanced Centre for Agricultural Research and Education' at Yezin, Myanmar to help Government of Myanmar's efforts in capacity building of scientific and technical staff. India is a donor member of CGIAR system and accordingly, provisions in Plan and Non-Plan budget were made for the financial year 2015-16. The ICAR hosted 23rd International Grassland Congress with 500 delegates from 47 countries.

AgrInnovate India Limited

The AgrInnovate India Limited (AgIn) coordinated various training and capacity building programmes. The National Bureau of Plant Genetic Resources (NBPGR) signed a Memorandum of Agreement (MoA) with a private company, facilitated by AgIn for licensing of five DNA-based GMO screening technologies. AgIn licensed designs of 31 agricultural engineering machineries from Indian Institute of Horticultural Research (IIHR), Bengaluru to a private company. AgIn also facilitated in organizing training programmes for West Africa Agricultural Productivity Programme nominated Nigerian candidates in Fish Breeding Technology at Central Institute of Freshwater Aquaculture, Bhubneshwar; a 24-week certificate course on Food Science and Technology at Central Institute of Agricultural Engineering, Bhopal; a 6-month programme on Seed Technology at Directorate of Seed Research, Mau.

Awards

For encouraging use of Hindi in day to day working, the official language Rajarshri Tondon Rajbhasha Purskar Yojana for 2013-14 policy, first prize in three categories: Big Institutes, Institutes/Centre of 'A' and 'B' Region, and Institutes/Centre of 'C' Region were given to Indian Veterinary Research Institute (Izatnagar), National Bureau of Soil Survey and Land Use Planning (Nagpur), and Central Research Institute for Dryland Agriculture, Santoshnagar (Hyderabad).

The Council conferred 82 awards under 18 different categories, which includes three institutions, one AICRP, nine KVKs, 55 scientists, seven farmers and six agriculture journalists. Fifteen women scientists include the list of awardees. For the first time administrative

awards were also given to administrative, technical and skill supporting personnel of ICAR for their outstanding contributions.

Finance

The Plan and Non-Plan allocation (R.E.) to DARE/ ICAR for 2014-15 were ₹ 2,500.00 crore and ₹ 2,384.00 crore respectively. An internal resources of ₹ 200.68 crore (including interest on Loans and Advances, Income from Revolving Fund Schemes and interest on Short Term Deposits) was generated for the year 2014-15. The Plan and Non-Plan allocation (B.E.) for 2015-16 are Rs 3,691.00 crore and Rs 2,629 crore respectively.

I wish to place on record our gratitude to the Hon'ble Union Minister of Agriculture and Farmers Welfare and President of the ICAR Society; and Hon'ble Union Ministers of State for Agriculture and Farmers Welfare, for their keen interest, valuable guidance, support and encouragement in all endeavours of the DARE/ICAR. I wish to thank the diverse stakeholders especially, Ministries and Departments of the Government of India, State Agricultural Universities, National and International Organizations, Private sector industry and Farmers, for their association, and cooperation in formulation of different research programmes of the ICAR, as well as all-round efforts at efficient-agriculture. We are confident that concerted efforts of the Council would lead to technological empowerment of farmers to achieve higher levels of input efficiency and productivity, to ensure sustainable agricultural growth.

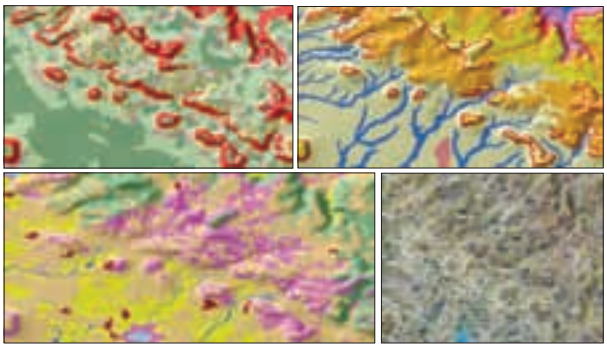
It is hoped that the report would be useful for policy-makers, planners, development agencies, researchers, farmers and students alike in our endeavor to make Indian agriculture more resilient and the farmer, more prosperous.

(S Ayyappan)
Secretary
Department of Agricultural Research and Education
and
Director General
Indian Council of Agricultural Research,
New Delhi

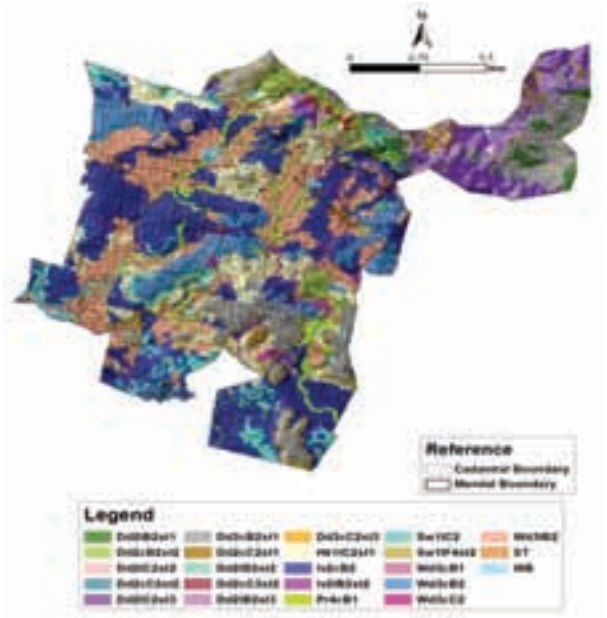
2. Soil and Water Productivity

Soil resource inventory and land use planning

Land resource inventory (LRI) on 1:10000 scale: In the first phase (2014-2018), land resource inventory of 60 blocks/mandals/talukas covering 60 agro-ecological sub-regions (AESRs) of the country targeting 3.3 million ha area has been taken up as a model. During 2014-15, 34 blocks were surveyed, 5 from Southern; 10 from Western; 14 from Eastern; 5 from North-eastern; 3 from Northern and 2 from Central region. Landscape ecological unit (LEU) consisting of landforms, land use and slope is taken as the base map for LRI instead of landforms alone. Contours at 10 m interval and drainage pattern were developed for delineation of slope and landforms using Cartosat digital elevation model. Other remote sensing data like IRS-LISS IV of 5.8 meter resolution and those available in public domain are used for land use-landcover (LULC) mapping. Landforms, slope and LULC maps are integrated for developing landscape ecological unit in GIS environment as shown for a part of Indervalle mandal, Adilabad district, Telangana. Interpretation of each LEU is done in terms of physiography, sub-physiography, broad landforms, landform units within broad landforms, slope and land use as shown for Indervalle mandal. Soil-landscape ecological unit relationship is developed by studying soil profiles, minipits and auger observations. On laboratory confirmation, phases of series are delineated on soil map on 1:10,000 scale.

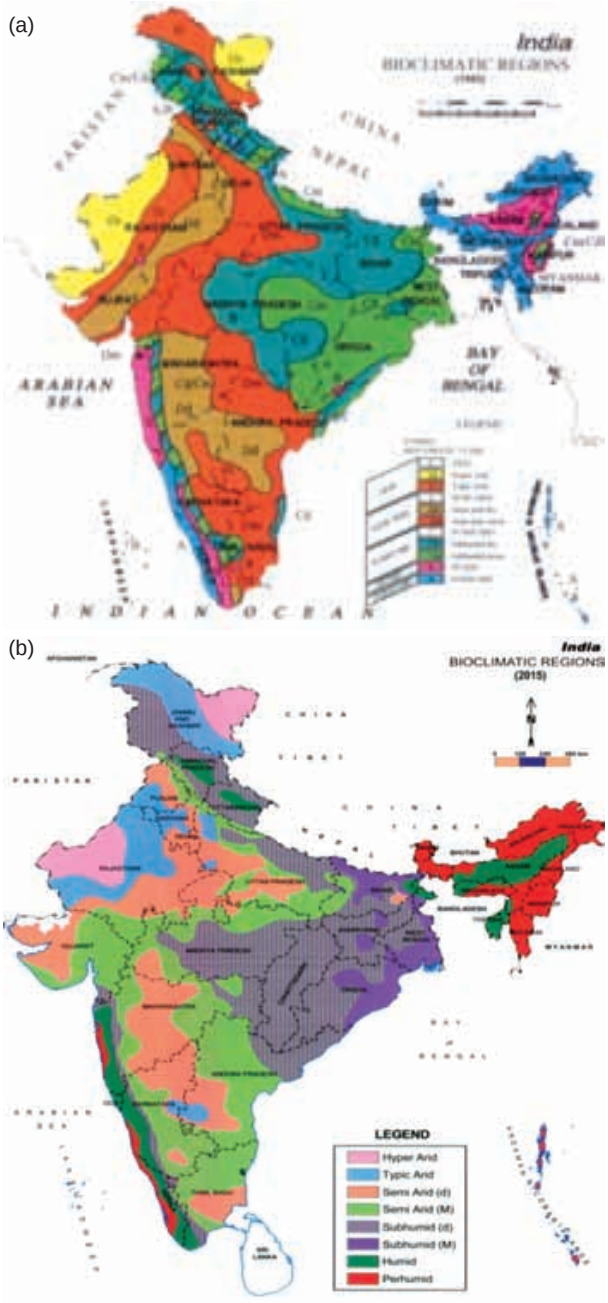


Landscape ecological unit in a part of Indervalle block, Adilabad district, Telangana



Soil map, Gajwelmandal, Medak district, Telangana

Refinement of bio climatic maps of India: Change in the bio-climate map published by ICAR-NBSS&LUP



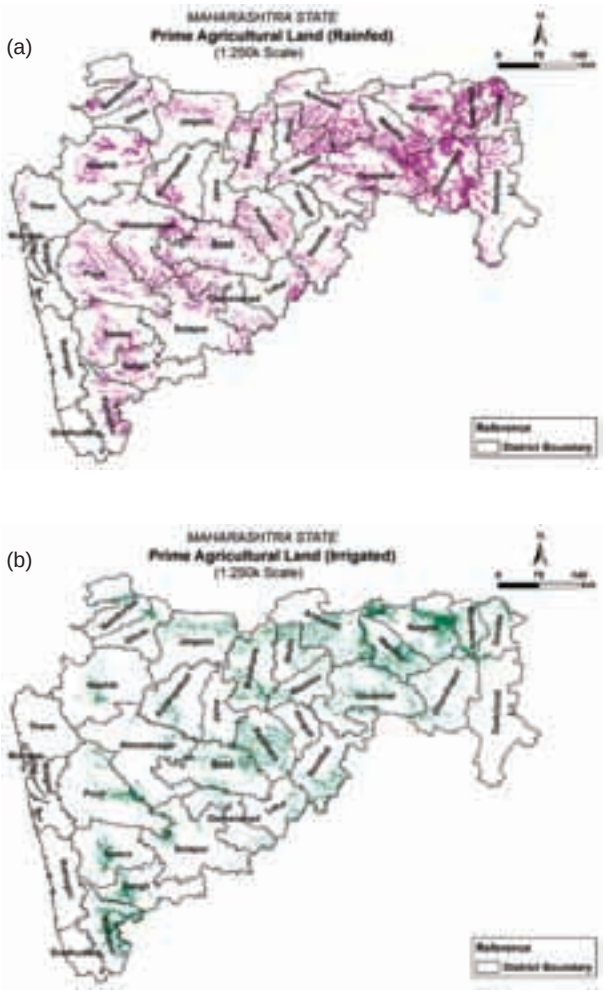
Bio-climatic maps. a, 1992; b, 2015

in 1992 was analysed, and revised bio-climate map was developed in 2015. New soil data (derived from 1:1 million soil database) and rainfall data of 530 stations were used in the process along with the variations in Moisture Index (IM), length of growing period and the average data value of 1,900 stations computed earlier. The Hyper Arid zone which covered 22.9 million ha in 1992 has considerably reduced to 12.5 million ha (i.e. a decrease by 45.4%), whereas Typic Arid area has increased by 8.4% from the earlier value of 22.7 million ha. Semi-arid (dry) areas have shown insignificant change (2.5%) but semi-arid (moist) areas have increased by approximately 30% from earlier estimated 72.2 mha. This is at the expense of dry and moist sub-humid areas of the country. The dry sub-humid areas have increased by approximately 47% from the earlier estimate of 54.1 million ha at the expense of moist and transitional sub-humid areas in Maharashtra, Madhya Pradesh, Chhattisgarh (north west), Andhra Pradesh (central) and north fringes of Odisha, Jharkhand and Bihar (south). The humid area has increased by 74% from earlier estimated value of 16.6 million ha, which falls under coastal parts of West Bengal and Odisha, deltaic regions of Andhra Pradesh, Bengal basin, Tarai plains of West Bengal, Brahmaputra Valleys and Western Coastal Plains.

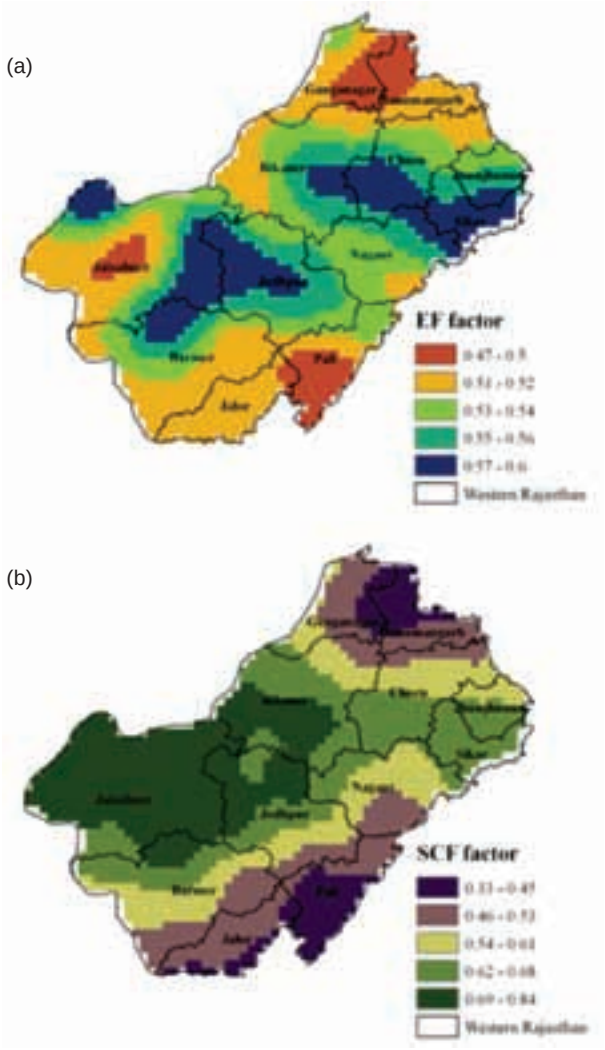
Delineation of prime and non-prime lands in Maharashtra: Prime land is characterized as the land having less than 8% slope, moderately deep to deep (soil depth >75 cm) and pH ranging from 6.5 to 8.5. An exercise of delineating prime and non-prime land has been taken up for Maharashtra as a pilot study using available soil information at 1:250,000 scale. Extent of irrigation, both in prime and non-prime land, is defined by superimposing LULC map of 2013-14. The area under the double/triple crops is considered as the irrigated part of prime and non-prime lands.

Total net sown area in Maharashtra is 21.82 million ha. Rainfed and irrigated agriculture are practiced in 63.1 and 36.9% of the total area, respectively. Out of the net sown area, 6.2 and 15.6 million ha were classified as prime and non-prime land, respectively. About 30 and 37% area of prime and non-prime land, respectively were irrigated.

Wind erosivity assessment: Average wind erosivity factor for four selected locations in Western Rajasthan was calculated as per the revised wind erosion equation (RWEQ) using long term (2000-2010) wind speed data. In general, wind speed becomes erosive from first fortnight of May and remains active up to second fortnight of August for all four selected locations. Jaisalmer and Chandan sites have been found more



Prime land in Maharashtra. a, Rainfed; b, Irrigated



RWEQ factors in western Rajasthan. a, Soil erodible fraction (EF) factor; b, soil crust factor (SCF)

erosive than other sites. Highest wind erosivity has been observed during the second fortnight of July at Chandan (2.81 kg/m/s).

Thematic maps of soil erodibility factors, e.g. erodible fraction (EF) factor and soil crusting fraction (SCF) factor as per RWEQ were prepared for Western Rajasthan. Area covering Jaisalmer, Bikaner, Churu, Jhunjunu, Sikar, Jodhpur and Nagaur district of Western Rajasthan lies under high EF factor (0.57-0.60). Jaisalmer, Bikaner and Western part of Jodhpur lies under high SCF factor (0.69–0.84).

Development of spectral algorithm for rapid soil assessment: A soil spectral library consisting of 138 spectra of surface soil representing different land use situation of Western Rajasthan covering Jaisalmer, Barmer, Jodhpur, Pali, Churu and Jalore was developed. Sand and clay content of arid Western Rajasthan were satisfactorily estimated from linear models (R^2 = 0.41 to 0.43). Soil reflectance spectra based algorithm was developed for rapid assessment of soil erodibility factor in Western Rajasthan.

Soil and water productivity

Bio-engineering interventions for degraded ravine lands: Bamboo plantation based bio-engineering interventions, viz. (i) Bamboo plantation with staggered contour trenches, (ii) Bamboo plantation as live check dams, and (iii) Bamboo plantation supported by *bori* bunds were found promising for reclamation and productive utilization of three major ravine systems of India namely, Mahi ravines at Vasad (Gujarat), Chambal ravines at Kota (Rajasthan), and Yamuna ravines at Agra (Uttar Pradesh). These interventions could absorb more than 80% of rainfall and reduced the soil and nutrient losses by 90% and 70%, respectively. The system increased the soil organic carbon content by 5 times on degraded ravine bed over the years. The gully head and bank extension was checked completely. These interventions gave average annual net return varying from ₹ 63,910 to 88,780/ha with benefit cost ratio from 1.96 to 2.09. Upscaling the package in one third of ravines is estimated to give a present net worth of ₹ 6,430 million over 20-year period, build 44 million tonnes soil carbon and conserve soil worth ₹ 4,100 million at 2011-12 prices.

Bamboo plantation with staggered contour trenches in degraded Mahi ravines of Gujarat

The density of staggered contour trenching (SCT) of size 4.5 × 0.6 × 0.45 m^3 has been optimized for horti-pastoral land use system in medium deep ravines of Chambal river for their economic utilization. Results showed that the highest reduction in mean runoff (86.1%) was in a small ravine watershed treated with SCT density of 417 trenches/ha over the control (no trench), followed by watershed with 278 trenches/ha (60.5%). Similar trends were also recorded in soil loss reduction from the treated watersheds. It was also observed that runoff trapped by the SCT significantly affected the productivity of the system. The total productivity of ravine lands was observed as 2.28, 3.8, 5.9 and 7.46 tonnes/ha/yr aonla fruit equivalent under trenching density of 417, 278 and 139 trenches/ha, respectively. Net income varied from ₹ 344,378 to ₹ 659,229.

Managing dry spells through foliar sprays of thio urea and KNO_3: Foliar sprays with various chemicals were evaluated by All India Coordinated Research Project for Dryland Agriculture (AICRPDA) network centres to mitigate dry spells during crop growing season across diverse rainfed agroecologies. Foliar spray of thiourea at 250 g/ha improved the yields of fingermillet (10%) at Bengaluru, maize (9.5%) at Ballowal Saunkhri and soybean (30%) at Indore, resulting in higher net returns and rainwater-use efficiency (RWUE) compared to water spray. Similarly, at Agra, foliar spray of urea and KNO_3 at 2% each in pearlmillet helped in mitigating the dry spells during August and improved crop yield by 27% closely followed by 2% KNO_3 (22%) compared to water spray. At Solapur, foliar spray of 1.0% KNO_3 at 35 and 55 days after sowing enhanced the crop yield by 12% with higher net returns and RWUE compared to water spray.

Resource conservation and mini-sprinkler in semi-reclaimed sodic soil: A field experiment was initiated in 2011 to evaluate the effect of resource conservation strategies, viz. tillage, residue and irrigation methods for enhancing crop productivity and sustaining the health of semi-reclaimed sodic soils. The results indicated that highest grain yield of rice (7.8 tonnes/ha) was recorded in conventional transplanting method (CV) with wheat residue incorporation followed by conventional tillage (7.3 tonnes/ha) and DSR with reduced tillage and surface irrigation. The highest grain yield of wheat (6.5 tonnes/ha) was recorded in reduced tillage with rice residue incorporation as compared to conventional tillage (5.7

tonnes/ha). Crop residue incorporation increased the grain yield of wheat by 10.2 per cent over CV. Optimum soil moisture and favourable temperature regulation under residue incorporation treatments facilitated better seed germination and crop growth as compared to no-residue treatments.

Sprinkler irrigation system saved 48.3% water over the surface irrigation in wheat. Zero tillage with 100 per cent rice straw mulch produced the highest wheat yield (6.41 tonnes/ha) under surface irrigation system followed by 5.72 tonnes/ha in zero tillage with 100 per cent rice straw mulch with mini sprinkler irrigation system. About 1.94 times higher wheat and water productivity was obtained in mini sprinkler irrigation method with ZT and 100 per cent rice residue mulch as compared to conventional wheat sowing with surface irrigation. Considerable electric energy (17.12%) was saved in mini sprinkler irrigation in comparison to conventional wheat sowing method. The highest nitrogen use efficiency (76.3 kg/kg nitrogen) was observed in mini sprinkler fertigation method as it saved 50 per cent of the recommended nitrogen (75 kg) in wheat as compared to conventional surface irrigation method.

Effects of stage dependent deficit irrigation on tomato: In a two-tier experiment with tomato imposed with either the regulated deficit irrigation (RDI) or at phenological stages and disruption of irrigation, the marketable fruit yield (MFY) was not affected at RDI (0.8 × ETc) but there was loss of about one-fourth MFY with RDI (0.6×ETc). Nevertheless, the water productivity (19.2 kg/m^3) was the maximum under RDI (0.8 × ETc). When the deficit irrigation (RDI, 0.6 × ETc) was applied at vegetative stage, MFY was rather improved by 4% while a decline of 7% was monitored with DI at fruiting. The DI applied at either of the two stages amongst vegetative, flowering and fruiting resulted in 14-18% decline in MFY. The crop was able to tolerate interruptions of irrigation for 15 days, i.e. simulating canal closures and the decline in yield was only 3-7%, the highest being at fruiting stage. The major advantage of DI was improvement in quality in terms of total soluble solid, ascorbic acid, acidity and colour index (lycopene) though the fruit size was affected. It was concluded that

View of farm pond and catchment area

Vegetable on bench and fodder (hybrid Napier on terrace riser)

benefits of deficit irrigation in terms of improved quality and water productivity while sustaining fruit yield could be achieved with regulated DI at 0.8 × ET and at 0.6 × ET during vegetative stage followed by flowering.

Water harvesting and multiple use of water in Southern hilly areas: The Nilgiri farm pond and integrated farming system module was developed by Research Centre, Udhagamandalam under rainfed ecosystem with the components of vegetable (potato, carrot, cabbage and beans) cultivation in the benches, growing hybrid Napier (CO 4) on the riser portion of the bench terraces, cold water fishes (minor carps) in the pond and livestock. Farmers' in the region hesitate to go for bench terraces, which is recommended for the region, as they have to lose some portion of the land (terrace risers) when it is converted into benches. This problem was solved by bringing riser portion of bench terraces under fodder cultivation. Farm pond of size 750 m^3 was created in the valley portion and the downstream side of the pond was lined with silpaulin sheet to arrest the seepage. This farm pond supports irrigation for 2.5 ha of land involving 5 farmers, increasing the cropping intensity to 300% vegetable yield by 20%. Fish production (4.5 tonnes/ha) from pond and fodder production (20 tonnes/ha) from the riser portion of bench terraces augment the agricultural output in this region besides arresting the soil erosion.

Terrestrial weed based phytoremediation system for waste water treatment for irrigation: To find out effect of waste water application on metal accumulation in soil and to assess heavy metal uptake in tomato at DWR farm, the eight treatment combinations were made including four main (tube well water, filtered water-I (*Typha* based), filtered water-II (*Vetiveria* based) and drain water as control as irrigation treatment, which were split-up with two treatment of with and without EDTA.

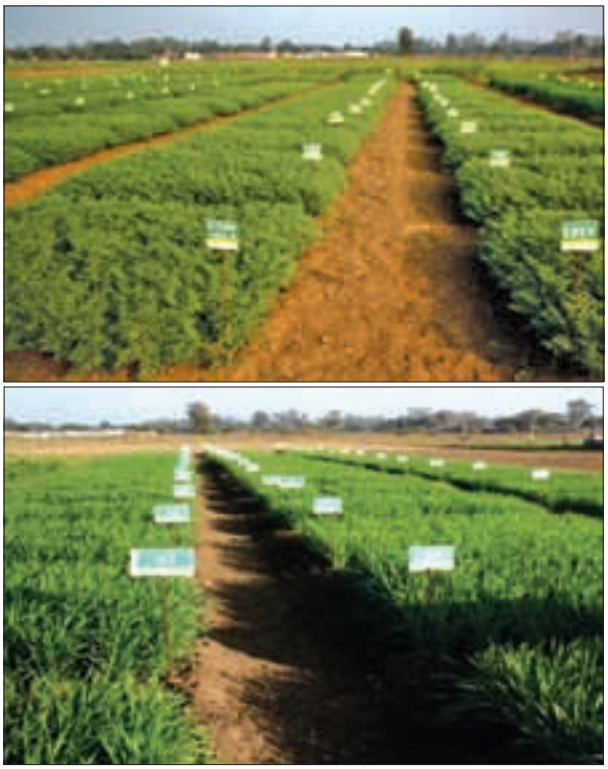
Higher concentration of DTPA extractable cadmium and lead were observed in plots irrigated with untreated drain water as compared to tube well water. The Pb accumulation in soils was 2.59, 2.67, 2.71, 3.08 mg/kg in surface soil under tube well water, filtered-I (*Typha* treated), filtered-II (*Vetiveria* treated) and drain water irrigated plots, respectively. After irrigation with drain

water tomato absorbed higher concentration of heavy metal than tube well water irrigation. Comparatively lower concentration of heavy metals was retained in fruits of tomato than its shoot part. EDTA application enhanced the translocation of heavy metals in tomato. Significantly higher tomato yield was observed under plots irrigated with drain water.

Nutrient management

Soil test crop response based integrated plant nutrition packages: Soil fertility under drip fertigation plays a major role for attaining higher crop productivity with sustained soil health. Fertilizer prescription equations (FPEs) under IPNS were developed for Vertic Ustropept (mixed black calcareous soils) under drip fertigation.

Validation experiments were conducted with hybrid cotton at TNAU Farm, Coimbatore and at two farmers' holdings of Salem district (North Western Zone) of Tamil Nadu on Vertic Ustropept. It revealed that the targeted yield has been achieved within ±10 per cent variation suggesting validity of the equations. The highest mean yield of 3.97 tonnes/ha of seed cotton was recorded in STCR-IPNS for the yield target of 4.0 tonnes/ha with an increase of 41.3 and 44.9%, respectively, over blanket and farmer's practice. Further, it has proved its superiority over all other treatments in terms of RR, BCR and quality parameters.



Field testing of *Arthrobacter* isolates on maize and Actinomycetes consortium on chickpea in Vertisol

New microbial inoculants: Novel plant growth promoting rhizobacteria and *Arthrobacter* were isolated, characterized and field evaluated in Vertisols of Madhya Pradesh. Average yield increase of wheat due to actinomycetes inoculation (17 strains) at recommended fertilizer doses was 4.6 Mg/ha (16% higher) over control. Mixed consortium of superior actinomycetes isolates (A10 and A17), PGPR (P3, P10 and P25) along with *Rhizobium* R33 and R34 in soybean and *Rhizobium* R40 and R56 in chickpea were found very effective. Thirteen shortlisted *Arthrobacter* isolates were found very effective in maize and soybean.

Technique for acceleration of decomposition process using thermophilic microbes: A new technology Rapo-compost technique has been developed by ICAR-IISS in collaboration with ICAR-CIAE and

'Rapo-compost technique' developed by ICAR-IISS

ICAR-NBAIM, Mau to decompose kitchen waste and vegetable wastes. Using consortium of ligno-cellulolytic thermophilic organisms, decomposition period has been considerably reduced to 45 days. The samples were collected initially, at 15 days and 30 days of decomposition and were analysed for its physical, chemical and biological properties. At 30 days of decomposition the colour of the compost was dark brown, with no foul odour. C:N ratio fell from 62:1 to 14:1, cation exchange capacity (CEC) reached to 94 cmol(p+)/kg, lignin/cellulose ratio increased from 0.5 to 2.4%, CEC/TOC ratio was 4.56 at 30 days of decomposition, water soluble carbon reached to 0.5%. Dehydrogenase activity, FDA and alkaline phosphatase activity increased from 111 to 413 µg TPF/g compost/day, 98-260 µg fluorescein/g compost/h and 94-171 µg PNP/g compost/h, respectively.

Biofertilizers

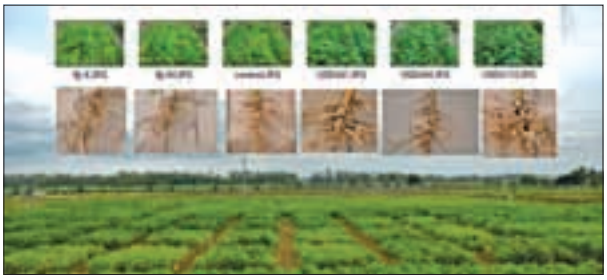
A novel "Actinobacterial Consortium" containing three *Streptomyces* spp. that have ability to solubilize insoluble P and Zn, suppress diseases and produce phytohormones and a variety of enzymes involved in organic matter recycling was developed. This consortium is a carrier-based product, which can be applied either through seed, seedlings, irrigation water or through the enrichment of compost/FYM/cocopeat. Its application improves yield of various vegetable crops from 13 to 24%.

A fermented cocopeat-based VAM fungal inoculum production technology using sterile fermented cocopeat (100 kg) as the sole substrate and a carrier-based bacterial inoculum (50g) containing nearly five times more

infective propagules was developed. This inoculum can be prepared within 45-60 days both outdoor or in glasshouse.

Removal of heavy metals from municipal solid waste: Six mesophilic fungi have been isolated, viz. *Trichoderma viride*, *Aspergillus heteromorphus*, *Rhizomucor pusillus*, *Aspergillus flavus*, *Aspergillus terrus*, and *Aspergillus awamori.* The functional groups were mainly observed in the cytoplasmic membrane of isolated fungi namely, amide group (-NH), hydroxyl group (-OH), carboxylate anions (-COO), carbonyl groups (-CO), C-F and C-Br and these were mainly responsible for biosorption of heavy metals. It was also found that the four fungi, viz. *Aspergillus flavus*, *Aspergillus terrus*, *Aspergillus awamori* and *Rhizomucor pusillus* are having these functional groups. These functional groups ligands with heavy metal like Cd, Cu, Ni, Cr and Zn. The adsorption peak due to bonded OH groups (R-O-H, hydroxyl group) are observed in the range of 3,340-3,380/cm in *Trichoderma viride*, (3,376.94/cm) and *Aspergillus heteromorphus* (3,375.7/cm). These functional groups also help for metal ligand classes of Cr, Ni, Cu, Zn and Cd. Among these six fungi Pb biosorption was maximum and least was observed for Zn. The removal of heavy metals through bio-filter, Pb was maximum 31.6% over initial value followed by Ni (28.8%) and Zn (22.4%). Further it was observed that among the six fungi,*Trichoderma viride* performed better for removal of Pb, Ni, Zn and Cd followed by *Aspergillus flavus.*

***Bradyrhizobium* with rtx gene for induction of nodulation and drought tolerance:** In field experiments on virgin soils converted from basaltic murrum with very low fertility, inoculation with only the rhizobitoxine producing strains (*Bradyrhizobium elekani* USDA 61, *B. elekani* USDA 94 and *B. japonicum* USDA 110) was effective in inducing early stage nodulation in soybean and thus produce higher seed yields under drought stress conditions while none of the 79 nationally collected and 4 commercially available rhizobium strains was effective in nodulation in this soil.



The effectiveness of rhizobitoxine producing strains

e-Atlas of water bodies: Electronic atlas of water resources of Odisha and Himachal Pradesh was developed using vector data representing administrative boundaries of the blocks, districts and states. e-Atlas is user friendly and can be comprehended from a single screen display, ranging from the name of state to the details of village name, water body name, area during pre- and post-monsoon seasons as well as number of water bodies present in any hierarchical administrative unit. It is a useful tool for catch assessment and developing GIS based decision support system and will help planners to concentrate efforts, allocate resources and deploy manpower according to the distribution of fishery resources.

Organic matter degrading microbes: *Bacillus licheniformis* (strain CPSM8) grew well in sewage water and degraded 66% of organic matter present in sewage, 57% of glucose or 50% of peptone added to sewage, within 4 days of incubation showing its total organic carbon degradation ability. Its genome displayed several complex organic matter mineralizing genes for the production of glucanases, xylanase, glucosidases, galactosidases, lipase, proteases, phytase, alkaline phosphates, etc.

Bio-sorbent for amelioration of heavy metal contaminated wastewater: Cation-exchange bio-sorbent was developed from water hyacinth leaf biomass (WLB) and azolla biomass. Both bio-sorbents were effective in removal of copper up to 95% from wastewaters. Sorption equilibrium was reached within 10 min and 25 min for WLB and azolla biomass, respectively. These bio-sorbents can be reused up to five cycles and were effective for developing low cost re-circulatory aquaculture system.

3. Climate Change and Resilient Agriculture

Green house gas (GHG) emissions in diversified agriculture on reclaimed sodic land: The Cool Farm Tool model used to estimate GHGs emission, integrates several globally determined empirical GHG quantification models. Estimated total GHG emission, i.e. global warming potential per hectare in terms of CO_2 equivalent (CO_2-eq) varied amongst different crop production systems. On an average, rice-wheat system emitted 1,823 kg CO_2-eq, whereas maize-wheat, fodder, vegetables and horticulture emitted 410, 245, 188 and 117 kg CO_2-eq from the respective areas of these cropping systems.The total emission from 1.8 ha area under diversified cropping system was 2,784 kg CO_2-eq as compared to 5,152 kg CO_2-eq from the rice–wheat system in the same area. On hectare basis, diversified agriculture system emitted 1,547 kg CO_2-eq/ha as compared to 2,862 kg CO_2-eq/ha in rice-wheat system. The global warming potential under diversified agriculture system was 46% (1,316 kg CO_2-eq/ha) less than that of rice-wheat.

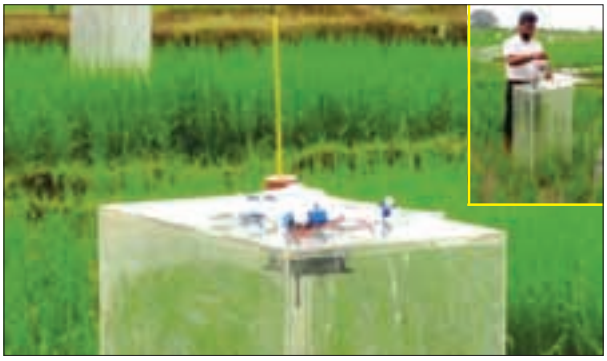
Quantification of green house gas emissions: Measurement of GHG fluxes (carbon dioxide and methane), moisture and heat in the soil-plant-atmosphere systems using the Eddy Covariance technique was carried out in rice-wheat rotation. The net ecosystem carbon dioxide exchange (NEE) and net ecosystem methane exchange (NEME) were monitored in rice and wheat crops and also during the fallow season. The gross primary productivity (GPP) and NEE was found to be highest between heading to ripening stage in rice, whereas it was maximum at flowering stage in wheat.

The net ecosystem methane exchange during rice growth period was the highest between active tillering to maximum tillering stage in rice. The diurnal variations in mean net ecosystem exchange in submerged rice ecosystem in both dry and wet seasons varied between + 0.2 to - 1.2 and + 0.4 to - 0.8 mg $CO_2/m^2/s$.

The cumulative seasonal methane emission was reduced by 75% in aerobic rice when compared with continuosly flooded rice. The seasonal emissions were lower in slow release N fertilizer, especially, when applied on the basis of Customized Leaf Color Chart (CLCC).

Measurement of CH_4 and N_2O fluxes in rice: Fluxes of methane CH_4 and N_2O were measured under different establishment methods and source of nitrogen in irrigated rice in a Typic Ustochrept soil. Maximum methane flux was noticed under the treatment of transplanted puddled and normal urea application combination compared to all other treatment combinations at different stages of the rice crop.

Closed chamber method was used to collect air samples from the experimental field and the air samples were analyzed by Gas Chromatography (Model SRI-8601C) equipped with a detector ECD and FID. The highest methane flux occurred in 72 days after sowing in all the treatment combinations. There is 54% reduction in CH_4 flux under the combination of aerobic rice and neem coated urea application followed by 49% reduction in aerobic rice and sulphur coated urea application compared to the combination of conventional puddling and normal application of urea. There is 33% reduction in N_2O flux under the combination of aerobic rice and neem coated urea application compared to conventional puddling and normal urea application.



Closed chambers used for collection of air samples at regular intervals from the paddy fields

Enhancing climate resilience through crop improvement and adaptation: Development of crop genotypes adapted to multiple climatic stresses is important for coping with climate variability. To address this, genetic enhancement of tolerance to drought, heat, flooding and salinity stresses in major food and horticultural crops is being attempted under NICRA. In wheat, 45 terminal heat tolerant advanced lines were evaluated in multi-locational trials.

Two rice genotypes, viz. Bhundi and Kalaketki were registered for submergence tolerance. Two lines CR2851-1-1-S-7-2B-1 and CR2839-1-S-11-1-B2-B-46-2B have been nominated for AICRP multi-location trial under coastal saline area. Further, three hybrids, IR58025A × NH-12-141R; APMS6A × NH-12-124R; APMS6A × NH-12-144R have entered multi location testing for heat tolerance.

Four lines, Somaly-2-023-3-5-1-2-1, IR 55178, SG 26-120 and IR 82310-B-B-67-2 confirmed the stability under late planting situation in 8 locations. Six promising lines of rice with superior NUE entered multi-location testing.

In pigeonpea, waterlogging tolerant (IPAC 79 and MAL 9) and drought tolerant genotypes (JSA 59, JKM 189, BSMR 736, RVK 275) were identified.

Assessment of hailstorm damage using satellite data: During February-March 2014 hailstorms struck central India and caused severe losses to several crops. Landsat-8 satellite data of pre- and post-hailstorm periods were used to map the hail streaks. High-resolution LISS-IV data were used to distinguish different crops within the hail streak so as to assess extent of damage to different crops in the study area. To detect changes in vegetation due to hailstorm damage, a NDVI difference image was generated by subtracting the pre- and post-hailstorm NDVI images. About six hailstorm-damaged streaks were identified in the study area. The mean length and width of streaks was about 18 and 5 km, respectively. The maximum length of streak was about 33 km, width was 8 km, perimeter was 76 km and area was 36,262 ha. Total damaged area under different crops estimated from the data was about 20,779 ha. Using LISS IV data, crop classification was performed by the minimum distance classifier method. Grape was the major crop affected due to hailstorm in the study area (about 3,122 ha). Damaged fields of papaya, pomegranate and sugarcane were also identified in the classified image.

Carbon-management index: In different wheat-based cropping systems, the index, based on the carbon pool index and carbon liability index, was maximum in zero-tilled narrow-bed with residue in 0-30 cm soil depth under conservation tillage vis-à-vis conventional tillage. Among the cropping systems, maize-wheat cropping system registered the highest carbon management index.

Carbon sequestration in vegetable-pea-Frenchbean cropping system: To reduce C emission, an experiment was conducted with different levels of FYM and recommended NPK in vegetable- pea-Frenchbean system. Application of 5.04 tonnes FYM/ha nullified 62 kg CO_2 emitted during FYM preparation through soil C sequestration. The highest net positive C sequestration (1,585 kg CO_2/ha) and highest C sequestration (1,792 kg CO_2/ha) can be achieved with 16.6 and 17.1 tonnes FYM/ha, respectively. The highest net positive C sequestering FYM application rate lead to 1,443 kg CO_2/ha ; higher C sequestration than the recommended NPK. It yielded 48% higher pods of vegetable pea - Frenchbean system than the recommended NPK.

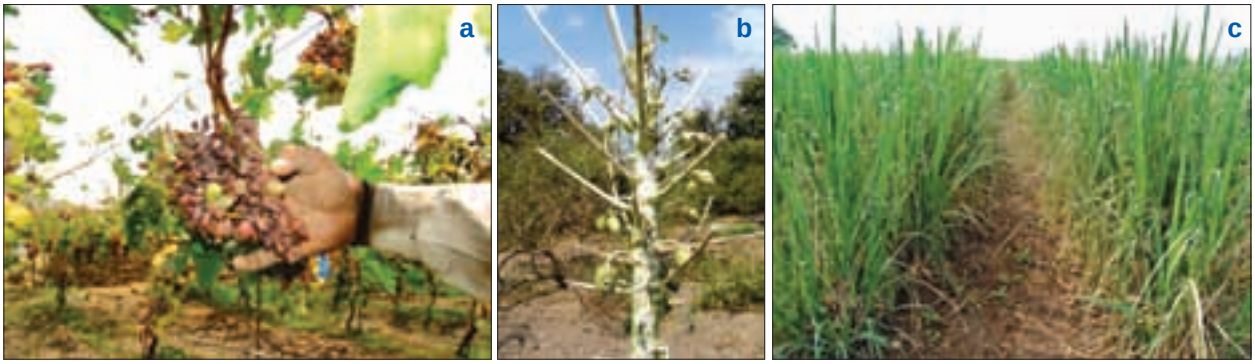
Impact of climate on breeding of carps: Delayed and deficit rainfall during the pre-monsoon season (especially during May) adversely affected fish seed production in Asom. As a strategy to overcome these circumstances, grass carps (*Ctenopharyngodon idella*) were bred during drought period as they are tolerant to deficit-rainfall situations. With reduced incubation period, fishes grew faster in the present situation than that observed in former years. This could be attributed to elevated ambient temperature in recent years.

Carbon sequestration in aquaculture ponds: The nursery and stocking ponds of Khurdha district, Odisha had sediment depth of 0.075 ± 0.030 m and 0.065 ± 0.021 m, respectively. The organic carbon was 1.19 ± 0.30% in nursery pond soil and 0.68 ± 0.11% in the stocking pond soil. The dry bulk density of soil was 1.06 ± 0.45 Mg/m^3 in nursery pond and 1.05 ± 0.37 Mg/m^3 in stocking pond. The carbon sequestration was 9.31 ± 3.93 Mg C/ha in the nursery pond soil and 4.46 ± 1.12 Mg C/ha in the stocking pond soil. Considering 1.0 cm depth, the average C pool was 1.30 and 0.70 Mg C/ha in nursery and stocking pond soil, respectively.

Impact of temperature: Pearson's correlation between maturity percentage and length at maturity of pelagic species showed that the variability in sea surface temperature (SST) negatively influenced the length at maturity of Bombay duck (*Harpadon nehereus*) and ribbon fish (*Trichiurus lepturus*).

For the period of five decades from 1960-2010, the SST plots showed rise in temperature by 0.4°C (average SST 28.38°C) for Andhra Pradesh, 0.9°C (average SST 28.33°C) for Odisha and 1.0°C (average SST 27.97°C) for West Bengal. Average annual chlorophyll-a values were highest for West Bengal with an average value of 4.04 mg/m^3, followed by Odisha (1.27 mg/m^3) and Andhra Pradesh (0.47 mg/m^3). Peak chlorophyll-a values were recorded from July-September for Andhra Pradesh, July-November for Odisha and August-December for West Bengal during 1997-2010. In trawls fish catch rates increased with decreasing SST along the NE coast of India.

Spawning biology of *Nemipterus japonicas:* The average SST during Apr-Sep (2011-2013) at Chennai was 29.9°C and at Mangalore 26.7°C and during Oct-Mar



Damaged fields of grape (a), papaya (b), sugarcane (c) due to hailstorm

27.8°C at Chennai and 27.3°C at Mangalore. Fish prefers lower temperatures for better reproductive output. Along the southeast coast species appeared to mature earlier, has lower life span and a lower fecundity. The proportion of spawners during Apr-Sep was 12.1% at Chennai and 60.1% at Mangalore and during October-March 58% at Chennai and 74.7% at Mangalore. However, the percentage of spawners was higher at Chennai during November, December and January. The L_{m50} was 140-145 mm at Chennai and 165-180 mm at Mangalore. L_{∞} estimates were 295 mm at Chennai and 330 mm at Mangalore. L_{m50}/L_{∞} (%) was 47.5% at Chennai and 50% at Mangalore. Fecundity estimates were 7,440-37,627 at Chennai and 38,500-571,913 at Mangalore.

4. Genetic Resources

Genetic resource of living organisms constitutes the "first resource" of natural resources in this planet. It includes populations, gene pools, races of species, which possess important attributes not found uniformly throughout the species, breeding lines, and research materials such as mutant, genetic or chromosomal stocks. Genetic resource can also be genes themselves, maintained in selected individuals or cloned and maintained in plasmids.

Horsegram diversity in seed colour

Calapo (*Calopogonium mucunoides*) an introduced cover-crop of peninsular region

Germplasm of grain-amaranth

Crops

Germplasm augmentation, conservation and utilization: Twenty-nine explorations were undertaken in eight states and 1,454 accessions including 500 of wild species were collected. Three hundred eighty-three herbarium specimens were added to the National Herbarium of Cultivated Plants. In the National Gene Bank, 7,668 gerrmplasm accessions of orthodox seed species were stored; shoot tips/meristems (48) of different vegetatively propagated species were cryostored, and 11 accessions were added to *in-vitro* storage for long-term storage. From 45 countries, 32,552 accessions were imported including international trial materials (81,969 accessions). Promising introductions included genetic stocks with heat tolerance (EC 836759), resistance to diseases and drought (EC 841516) from the USA and core sets (EC 831784-93) from Mexico of **wheat**; near isogenic lines with leaf rust resistant genes *Lr34*, *Lr46*, *Lr67*, *Lr68* (EC 841152-65) from Mexico of **barley**; tolerance to insect, drought and lodging (EC 852391-435) from the USA, bacterial leaf blight and blast resistance (EC 830646-897) from Indonesia, submergence and drought tolerance (EC 839761-5) from Philippines, high Zn content (EC 837459-585), lodging, shattering and drought tolerance (EC 846750-861) from China of **paddy**; and **tomato** and transgenic stress -tolerant **soybean** (EC 859310-11) from the USA.

Characterization and evaluation of 29,006 accessions, including wheat for terminal heat tolerance and rice for tolerance to submergence and salt, were done. Phytochemical characterization enabled identification of promising genotypes — amaranth IC 082625 with high Fe (14.6 mg/100g); buckwheat IC 026598 with high K (594 mg/100 g); faba-bean EC 243764 and adzuki-bean IC 108854 with high protein(29.3% and 23.8%, respectively) and chenopodium IC 415493 and NC 058233 with high Fe (14.7 mg/100g) and K (7.9 mg/100g), respectively.

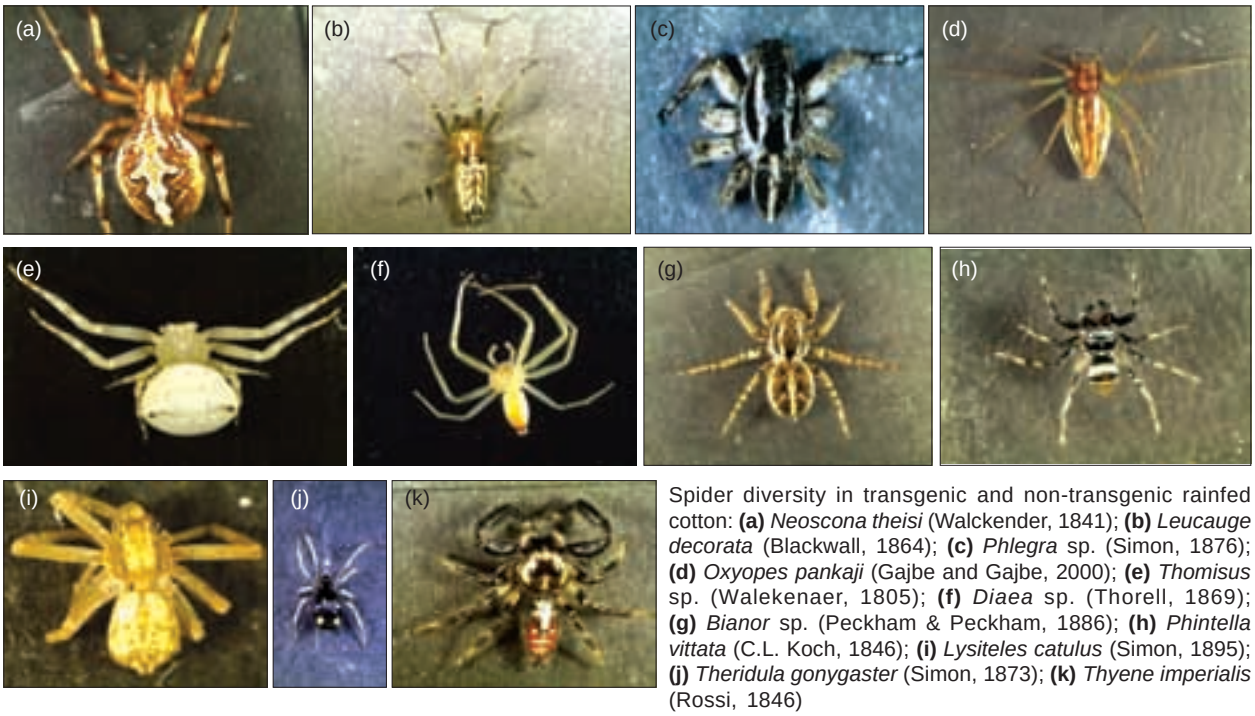
Germplasm registration: Thirty-six novel germplasm lines were registered, including cereals for resistance to leaf and neck blast, high antioxidant activity, immunity to yellow rust, open florets for exceptionally long-time, high gluten index, heat tolerance and rust resistance (9); grain-legumes for tolerance against aluminium toxicity under low *p*H (1); vegetables with triple pods at every node, resistance to downy mildew, powdery mildew and rust (3); fruits with low moisture-stress tolerance, bold -seeded with high 100-seed weight, irregular seed shape, large fruit size, highest number of seeds/fruit and field tolerance to papaya ring spot virus with yellow pulp colour (4); oilseeds with wilt resistance, early and non-spiny, extra early maturity, male line and lipoxygenase - 2 free with early maturity (3); fibres with narrow leaf lobe and brown lint, high ginning out-turn, distinct yellow top leaves and narrow leaf lobe with spotted petals and brown lint (5); forages with shoot-fly resistance, high digestibility with low lignin and brown midrib, black seeded with penta-foliate leaves (3); ornamentals with double- flower shape of medium (>8 cm flower diameter) to standard size (>10 cm flower diameter), white and yellow-orange flower colour, petaloid sterile flowers multiplying through cuttings (3); and sugarcane with regular flowers (5.5% pollen fertility) to be used as female parent in introgression, regular flowers with good seed-setting, high juice quality under waterlogging and high early sugar accumulation (5).

Novel genetic stocks registered

Crop	National identity	INGR No	Novel unique features
Rice	IC 0611701	15001	Resistant to leaf and neck blast
Rice	IC 0611702	15002	Resistant to leaf and neck blast
Barley	EC 0532635	15003	High antioxidant activity
Barley	IC 0612434	15004	Immune to yellow rust (*Puccinia striiformis* f. sp. *hordei*)
Cotton	IC 0613959	15005	Narrow leaf lobed and brown lint
Sorghum	IC 0611700	15006	Shoot-fly resistance
Castor	IC 0611596	15007	Wilt resistance. Early maturity. Male line
Castor	IC 0612166	15008	Non-spiny-extra-early maturity
Garden-pea	IC 0610501	15009	Triple pods at every node
Lentil	IC 0595543	15010	Tolerance against aluminium toxicity under low *p*H
Ber	IC 0598427	15011	Low moisture stress tolerance
Makhana	IC 0610821	15012	Large seeded (Seed diameter: 14mm). Highest 100-seed weight of 141g
Makhana	IC 0610822	15013	For irregular seed shape (mutant). Large fruit size (fruit diameter: 8.1 cm). Highest number of seeds/fruit (139)
Rice	IC 0613963	15014	For open florets. Florets remain sufficiently open for exceptionally long time. The anthers are considerably protruded outside spikelet and stigma is well exposed
Cotton	IC 0611336	15015	High ginning out-turn
Cotton	IC 0613964	15016	Distinct yellow top leaves
Soybean	IC 0612435	15017	Lipoxygenase-2 free with early maturity (85 days)
Gerbera	IC 0613966	15018	Double flower shape. Medium size (~8 cm flower diameter). White flower (RHS 155D)
Gerbera	IC 0613967	15019	Double flower shape. Standard size (>10 cm flower diameter). Yellow-orange flower (RHS 16C)
Wheat	IC 0610417	15020	High gluten index (86%)
Wheat	IC 036761A	15021	Heat tolerant
Wheat	IC 0536140	15022	Rust resistance with 3 minor/APR genes — *Lr34/Sr57/Yr18/Pm38; Lr46/Sr?/Yr29/Pm39* and *Lr67/Sr55/Yr46/Pm46*
Wheat	EC 0573562	15023	Rust resistance with 3 minor/APR genes — *Lr34/Sr57/Yr18/Pm38; Lr46/Sr?/Yr29/Pm39* and *Lr67/Sr55/Yr46/Pm46*
Cotton	IC 0613960	15024	Narrow leaf lobed, spotted petals and brown linted
Cotton	IC 0613961	15025	Narrow leaf lobed, spotless petals and brown linted
Berseem	IC 0613360	15026	Black-seeded with pentafoliate leaves
Sorghum	IC 0612063	15027	High digestibility (IVOMD%), low lignin content; brown midrib (bmr)
Garden-pea	IC 0598281	15028	Resistant to downy mildew and rust
Garden-pea	IC 0598280	15029	Resistant to powdery mildew
Papaya	IC 0611690	15030	Field tolerance to papaya ring spot virus with yellow pulp colour
Sugarcane	IC 0612055	15031	Good seed-setting
Sugarcane	IC 0612056	15032	Regular flower bearer with pollen fertility of 5.5%; to be used as a female parent in introgression
Sugarcane	IC 0612058	15033	Regular flower bearer with good seed-set (128 seedlings)
Sugarcane	IC 0612060	15034	High early sugar accumulation
Sugarcane	IC 0612061	15035	High juice quality under waterlogged condition
Marigold	IC 0613361	15036	Petaloid sterile flowers; multiplies through cuttings

Agriculturally important arthropods

Spider diversity in rainfed cotton: Fifteen species of spiders belong to six families — Araneidae, Oxyopidae, Thomisidae, Salticidae, Tetragnathidae and Theridiidae. Family Araneidae contributed to one-third spider population (34. 6%), followed by Oxyopidae (27%) and Thomisidae (24.5%). Frequent occurrence of *Neoscona theisi*, followed by *Oxyopes pankaji* and *Thomisus*



Spider diversity in transgenic and non-transgenic rainfed cotton: **(a)** *Neoscona theisi* (Walckender, 1841); **(b)** *Leucauge decorata* (Blackwall, 1864); **(c)** *Phlegra* sp. (Simon, 1876); **(d)** *Oxyopes pankaji* (Gajbe and Gajbe, 2000); **(e)** *Thomisus* sp. (Walekenaer, 1805); **(f)** *Diaea* sp. (Thorell, 1869); **(g)** *Bianor* sp. (Peckham & Peckham, 1886); **(h)** *Phintella vittata* (C.L. Koch, 1846); **(i)** *Lysiteles catulus* (Simon, 1895); **(j)** *Theridula gonygaster* (Simon, 1873); **(k)** *Thyene imperialis* (Rossi, 1846)

spectabilis was recorded. Maximum population of spiders was observed during second fortnight of October to first fortnight of November, coinciding with boll-development stage. Positive correlation of spiders with prey density of cotton-sucking pests was observed in the case of whitefly and mirid while it was negatively correlated with aphids, leafhoppers and thrips. No noticeable effect of either genotype-based variation (transgenic or non-transgenic) or limited pesticide intervention was observed on spider population. These observations indicate a potential for their utilization in biological control of whitefly and mirid bugs.

Horticulture

A total of 1,503 indigenous collections comprising fruits, vegetables, tuber crops, plantation crops and nuts, spices, medicinal and aromatic plants, ornamental crops and mushrooms were made from different states.

Fruit crops: Sixteen exotic grape accessions were received from the United States Department of Agriculture, of which six were successfully established in field gene bank. Pomegranate accessions (132) were collected from the Michigan State University, of which 120 regenerated and successfully established in field for further evaluation. Datepalm saplings (41) comprising three different germplasm accessions (M1MI, MHNB and MRKS) were introduced from ICARDA, Amman, Jordan, and established in field gene bank at Bikaner. Exotic cocoa germplasm accessions (22) including white bean types rich in flavour components were introduced through International Cocoa Quarantine Centre, University of Reading, United Kingdom. A total of 13 exotic germplasm of *Phaseolus* spp., comprising *Phaseolus lunatus* (9), *P. coccineus* (2), *P. acutifolius* (1) and *P. vulgaris* (1) were introduced at Varanasi from the Asian Vegetable Research Center, the World Vegetable Centre, Taiwan.

Benaulini, a cocunut land rave of Gra, was identified. It has tender cocunut water traits and copra.

A total of 33 mango varieties from Custodian Farmers were identified from Malihabad and adjoining areas of Lucknow, Uttar Pradesh and multiplied for on-farm and *in-situ* conservation. Of the 152 accessions screened, Lazzat Baksh, Kishen Bhog, Guruvam and Starch showed least susceptibility (< 1/panicle) to hopper, *Idioscopus* spp. The species diversity of mango hoppers across the mango accessions was > 90% of *Idioscopus niveosparsus*, 7% of *Idioscopus nagpuriensis* and rest others.

Of the 50 accessions of jackfruit evaluated for infestation of shoot- and fruit-borer, *Diaphania caesalis*, accessions, G-1, G-2, G-9 and G-65, were free from infestation. A potential chance seedling, CIAH-Ber-S-15, of ber with semi-erect growth, 18% pulp TSS and 0.47% acidity was identified for late maturity (mid to late February). A promising aonla clone, CISH-A-33, was identified most promising for yield (55.45 kg/tree) and neutraceuticals (ascorbic acid, 490 mg/100g fruit; polyphenol, 1.718 TAE g/100 g). Similarly, another accession, CISH-A-35, was found promising for neutraceuticals (gallic acid-7.05 mg/g; caffeic acid-301 mg/g).

Of the 36 bael accessions evaluated, CISH-B-18 was found high-yielding (73.32 kg/tree) with medium-sized fruits (1.88 kg), high TSS (42.4°Brix), high total sugar (22.53%), total carotenoids (3.79mg/100g) and tannins (3.79%). Of the 1,000 pomegranate 'Daru' progenies evaluated, six were found free from bacterial blight, while 14 showed tolerance (≤5% blight) to bacterial blight.

Of the 91 germplasm accessions of walnut evaluated, four accessions with higher nut and kernel weight, viz, CITH W-1 (29.05g and 14.09g), CITH W-6 (24.35g and 13.64g), CITH W-9 (23.77g and 12.02g) and CITH W-8 (23.1g and 11.08g) were observed promising for further evaluation. Of these, CITH W-1 had 53.11% kernel

recovery. Similarly, of the 23 germplasm accessions of almond evaluated, CITH A-8 (50%), CITH A-21 (48.38%) and CITH A-23 (45.85%) were found promising for higher kernel recovery. CITH A-8 being soft-shelled and others semi-hard shelled.

A promising rose apple clone, CHRA-1, with 35.4 g fruit weight, 14.5 kg/plant fruit yield, 13.8% TSS, 84.5% pulp and fruit maturity during March-May was identified for east coast region. A promising star gooseberry clone, CHSG-1, with 3.8 g fruit weight, 900-950 fruits/plant, 3.8 kg/plant fruit yield, 7% TSS, 92% edible portion and 90-100 mg ascorbic acid/100g pulp was identified promising for east coast region. A promising carambola clone, CHCM-4, with 95-100g fruit weight, 170-180 fruits/tree (14-15kg), 11% TSS, 90 - 92% edible portion was identified promising for east coast region.

Vegetable crops: Nine exotic collections of watermelon and four each of ridge gourd and sponge gourd were introduced from the USDA, ARS, Griffin, Georgia, USA at Bikaner. An accession, VRPG-89, of pointed gourd was identified for low seed (4-8 seeds/fruit) content. **C**hilli genotypes, BS-20 and BS-79, were identified for tolerance to leaf curl under field condition. A Dolichos yellow mosaic virus tolerant accession of Indian bean (VRSEM 12) was identified. A unique onion genetic stock (DOGR-1203-DR) with extra early maturity (90 days after planting) and uniform neck fall in *rabi* was registered (IC0598327, INGR14057) with NBPGR, New Delhi.

Spices: A total of 243 accessions of black pepper including 158 cultivars and 85 accessions of related taxa were collected. An accession of *Piper barberi*, considered an endangered species, was located in the evergreen forests of Anakulam forest range of Kerala.

Farmers' participatory germplasm collection of spices: In a farmers' participatory germplasm collection, 31 nutmeg (*Myristica fragrans*) types including farmers' varieties and unique germplasm were collected and conserved. This includes rudimentary sterile seed; bold nut; thick and entire mace; high-yielding monoecious types. Punnathanam Jaythi, a farmers' variety of nutmeg, with very bold nut and thick mace was collected. In addition, three unique high-yielding black pepper, 10 bold and one unique black ginger (*Kaempferia parviflora*) and three unique clove (dwarf clove, king clove and extra bold Madagascar clove) were collected and added to the field gene bank.

An accession of turmeric (Acc. 849) was identified promising for high yield (42.5 tonnes fresh corm/ha). Long pepper (*Piper longum*) germplasm accessions, viz. JPL-12 (7.85%), JPL-6 (7.64%), JPL-17(7.66%), JPL-3 (5.46%) and JPL-19 (5.24%) with higher piperine than Viswam (5.15%) were identified.

Livestock

Registration of new breeds: Seven new breeds of indigenous livestock (two breeds of cattle, one breed each of goat, sheep, pig, camel) and one line of chicken were registered during 2015. Presently, the total number of registered indigenous breeds in the country is 151 (39 cattle; 13 buffalo; 24 goat; 40 sheep; 6 horses and ponies; 9 camel; 3 pig; 1 donkey; and 16 chicken). One chicken line - PD1 (Vanaraja male line) developed by ICAR-DPR, Hyderabad has been registered for the first time in the country.

Newly registered breeds

Breed	Home tract	Accession number/Description	Photograph
Belahi cattle	Haryana and Chandigarh	INDIA_CATTLE_0532_BELAHI _03038 **Belahi** is a dual type cattle reared for milk and draught by Gujjar community in foothills of Haryana. It is reared under low input migratory system. Belahi produces about 3.25 kg milk/day.	
Gangatiri cattle	Uttar Pradesh and Bihar	INDIA_CATTLE_2003_GANGATIRI_03039 **Gangatiri,** a dual purpose cattle breed, is found in Eastern Uttar Pradesh and Western Bihar along the river Ganga. These cattle are well adapted to low to medium input production system and produce about 2.5 to 8.0 kg milk/day.	
Pantja goat	Uttarakhand and Uttar Pradesh	INDIA_GOAT_2420_ PANTJA _06024 **Pantja** goats are reared for meat and milk in Udham Singh and Nainital districts of Uttarakhand and adjacent *Tarai* area of Uttar Pradesh. These goats are well adapted to humid condition of Tarai. Twining is common in Pantja goats.	

Breed	Home tract	Accession number/Description	Photograph
Kachaikatty Black sheep	Tamil Nadu	INDIA_SHEEP_1800_KACHAIKATTY BLACK_ 14040 **Kachaikatty Black** sheep are maintained as small flocks in Vedipattitaluka of Madurai, Tamil Nadu. Animals are of medium size, compact body and black with hairy coat. The breed is reared for meat and manure. Rams are well known for fighting.	
Kharai camel	Gujarat	INDIA_CAMEL__0400_CAMEL_02009 **Kharai** camel is found in coastal part of Kachchh, Gujarat. These camels are well adapted to both dry-land as well as costal ecosystems. These have excellent swimming capacity in sea water and graze mainly on mangrove and other saline species. Kharai camels can thrive on high saline water and tolerate high total dissolved solids.	
Agonda Goan pig	Goa	INDIA_PIG_3500_AGONDA GOAN_09003 **Agonda Goan** are small size local pigs of Goa. These pigs are mostly black with short snout. Bristles are rough. People prefer these animals for sausage making. It is well adapted to local coastal environment.	
Mewari chicken	Rajasthan	INDIA_CHICKEN_1700_MEWARI_12016 **Mewari** chicken is found in Central and Southern parts of Rajasthan; reared for egg and meat under free range or scavenging system. Adult cocks weigh about 1.9 kg and hens 1.2 kg. Annual egg production ranges from 37 to 52. Egg weight is about 53g.	
PD1 (Vanraja male line)	Andhra Pradesh	INDIA_CHICKEN_001_PD1_13001 PD1, the first registered line of chicken in India, was developed by ICAR-Directorate of Poultry Research, Hyderabad for higher shank length and is used as male parent for Vanraja commercial, a dual purpose backyard poultry. Average adult body weights of males and females ranges from 3.5 – 4.0 kg and 2.5 – 3.0 kg. Egg production is about 85 up to 52 weeks of age.	

Phenotypic characterization

Siri cattle of Sikkim: The Siri cattle is brown, black with white spots and admixtures. Skin is grey, muzzle and eyelids are black and forehead is convex, wedge shaped with white patches. Ears are small and horizontally oriented, horns are small and curved outward, forward and upward. Udder is small with funnel/ cylindrical shaped teats. Naval flap is absent. Tail is with black, brown and grey switch reaching up to the hock. The average body length, height at withers, heart girth, paunch girth, horn length, ear length, face length, face width, tail length without switch and with switch in cows are 106.32±1.40 cm, 114.20±1.55 cm, 157.80±2.52 cm, 162.16±2.61 cm, 16.48±0.79 cm, 18.24±0.26 cm, 40.88±0.75 cm, 20.84±0.37 cm, 75.56±2.29 cm and 95.56±6.59 cm, respectively. The age at first calving, lactation length and calving interval ranges from 40-60 months, 200-240 days, 450 to 600 days, respectively. The daily milk yield ranges from 2.0 to 6.50 kg.

Kajali sheep of Punjab: Kajali, a mutton type sheep, is distributed in Sangrur, Barnala, Ludhiana, Moga and adjoining districts of Punjab. The average body weights of adult males and females are 56.98 ± 1.02 and 43.23 ± 0.36 kg, respectively. The overall means for body length, height, chest girth, ear length and tail length are 73.97± 0 .28, 73.36 ± 0.20, 84.23 ± 0.27, 21.33 ± 0.08 and 55.83± 0.37 cm, respectively. Kajali sheep has colour variants: Black (Kali) and White (Chitti). The animals are large with well-built body, having roman nose, long and pendulous ears and long tail touching ground. Both sexes are generally polled. Average greasy wool production is 800 to 1,000 g.

Singharey goat of Sikkim: Singharey goats constitute the major part of the goat population of Sikkim. They can be distinguished from other populations by the facial stripes. The ears are short to medium semi pendulous with round tip. The ears have black or white margin on the apical half. The horns are strong, flat, thicker at the base but pointed at the tip, orienting upward and backward. Legs are short, stout, medially black or white. Black top line was seen in many of these goats. Height at withers, body length, chest girth, paunch girth, face length, horn length, ear length and tail length (cm) of adult females are 52.52±0.71, 60.29±0.66, 67.98±0.59, 74.52±1.25, 16.16±0.19, 8.84±0.33, 13.48±0.18 and 10.88±0.24, respectively, and of males 55.67±0.93, 61.48±0.86, 71.66±0.85, 76.47±1.16, 17.20±0.22, 14.58±0.57, 12.92±0.24 and 11.89±0.25, respectively. The average body weight in females is 27.33±0.65 kg and in males 31.03±0.92 kg.

Molecular characterization

Laddakhi cattle: Microsatellite based genotypic data were generated using 20 markers. A total of 200 alleles were detected with mean number of 9.95 alleles/locus. The within breed diversity measures in terms of observed number of alleles (9.95), effective number of alleles (4.84), observed heterozygosity (0.75) and expected heterozygosity (0.79) for Ladakhi cattle revealed sufficient genetic variability. The values were significantly different from zero. The average inbreeding coefficient (F_{IS}) in Ladakhi cattle was 0.037. The interbreed differentiation between Ladakhi and other cattle populations depicted by F_{ST} reflected high genetic divergence between different cattle breeds.

Breed signature for cattle: The data on 541 farm individuals from 3 breeds (Gir, Sahiwal and Tharparkar) using 4 STR loci were generated and analysed to develop breed signature. F_{ST} values were 0.173, 0.281 and 0.235 between Gir and Sahiwal, Gir and Tharparkar and Sahiwal and Tharparkar, respectively. Selection of loci was attempted and finally eight loci were able to assign 100% individuals belonging to the farms of these three breeds and 93% when added the field samples. All the individuals from organized farms were found to be correctly assigned and 3 breeds formed different clusters. These loci were used to develop a multiplex PCR kit. The kit was tested and validated to be used for Sahiwal, Gir and Tharparkar cattle breed assignment.

Ex-situ conservation

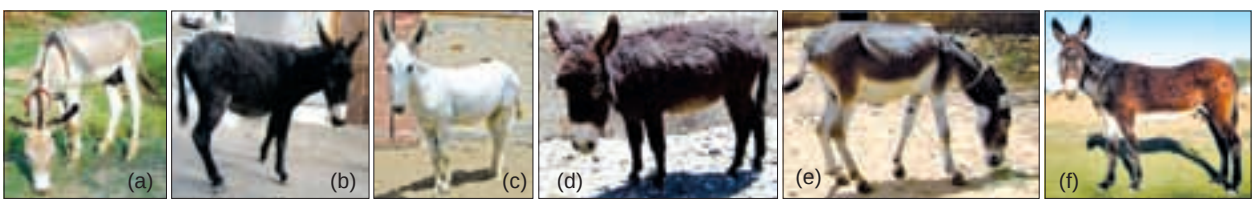
Total 7,600 frozen semen doses of cattle (Gaolao and Tharparkar) and buffalo (Toda) were added to repository in Gene Bank during the year. Jaffarabadi buffalo semen stored in Gene Bank was also utilized in its breeding tract for supporting conservation and improvement. The National Gene Bank at NBAGR now stores 129,174 frozen semen doses belonging to 44 breeds of cattle, buffalo, goat, sheep, camel, equine and yak.

To utilize caprine cauda epididymal spermatozoa for cryopreservation, an extender was standardized for freezing epididymal semen. The storage of testes at low temperature indicated suitability of utilizing them for extraction of epididymal sperms for their conservation, even after extended hours post slaughtering of bucks. *In vitro* fertilization revealed that frozen epididymal spermatozoa retained the fertilizability.

Cattle

Screening of Frieswal bulls and bull calves for genetic diseases: Frieswal bull calves (151) were screened against bovine leukocyte adhesion deficiency (BLAD), deficiency of uridine monophosphate synthase (DUMPS), and bovine citrullinaemia. A carrier prevalence percentage of 4.6 was noticed for BLAD in Frieswal bull calves, while no carriers were noticed for other genetic disorders studied.

Genetic studies in donkey population: Donkey germplasm of six donkey populations belonging to Spiti (Himachal Pradesh), Leh (Jammu and Kashmir), Baramati (Maharashtra), Bihar, Gujarat and Rajasthan areas along with exotic Poitu breed (an outgroup) were



Donkeys from—(a) Bihar, (b) Jammu & Kashmir, (c) Gujarat, (d) Himachal Pradesh, (e) Rajasthan and (f) Exotic (Poitu)

evaluated for assessing genetic diversity within and between them using 24 polymorphic microsatellite markers with 299 donkey DNA samples. The estimates of F_{ST} between each pair of breeds revealed that genetic differentiation between donkey population from Gujarat and Leh were the maximum followed by Rajasthan and Leh donkey populations while donkey populations from Rajasthan and Spiti (Himachal Pradesh) areas were the least differentiated. On comparing all the donkey populations, donkeys from Spiti and Rajasthan were very close to each other, whereas donkeys from Leh (Jammu and Kashmir) and Gujarat areas were far apart.

Camel: Partial amplification of TLR5 gene (1136 kb) and TLR1 gene (930 bp) of *Camelus dromedarius* was achieved and cloned. Eight 5' flanking regions/exons/mRNA of milk protein genes were successfully amplified in dromedary and amplified fragments were characterized by RFLP using suitable restriction enzymes. Uniqueness of the five sequences was established.

Identification of male specific genes of yak: The male subfertility in yak population is a major issue, which causes huge economic losses to yak farmers. Mammalian Y chromosomes tend to acquire sequences which are necessary for spermatogenesis and male reproduction. The critical Y-linked fertility genes are present in multiple copies with testis-limited expression. To understand this novel complexity, 12 MSY genes i.e. *SRY*, *TSPY*, *TSPY4*, *TSPY6P*, *FAM197Y1*, *USP9Y*, *UTY*, *DDX3Y*, *AMELY*, *TXLNG2P*, *HSFY1* and *HSF2Y* were identified and their expression pattern was established in yak genome.

Standardization of chicken sperm transfection

Transfected sperm are the pre-requisite for sperm mediated gene transfer. The procedure for transfecting the chicken (broiler breeder) sperm using lentivector with GFP gene was standardized. The sperm up to two washes were adjudged to be suitable for fertilization of eggs and were subjected to incubation with GFP lentivector while a negative control was also kept. After incubation, exogenous vector which was not internalized was removed. Thereafter, RNA was collected from sperm cells. The cDNA was prepared and used as template in PCR reaction with eGFP genes specific primers. The amplified PCR product for eGFP was detected in 1.5% agrose gel. A band of 137 bp in sperm samples confirmed transfection.

Mitochondrial genotyping of mithun: Phylogenetic analysis of mitochondrial genotyping of mithun, on the basis of Cytochrome B gene, revealed the placement of mithun in the same clade with gaur. The mithuns from different geographical locations (Nagaland, Arunachal Pradesh, Manipur, and Mizoram) showed a close relationship (0.929) among themselves, but were found distantly related to cattle (0.879) and yak (0.879).

In first ever study of flurorescent *in-situ* hybridization (FISH) of mithun chromosomes, highly repetitive regions of centromere and telomere were amplified using bovine primers. The centromeric signals were observed in all the acrocentric autosomes of all the species. However, in contrast to Tho-Tho cattle, FISH signals could not be detected in the sub-metacentric chromosomes of mithun, mithun – cattle crossbreds and gaurs.

The results of mitochondrial genotyping and FISH confirmed a more ancestral closeness of mithun with gaur than that with cattle.

Genomic profiles of chicken lines: The whole mitochondrial genome sequence of seven Indian native chickens, namely Aseel, Ghagus, Nicobari (Black and Brown), Tellicherry, Kadaknath, Haringhata Black and Red Jungle fowl was explored. All indigenous breeds, except Tellichery were very close together and close to the lineage of Red Jungle fowl. Polymorphism in BMP3 and BMP4 genes in chicken was explored. This gene was also polymorphic in control layer (CL) line having 4 haplotypes. The BMP4 gene was polymorphic with presence of 4 haplotypes. The haplogroups of both genes had significant association with juvenile body wt. Protocol for gene silencing using shRNA molecules for myostatin gene in chicken was perfected.

Native chicken populations: Four native chicken populations, PD-4 (Improved Aseel), Aseel, Ghagus and Nicobari fowl were conserved at the ICAR-DPR, Hyderabad. The survivors' egg production up to 72 weeks of age was 156.5±2.79 eggs in PD-4 birds in S-4 generation. Body weight at 8 and 16 weeks of age was improved by 33 and 126 g, respectively. The egg production up to 64 weeks of age in native Aseel chickens, brought from home tract in Andhra Pradesh was 43.76 eggs during the first generation. The age at sexual maturity (ASM) was 215 d. In G-2 generation of Ghagus, ASM, egg production up to 40 weeks and egg weight at 40 weeks of age were 169.5±0.74d, 32.9±1.24 eggs and 46.7±0.48 g, respectively. In Nicobari fowl, egg production up to 40 weeks of age was 62.4±1.67 and egg weight and shank length at 40 weeks of age were 43.8±0.43 g and 80.0±0.65 mm, respectively.

Ghagus cock

An adult pair of PD-4

Meat species identification: A proteomic based approach using OFFGEL fractionation and tandem mass spectrometry (LC-MS/MS) was developed, which can efficiently detect 1.0% contaminating buffalo meat mixed with sheep meat in both raw and cooked samples. The polymerase chain reaction-restricted fragment length polymorphism (PCR-RFLP) based molecular technique was efficient in detecting 0.5% of beef mixed with buffalo meat.

Fish

Fish biodiversity in rivers: Exploratory surveys were carried out in the Western Ghats, the North Eastern Region and central India.

Freshwater fish species (67) including four exotic species were recorded in Sharavathi river basin. Specimen of lesser known catfish *Batasio sharavatiensis*, miniature gobiid *Redigobius bikolanus* and *Schismatogobius deraniyagalai*, and minnows *Laubuka laubuka* are the new records from this river basin. Finfish (39) and crustaceans (6) species were recorded from Valapattanam river basin. *Mesonoemachilus guentheri*, *Pethia pookodensis* and *Pseudogobiopsis oligactis* are the new records from this river system. Chaliyar and Chandragiri river basins yielded 25 and 35 finfish species, respectively, while Chandragiri river basin also yielded six crustacean species.

Batasio sharavetiensis

Redigobius bikolanus

Schismatogobius deraniyagala

In upper Mahanadi river basin 23 sites and its six tributaries and sub-tributaries namely, Sheonath, Mand, Hasdeo, Maniyari, Arpa and Lilagar were explored and 82 fish species were recorded. Along the 650 km stretch of river Mahanadi from Seorinarayan to Bahakuda Ghat, 144 fish species were recorded indicating dominance of Cyprinids.

In Torsha and Gandak rivers of the Ganga-Brahmaputra basin, surveys conducted in 100 km stretch of Torsa river from Madarihaat, Maltiguri (Cooch Behar, West Bengal) and Balarampur, recorded 16 small indigenous fish species. *Aspidoparia morar*, *Barilius* sp., *Puntius* sp., *Cirrhinus reba* and *Salmophasia* sp. were dominant. *Tor putitora* and *Cyprinion semiplotum*, the endangered species in IUCN list, were also recorded from the river stretch.

In Gandak river along Hajipur, Muzaffarpur and Bettiah stretches, *Aspidoparia morar* (63%), *Ailia coila* (3%), *Mystus vittatus* (6%), *Puntius conchonius* (6%), *Gagata cenia* (6%), *Botia lohachata* (4%), *Securicula gora* (2%), *Crossocheilus latius latius* (8%) and *Sicamugil cascasia* (2%) were recorded. Among them *Ailia coila, Nangra nangra, Puntius conchonius, Sicamugil cascasia* and *Botia lohachata, Eutropiichthys vacha, Ompok pabda* are in the list of vulnerable and endangered category, respectively.

Mitogenome of fishes: Complete mitochondrial genome of brown trout (*Salmo trutta fario*) was sequenced. A phylogenetic analysis among 42 complete mitogenomes of family Salmonidae and one sequence of *Danio rerio* depicted the position of species among genus *Salmo*.

The complete mitochondrial genome of endangered deccan mahseer, *Tor khudree* is 16,573 bp in size, and consists of 13 protein coding genes, 22 tRNAs, 2 rRNA genes and one control region. The overall base composition is - A: 31.9%, G: 15.6%, C: 27.68%, T: 24.76%; A + T content 56.6%; and G + C content 43.32%.

Complete nucleotide sequence of mitochondrial genome of Indian oil sardine, *Sardinella longiceps* is a 16613 bp circle, containing 37 mitochondrial structural genes (two ribosomal RNA, 22 transfer RNA, and 13 protein-coding genes).

Genetic characterization of Spanish mackerel: The population genetic structure of the commercially important fish, narrow barred Spanish mackerel, *Scomberomorus commerson* along Indian coast

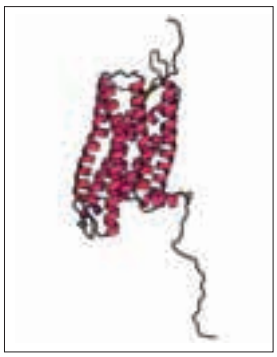
Scomberomorus commerson

(Mangalore, Cochin and Veraval in the west coast; Chennai and Vishakhapatnam in the east coast), was analysed. Pair wise co-efficient of genetic differentiation (F_{ST}) values did not exhibit any significant difference between the populations of *S. commerson* indicating that the species can be considered as a unit stock for fishery management in Indian waters.

Stock characterization in Indian shad: Distribution of Indian shad (*Tenualosa ilisha*) in freshwater habitat extends through the rivers Hooghly, Brahmaputra, Ganga, Godavari, Mahanadi, Narmada and Tapti while in marine habitats it is found in Arabian Sea and Bay of Bengal.

Mitochondrial cytochrome b F_{ST} value of 0.58807 indicated significant genetic divergence between east and west coast samples and phylogeny into two distinct clades with a common origin. Freshwater samples from Ganga, Brahmaputra and Padma showed population sub-structuring, however, discriminate analysis on the basis of morpho-metric traits indicated existence of a single stock. Marine samples from Digha (West Bengal) and Kirtinia (Odisha) were genetically distinct from that of Barrackpore area and Godhakali (Hooghly river) but not from Brahmaputra and Ganga.

Kisspeptin-1 (*kiss1*) gene and its receptor: Kisspeptin-1 (*kiss1*) and kisspeptin-1receptor (*kiss1r*), important regulators of reproduction, were isolated, cloned and characterized from brain tissue of Himalayan golden mahseer, *Tor putitora*. The structure modelling of *Kiss1r* showed strong conservation of tertiary structure with other vertebrates. Structural analysis of *kiss1r* pre-protein was carried out to evaluate the degree of conservation in tertiary structure during the course of evolution.



Tertiary structure of golden mahseer *Kisslr*

Whole genome analysis of *Halomonas salina* CIFRI1: An extreme salt stress tolerant bacterium *Halomonas salina* Strain CIFRI1 was isolated from salt crystals in salt pans of Digha, West Bengal. The draft genome of *Halomonas salina* had 3,450,272 bases with 3,139 protein-coding loci including 62 RNA genes.

Discovery of new fish species *Clarias serratobrachium* sp. nov: A new fish species *Clarias serratobrachium* sp. nov. was discovered from the wetlands near Moreh, Manipur in the Chindwin basin, along Indo-Burma border. The diagnostic characters include separation of median fin from caudal fin; anal-fin with 66–68 rays; anterior fontanel short and squat, anterior tip reaching to line through two-thirds of orbits;

Clarias serratobrachium, a new species of south East Asian walking cat fish

pectoral spine serrated anteriorly as well as posteriorly. DNA barcoding of the individuals further supported the morphological and osteological features of *C. serratobrachium* sp. nov. The phylogentic analysis (maximum likelihood) of nine species of genus *Clarias* clearly differentiates the new species.

5. Crop Improvement

Global demand of crops for food, feed and fodder is increasing rapidly to meet requirement of ever-increasing population of human and also of livestock. Researches on genetic improvement of crops strive at improving productivity of crops in view of the shrinking arable land. Crop genetic improvement also aims at realizing nutritional security besides development of climate-resilient crops (biotic and abiotic stresses) and also crops suitable for diverse cropping systems.

Crop improvement programmes have been reoriented with a greater emphasis on the development of genomic resources for targeted traits and crops. Pre-breeding for accessing desirable genes from the related and the wild species has also been employed to broaden narrow genetic base and introgress desirable alleles. Characterization of economically important genes/alleles, their functional validation, marker-assisted selection of phenotypes encoded by such genes/functional alleles and ultimately cloning of genes for transgenic/cisgenic deployment holds a great promise for genetically improving crops.

Cereals

Twenty-one high-yielding varieties of rice, eleven of wheat, six hybrids of maize, three of pearl millet and four of sorghum were released for cultivation in different production ecologies of the country.

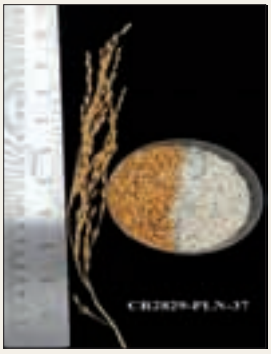
Commercialization of wheat variety 'HD 3086'

With a mission of "Translating Research into Prosperity", ZTM & BPD Unit at the IARI launched a marketing campaign of the variety, and commercialized it successfully in the Indo-Gangetic Plains (Punjab, Haryana, western Uttar Pradesh and Rajasthan).

Swarna Shreya rice for drought-prone areas: A medium duration (120-125 days) aerobic rice variety, Swarna Shreya (IET 24003), has been developed by the ICAR Research Complex for Eastern Region, Patna, Bihar, and released by the Bihar State Seed Sub-Committee on 14 May 2015. It has capacity to withstand drought and is also tolerant to major diseases and insects. Average

Swarna Shreya–A new rice variety for drought-prone areas

Biofortified CR Dhan 310 for high protein



Panicle, grains and kernel of CR Dhan 310 (IET 24780)

This protein-rich rice variety evolved from a cross between ARC10075 and Naveen is suitable for cultivation in medium-rainfed lands during *kharif* and irrigated areas during *boro/rabi* season. It has semi-dwarf plant type (100-110 cm), maturing in 120 days in *kharif* under transplanted conditions. In *rabi*, it matures in 125 days under trans-plantation. The variety has medium slender grains with 69.7% head rice recovery. It yields 4.5-5.0 tonnes grains/ha during *kharif* and 5–6 tonnes/ha in *rabi*.

Released varieties/hybrids of cereals

Variety	Area of adoption	Salient features
Rice		
Arize 6444 Gold	Andhra Pradesh, Maharashtra, Uttarakhand, Uttar Pradesh, Tripura Odisha, Karnataka	IRM; R-BLB, GM
INH 97288	Punjab, Chhattisgarh, Uttar Pradesh	IRM, high-yielding with long bold seed
RC Maniphaou 12	Manipur	IRE; MR- SB
Indira Aerobic 1	Gujarat, Chhattisgarh, Tamil Nadu	Aerob; R-NBl, ShR, MR-LBl, ShBl, BS, RTD

Variety	Area of adoption	Salient features
Basmati 564	Jammu and Kashmir	SCR; MR-Bl, R-NBl, BPH
6129	Punjab, Tamil Nadu	IRE; MR- LBl, ShBl, BS
BNKR1	West Bengal	Late (RSL); MR- NBl, ShR
Pushpa	Karnataka	IRE; R-BPH
Vallabh Basmati 24	Uttar Pradesh, Haryana, Jharkhand	SCR; MR-BS, ShR
IR 64 Drt 1	Andhra Pradesh, Madhya Pradesh, Telangana, Tamil Nadu, Jharkhand, Chhattisgarh	IRME; MR-LBl
DRR Dhan 41	Bihar, Karnataka	Aerob; T-Nematode, GLH,LF
CO 51	Tamil Nadu	IRME; MR-LBl, BPH
Birsa Vikas Dhan 111	Jharkhand	RUP; MR-LBl, BS, SB
Sambha Sub 1	Uttar Pradesh	NIL-Sub; MR-RTV
Birsa Vikas Dhan 203	Jharkhand	RUP; MR-LBl, BLB, BS, SB
Vallabh Basmati 23	Uttar Pradesh	SCR; R-RTV, GM
Sabour Shree	Bihar	IRM, Medium slender grain type with 108 days to 50% flowering
PR 124	Haryana, Punjab	IRE; MR-BS, LBl, ShR, GMB1
Shalimar Rice 2	Jammu and Kashmir	HRIR; MR-LBl
Shalimar Rice 3	Jammu and Kashmir	HRIR; MR- ShBl, LBl
SAVA 127	Uttar Pradesh	IRE, short statured; and moderately tolerant to lodging
Wheat		
Pusa Kiran	Hills of Jammu and Kashmir, Himachal Pradesh, Uttarakhand	Rainfed, early sown; R- yellow rust and good for *chapati* quality
RSP 561	Plain and mid- hills of Jammu Division of Jammu and Kashmir	Irrigated, timely sown; MR- to yellow/ stripe, leaf and stem rust
Shalimar Wheat 2	Kashmir Division of Jammu and Kashmir	Early maturing
WH 1142	Punjab, Haryana, northern Rajasthan, western Uttar Pradesh, foot hills and plains of Jammu and Kashmir, Himachal Pradesh and Uttarakhand	Restricted irrigation, timely sown; is lodging resistant
Pusa Vatsala	Uttar Pradesh, Bihar, Jharkhand, West Bengal	Irrigated, late sown, good for bread industry
DBW 107	Uttar Pradesh, Bihar, Jharkhand, West Bengal	Irrigated, late sown; R- leaf blight and MR - leaf rust
DBW 110	Uttar Pradesh, Maharashtra, Gujarat, Madhya Pradesh, Chhattisgarh	Restricted irrigation, timely sown, higher yield gains at one and two irrigations
DBW 93	Maharashtra, Karnataka	Restricted irrigation, timely sown;R- stem and leaf rusts; high protein content, high test weight, high flour recovery
Pusa Anmol (Durum)	Uttar Pradesh, Maharashtra, Gujarat, Madhya Pradesh, Chhattisgarh	Irrigated, timely sown;R- stem and leaf rusts; suitable for pasta preparation
UAS 446 (Durum)	Maharashtra, Karnataka	Rainfed, timely sown; lustrous grains with high protein content and yellow pigment
Nilgiri Khapli (Dicoccum)	Tamil Nadu, Karnataka	Irrigated, timely sown; high degree of seedling resistance to most stem, leaf and yellow rust pathotypes

Variety	Area of adoption	Salient features
Barley		
DWRB 101	Punjab, Haryana, northern Rajasthan, western Uttar Pradesh, foot- hills and plains of Jammu and Kashmir, Himachal Pradesh and Uttarakhand	Two-row malt barley, good grain quality; timely sown conditions; resistant to stripe and leaf rusts
BH 959	Uttar Pradesh Maharashtra, Gujarat, Madhya Pradesh, Chhattisgarh	Six-row feed barley; tolerant to yellow and brown rust
Maize hybrids		
CoH (M) 10	Andhra Pradesh, Tamil Nadu, Karnataka, Maharashtra, Rajasthan, Gujarat, Madhya Pradesh and Chhattisgarh	*Kharif* season: medium maturity, orange-yellow, semi-dent; R- MLB, RDM ,MR- C. rust and TLB
HM13	Jammu and Kashmir, Himachal Pradesh and Uttarakhand	*Kharif* season, early maturity, yellow with cap, flint ;R- MLB, TLB, BLSB, C.rust and PFSR
PMH 6	Bihar, West Bengal, Jharkhand, Odisha and Uttar Pradesh	*Kharif* season, medium maturity, yellow, flint
NMH 713	Uttar Pradesh, Bihar, Jharkhand, Odisha, Andhra Pradesh, Karnataka, Tamil Nadu and Maharashtra	*Rabi* season, late maturity, yellow, dent
NMH 731	Gujarat, Rajasthan Chhattisgarh, Madhya Pradesh,Andhra Pradesh, Karnataka, Tamil Nadu , Maharashtra	*Kharif* season, late maturity, orange-yellow, semi-dent
NMH 1242	Andhra Pradesh, Tamil Nadu, Maharashtra, Karnataka, Punjab, Haryana, Delhi, Uttar Pradesh, Rajasthan, Gujarat, Chhattisgarh, Madhya Pradesh	*Kharif* season, medium maturity, yellow, dent; MT- MLB
Pearl millet		
NBH 5767	Maharashtra, Karnataka, Andhra Pradesh, Tamil Nadu	Medium maturing, purple anther colour, medium plant height, compact lanceolate ear-heads, deep grey-coloured grains
NBH 5061	Maharashtra, Karnataka, Andhra Pradesh, Tamil Nadu	Late maturing, purple anther colour, medium plant height, compact lanceolate ear- heads, grey-coloured grains
Dhanshakti	Rajasthan, Haryana, Madhya Pradesh, Gujarat, Uttar Pradesh, Punjab, Maharashtra, Karnataka, Andhra Pradesh, Tamil Nadu	Early-maturing variety with high iron (76-91 ppm) and zinc (39-48 ppm); bold, globular, shining slate- grey- coloured seeds, cylindrical -lanceolate ear-head; R- downy mildew
Sorghum		
SPH 1635	Maharashtra	*Kharif* hybrid, dual- purpose, mid- late group maturity; grain yield: 4.5 tonnes/ha ,dry fodder yield: 13 tonnes/ha; T- major insects and pests
Phule Suchitra	Maharashtra	*Rabi* variety, medium maturity, tall (235 cm) white midrib, compact cylindrical panicle, medium bold pearly -white seeds; T- shoot-fly, stem-borer and drought
CSH 33	Rajasthan, north Gujarat, south Andhra Pradesh,Tamil Nadu	*Kharif* hybrid, medium tall, early maturity; long bold panicles and bold grains,grain yield: 4.4 tonnes/ha, dry fodder yield: 11.8 tonnes/ha.; T- grain-mould and shoot-fly
CSV 32F	Maharashtra, Karnataka, Tamil Nadu	Forage sorghum variety, well- exerted panicle with clustering of grain in panicle branches, green fodder yield:46.2 tonnes/ha, dry fodder yield: 17.8 tonnes/ha; R- anthracnose, sooty stripe and grain-mould.

BL : Blast; **BLB:** Bacterial Leaf Blight; **RTV:** Rice Tungro Virus; **ShBl :** Sheath Blight; **BS :** Brown Spot; **GLH :** Green Leaf Hopper; **SB :** Stem Borer; **BPH:** Brown Plant Hopper; MLB: Maydis Leaf Blight, TLB: Turcicum Leaf Blight, BLSB: banded Leaf and Sheath Blight; C. rust: Common rust, PFSR: Post Flowering Stalk Rot; **WBPH :** White Backed Plant Hopper; **GM :**Gall Midge; **LF:** Leaf Folder; **T:** Tolerant; **R:** Resistant**; MR:** Moderately Resistant

Improved rice variety DRR Dhan 41 (IET 22779)


BC_3 F_1 rice-plants in glasshouse

productivity of this variety is 4.5 to 5.0 tonnes/ha. Under severe drought, it can produce 2.0 to 2.5 tonnes/ha. Under dry direct-seeded aerobic condition, it saves up to 40% water as compared to transplanted rice. It produces long bold grains, and quality-wise, it possesses 77.0% hulling, 69.7% milling, 60.2% head rice recovery (HRR) with desirable intermediate alkali spreading value (ASV=4.0) and amylase content (22.26%).

Marker-assisted breeding of abiotic stress tolerant rice: This project was aimed to transfer major quantitative trait loci (QTL) for salinity tolerance into locally adapted, high-yielding varieties of rice through marker-assisted backcross breeding. Genotype FL 478 was used as donor parent, whereas Sarjoo 52, PR 114 and Pusa 44 were used as recipient parents to transfer salinity tolerance genes. After crossing recipient parents with donor parent, F_1 seeds were obtained for Sarjoo 52 × FL 478, PR 114 × FL 478 and Pusa 44 × FL 478. Ten to fifteen per cent of F_1 seeds were obtained from each cross. A total of 250, 100 and 150 F_1 seeds were obtained from Pusa 44 × FL 478, PR 114 × FL 478 and Sarjoo 52 × FL 48, respectively. The available F_1 seeds were divided into two sets for advancing generation to BC_1F_1. In the first set, the experiment was conducted in glasshouse, and for second set, a field experiment was conducted to produce BC_1F_1 population. F_1s were used as male parent and recipient parent of the last year was used as female parent in cross.

True BC_1F_1 plants were selected using *Saltol* markers, through foreground and recombinant marker selection, for their further use in crossing programme. RM 3412 was used as marker for foreground selection. For recombinant selection, RM 493, RM 10748 and RM 10893 were used as markers. The selected true BC_1F_1 plants were backcrossed with their respective parents (Pusa 44, PR 114 and Sarjoo 52), and BC_2F_1 seeds were harvested. The seeds of parents and BC_2F_1 were sown on floating grids under hydroponics in Yoshida culture solution. After thirty days, seedlings were transplanted in field for further maintenance. True BC_2F_1 plants were selected using *Saltol* markers RM 3412 (foreground selection) and RM 493 and G11A (recombinant selection) for their further use in crossing programme to produce BC_3F_1 population. The selected true BC_2F_1 plants were backcrossed with their respective parents (Pusa 44, PR 114 and Sarjoo 52) and BC_3F_1 seeds were harvested.

Oilseeds

Sixteen high-yielding varieties of oilseeds were released for different agro-ecologies.

High oleic safflower genotypes: Nine hundred and twenty-seven F_5 progenies possessing >70% oleic acid oil content ranging from 19.0 to 40.1% were developed. The best check, A-1, recorded 27% oil content and 12% oleic acid.

Released varieties/hybrids of oilseeds

Variety/hybrid	Recommended state/region	Salient features
Rapeseed-mustard		
Gujarat Dantiwada Mustard 4	Gujarat	Irrigated conditions; recorded 11.1 -24.7% higher yield over checks; tolerant to powdery mildew and aphids
Albeli1	Eastern Rajasthan, Madhya Pradesh, Uttar Pradesh, Uttarakhand	Irrigated conditions; average seed yield 1,973 kg/ha; tolerant to A*lternaria* blight, white rust and powdery mildew
RSPN 25	Jammu	Irrigated conditions, 145-155 days to maturity; average seed yield 1,500-1,800 kg/ha; 36-39% oil content
GSC 7	Punjab, Himachal Pradesh, Jammu	Timely- sown, irrigated conditions, 139-232 days to maturity low erucic and low glucosinolate content; average seed yield 1,793-2,190 kg/ha, 38.6-42.0% oil content

Phule Agrani (KDS 344) variety of soybean; Raj Mungfali 2 of groundnut; NARI 57 of safflower and Tiara of linseed (fibre flax type) (*from left to right*)

Variety/hybrid	Recommended state/region	Salient features
Soybean		
NRC 86	Maharashtra, Madhya Pradesh, Chhattisgarh, Rajasthan	95-97 days to maturity; average yield 2,128 kg/ha, 19.8% oil content, 40.60% protein content; highly resistant to charcoal-rot, moderately to highly resistant for girdle beetle and moderately resistant to bacterial pustule, pod-blight, collar-rot and stem-fly
KDS 344 (Phule Agrani)	Karnataka, Andhra Pradesh, Telangana	94 days to maturity; average yield 2,555 kg/ha, 16.8% oil content, 34.6% protein content; tolerant to rust, moderately resistant to stem-fly, pod-borer and leaf- roller
Pusa 12	Punjab, Haryana, Himachal Pradesh	124-131 days to maturity; average yield 2,286 kg/ha, 19.6% oil content, 37.8% protein content; resistant to yellow mosaic virus, *Rhizoctonia* aerial blight and bacterial pustules
DSB 21	Karnataka, Andhra Pradesh, Telangana	90-95 days to maturity; average yield 2,500-3,000 kg/ha, 18.2% oil content; 38.2% protein content; resistant to rust
Groundnut		
Gujarat Junagadh Groundnut 18	Odisha, West Bengal, Jharkhand, Manipur	*Kharif* season, maturity 120 days; 1,557 kg pod/ha and 1,215 kg kernel / ha, oil content 48%
Raj Mungfali 2 (RG578)	Odisha, West Bengal, Jharkhand, Manipur	*Kharif* season; semi-spreading (Virginia bunch type); 1,480 kg pod/ha and 1,071 kg kernel / ha, large seeds (53 g / 100 kernels); tolerant to thrips
Phule Bharati	Northern Maharashtra, Madhya Pradesh	*Rabi*-summer, erect type (Spanish bunch); yield: 2,110 kg pod and 1,461 kg kernel per ha, oil content 50%, high proportion of sound mature kernels (92%); tolerant to *Spodoptera litura*
Safflower		
NARI 57	Maharashtra, Madhya Pradesh, Karnataka, Uttar Pradesh, Rajasthan, West Bengal Jharkhand, Punjab	151 days to maturity;yield 1,500 kg/ha, 29% oil content; resistant to wilt
Sesame		
Smarak	Odisha	*Kharif,* pre-*rabi* and summer season, white seed, 78-82 days to maturity; average yield 800-900 kg/ha, 48-51% oil content;tolerant to *Macrophomina*, leaf curl and *Alternaria*, resistant to lodging
Subhra	Odisha	*Kharif*, pre-*rabi* and summer; 80-85 days to maturity; Golden yellow bold seed, average yield 800-900 kg/ha, 48-52% oil content, delayed shattering, synchronous maturity; tolerant to *Macrophomina*, powdery mildew and *Alternaria*, resistant to water-stress
Linseed		
Pratap Alsi 2	Rajasthan	Blue flowered, shining brown large seeds, yield potential 1,957 kg/ha with 41.8% oil content; moderately resistant to *Alternaria* blight, powdery mildew, wilt and bud-fly
Tiara	Himachal Pradesh,Jammu and Kashmir Uttarakhand, North Eastern States, Uttar Pradesh ,West Bengal	Average fibre yield 1,294 kg/ha, fibre strength 25.55 g/tex; resistant to wilt and *Alternaria* blight

Released varieties of pulses

Variety	Recommended state/ region	Salient features
Chickpea		
Bidisha (BG 1084)	West Bengal	Moderately resistant to wilt
Vallabh Kabuli Chana 1	Punjab, Haryana, Rajasthan, Uttar Pradesh, Delhi, Jammu and Kashmir	Yield potential 2,300 kg/ha; moderately resistant to wilt
Raj Vijay Gram 202	Madhya Pradesh, Gujarat, Maharashtra, Uttar Pradesh, Rajasthan	Early maturing;yield potential 2,000 kg/ha; resistant to wilt and moderately resistant to dry root
Mungbean		
CO 8	Tamil Nadu	Early maturing (60-65 days); average yield 1,000-1,100 kg/ha; resistant to yellow mosaic virus
Shalimar Moong 2	Kashmir valley, up to an altitude of 1,850 mean sea level	Early maturing; average yield 1,000-1,100 kg/ha; resistant to *Cercospora* leaf spot, moderately resistant to aphid
Urdbean		
Vallabh Urd 1	Uttar Pradesh	Resistant to yellow mosaic virus
Lentil		
Shalimar Masoor 2	Kashmir valley, up to an altitude of 1,850 mean sea level	Average yield 1,300 kg/ha, large seeded; moderately resistant to rust
Fieldpea		
Shalimar Pea 1	Jammu and Kashmir	Matures in 210-215 days; yield potential is 1,300-1,400 kg/ha, is dwarf

Pulses

Eight varieties of pulses including three of chickpea, two of mungbean and one each of urdbean, lentil and fieldpea were released for cultivation.

Raj Vijay Gram 202 variety of chickpea

Goa Cowpea 3– A grain variety for Goa: It is an indeterminate type of local cowpea selection with bold pods and high yield. Under ideal conditions, it grows to a height of about a feet with profuse dense foliage (up to 40 trifoliate leaves/plant) with vine growth up to one metre having 4-5 primary branches. The selection takes 68-70 days for flowering with total crop duration of 100-105 days. Each plant produces 14-20 smooth greenish white pods in clusters measuring 23-25 cm and each pod has 13 to 17 light brownish seeds with a test weight of 25 g for 100 seeds. The selection has a potential seed yield up to 2 tonnes/ha and haulm yield of 4.30 tonnes/ha. The variety is highly tolerant to pests and diseases. It is fairly tolerant to drought situation and is suitable for residual moisture condition in rice fallows. This local cowpea is preferred in many of the culinary preparations

Goa Cowpea 3

Desirable genes introgressed from exotic lentil lines

Introgression of alien genes from wild lentil species widened genetic variability in segregating populations of wild × cultivated cross. Early vigour was introgressed in the background of improved lentil variety IPL 315 from exotic line ILL 7663, Minerals-rich breeding line IPL 220 was validated for Fe and Zn content. Lentil lines, ILL 755, ILL 364, ILL 6100, ILL6882, ILL 2556, KL 67, K 96, EC 267441 and PBJ/SSC 2/28, showed tolerance to Imazethapyr herbicide and EC 78503, EC 225503, ILL 1915, VKS 13/15, ILL 916, ILL 4551, ILL5902 to Metribuzin.

Exotic line ILL 7663 Improved lentil IPL 315

Introgression of alien genes from exotic line ILL 7663 in improved breeding line of lentil (IPL 315) for early vigour

owing to its unique taste, bold size and better cooking quality. As such, it fetches a premium price in the market. The variety was released during Group Meet on mung-bean and urdbean for spring/summer and rice fallow cultivation.

Forage crops

Six varieties of forage crops, three of oat and one each of Napier Bajra Hybrid, Marvel grass and lucerne were released for cultivation.

Commercial crops

Nirmal18 of cotton, JRJ 610 (Prankur) of sunnhemp, JROG 1 (Rithika) of tossa jute and CoP 2061 of sugarcane released for cultivation are high-yielding varieties for different agro-ecological regions.

Released varieties/hybrids of forage crops

Hybrid/ variety	Area of adoption	Salient features
Oat		
Jo 03-93	Uttar Pradesh, Maharashtra, Gujarat, Madhya Pradesh, Chhattisgarh	Superior green and dry forage yield
OS 377	Uttar Pradesh, Maharashtra, Gujarat, Madhya Pradesh, Chhattisgarh	Irrigated conditions in single-cut system in *rabi;* superior green fodder and dry matter yield; tolerant to major diseases
Shalimar Fodder Oats 4	Jammu and Kashmir	A medium maturing variety that fits well in rice-fodder oat system in the valley; bold seeded and high seed yield potential; resistant to leaf -spot and loose smut, armyworm
Napier Bajra Hybrid		
BNH 10	Punjab, Haryana, Rajasthan, Asom, Odhisa, Maharashtra, Gujarat, Uttar Pradesh,Madhya Pradesh,Andhra Pradesh,West Bengal, Telangana, Tamil Nadu, Karnataka	Superior for green forage, dry matter yield and per day productivity
Marvel Grass		
Phule Marvel 06-40	Maharashtra	Recommended for pasture land in rainfed areas; high green forage yield, high tillering ability, high L/S ratio;resistant to leaf-spot and rust
Lucerne		
Co2	Tamil Nadu	High crude protein content (23.5 %) and dry matter yield (21.94 tonnes/ha/yr), profuse flowering, enhanced seed yield, superior ratooning ability and early flowering results in 14 harvests a year

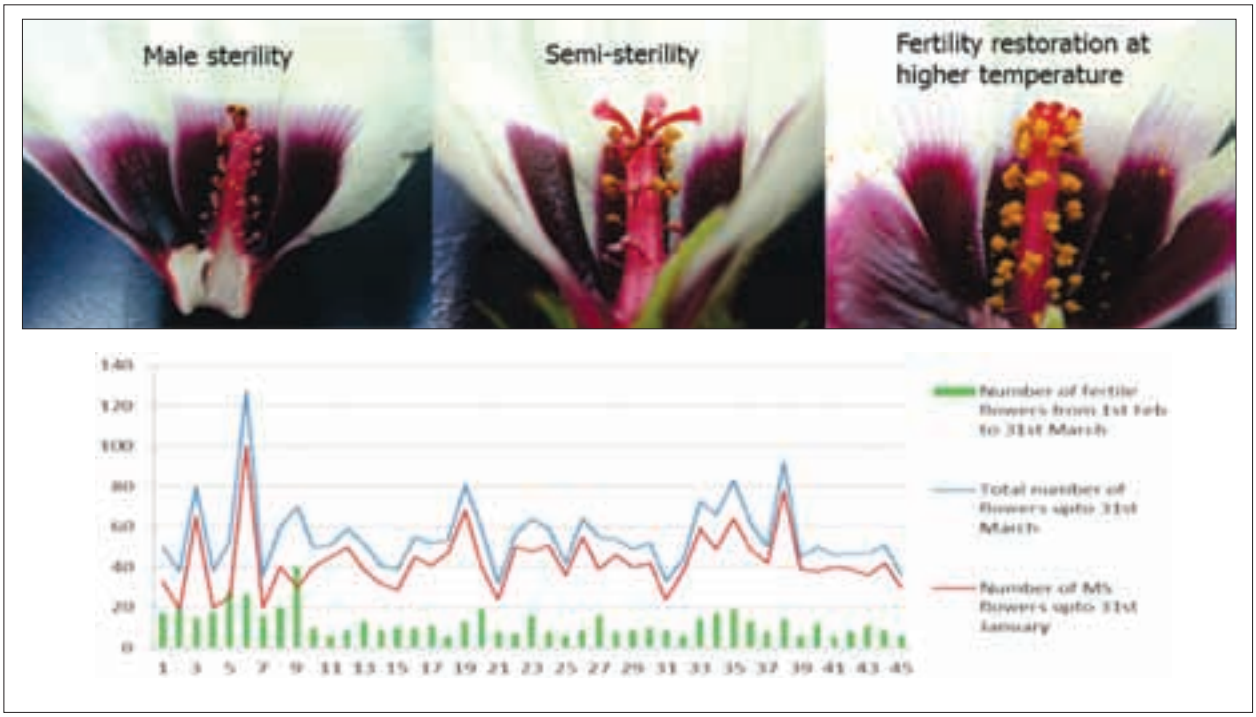
Released jute and allied fibres varieties

Variety	Area of adoption	Salient features
Sunnhemp (*Crotalaria juncea*) JRJ 610 (Prankur)	Sunnhemp-growing belt of India	Suitable for irrigated as well as rainfed and mid as well as highland situations; average fibre yield is 1,016 kg/ha and its potential is more than 1,400 kg/ha; it is tolerant to vascular wilt. Fibre quality is better in terms of strength (13.19 g/tex) than the check varieties K 12 yellow (11.19 g/tex) and SH 4 (11.93 g/tex)
Tossa Jute (*Corchorus olitorius*) JROG 1 (Rithika)	Tossa jute-growing belt of India	Average fibre yield is 2,780 kg/ha and yield potential is about 3,300-3,500 kg/ha; it is tolerant to semilooper and yellow mite

Tossa jute variety Rithika

Male sterility in mesta: Three sets of mesta (kenaf) male-sterile lines were identified from interspecific hybridization and natural mutation. The sterility was functional in nature, manifested by formation of rudimentary anthers, inhibited anther dehiscence and a combination of two. Sterility is induced under low temperature, while under high temperature anther dehisces. The male-sterile lines can be maintained by either growing them at high temperature regions or by sib-mating with the fertile lines derived from the single plant. Tolerance to premature flowering in pre-breeding materials of *Corchorus olitorius* was studied in F_4 progenies. The polulation exhibited high tolerance to premature flowering when sown on 1March 2014. Progenies were harvested from individual plants and a total of 42 F_5 progenies were evaluated for tolerance to premature flowering by sowing on 17 February 2015. Three F_5 progenies did not flower at 35 DAS, but exhibited 36% flowering at 65 DAS.

Transcriptome sequencing for resolving lignin biosynthesis pathway in jute: Employing comparative RNA-seq-based bast transcriptomics that used a deficient lignified phloem fibre (dlpf) mutant and its wild-type (WT) jute (*Corchorus capsularis*), genes and their isoforms involved in lignin biosynthesis *via* upstream shikimate-aromatic amino acid (AAA) and downstream monolignol pathways in jute fibres have been identified.



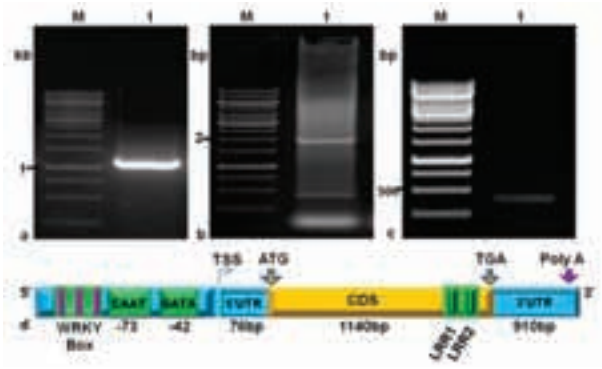
Phenological studies on male sterility in mesta

Altogether 60 WT and 57 mutant unigenes were mapped to shikimate-AAA pathway. While 91 WT and 85 mutant unigenes were mapped to monolignol pathway. Following cross-validation, a total of 38 isoforms of 16 genes involved in shikimate-AAA pathway were identified. The sequence and coding region length of these genes varied from 515 to 2,749 bp and 73 to 670aa.

Molecular approaches

Cereals

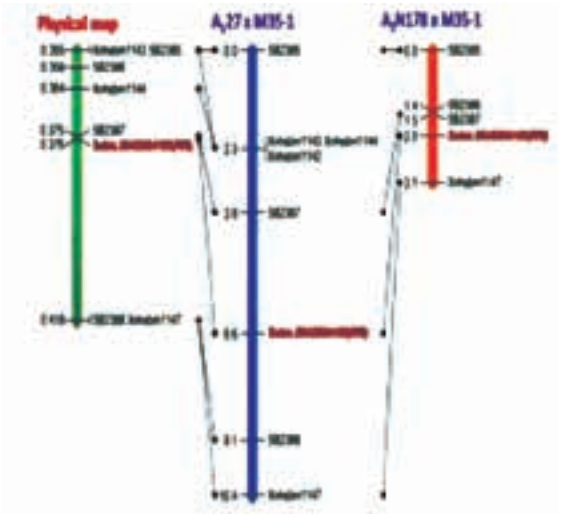
Cloning and characterization of a new orthologue for rice-blast resistance: Using allele mining an orthologue of *Pi54* was cloned from *Oryza officinalis* and designated as *Pi54of*. Gene conferred broad-spectrum resistance to rice blast, caused by *Magnaporthe oryzae*, which was also functionally validated. The full length gene has a small CC-NBS-LRR domain, a typical signature of disease resistant genes and a unique Zinc-finger domain. Its 1140 bp open-reading frame is the longest of the *Pi54* alleles cloned. It showed a basal expression that has been enhanced further by 23-fold, 72 h post-inoculation with *M. oryzae*.



Cloning of full length *Pi54of* gene from *Oryza officinalis*. (**a**) PCR amplified ORF region; (**b**) inverse PCR for deducing 5′ upstream and 3′ downstream of the *Pi54of* allele in *O. officinalis.* (M: 100 bp DNA ladder and lane 1: 2 kb amplicon using IL1 and IR1); (**c**) RLM RACE product of *Pi54of* orthologue. M: 1 kb ladder, lane 1: amplicon (400 bp) generated by 5′ RACE inner primer and AAP primer (provided with kit); (**d**) Schematic representation of *Pi54of* orthologue

Antioxidant genes cloned from Indian maize lines: Antioxidant defense is a major mechanism employed by plants to mitigate environmental stresses. Five different antioxidant genes were cloned from two Indian maize inbred lines– HKI 335 (drought tolerant) and MGUD 22(drought susceptible). The cloned genes were registered with GenBank as a part of the International Nucleotide Sequence Database Collaboration (INSDC). Subtle sequence polymorphisms, including polymorphisms in the putative miRNA binding sites, were observed between sequences from drought-tolerant and drought-sensitive genotypes. This could be the key for unravelling tolerance mechanism in maize.

Molecular tagging of a fertility restoration (*Rf6*) gene in sorghum: Of the several cytoplasmic male-sterility (CMS) systems, A_2 CMS was found a better alternative to widely exploited A_1 (*milo*) cytoplasm. A major gene for male-fertility restoration, *Rf6*, in sorghum was mapped on chromosome 4. Fertility restorer ability of the gene on both A_1 and A_2 CMS systems was ascertained using F_2 populations of 27A ×M35-1 and A2 × M35-1 crosses. The Rf6 locus is tightly linked to SSR markers SB2387 and SB2388. Sequence comparison of the CDS and peptide sequences of parents showed deletions and insertions in non-restorers, leading to truncated peptide. The marker SB2387 was very tightly linked with *Rf*6 locus (603bp away) on SBI 04, and it could successfully discriminate all restorer lines from maintainers (non-restoreres) of A_1 and A_2 cytoplasms with higher accuracy of 94-97%. An additional gene (*Rf6*)-based marker, MS-SB04 266, was validated in a set of 37 genotypes and could be employed for selecting potential restorers on A_1 and A_2 cytoplasms.



Map position of *Rf6* along with its linked markers (cM) in relation to physical map (Mb) in $A_1$27×M35-1 and A_2N178×M35-1 crosses

Oilseeds

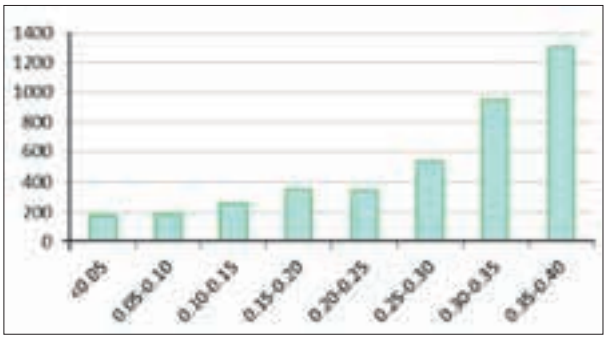
Abiotic stress-tolerant transgenic groundnut lines: Characterization of groundnut lines having *AtDREB1A* gene showed improved tolerance to drought and salinity stresses over wild type genotypes. Transgenic plants were characterized by delayed and less severe leaf wilting and improved growth parameters correlating with physio-

Use of somatic embryogenesis

Complete plantlets of *C. reticulata* cv. Nagpur Mandarin and C. *sinensis* cv. Sweet Orange were successfully regenerated from hybrid endosperm tissue via somatic embryogenesis. The surviving plantlets were tested for ploidy and DNA content. The triploid plants were mini-grafted on Rough lemon rootstocks for greenhouse acclimatization. These results demonstrated the recovery of stable viable triploids from hybrid endosperm via somatic embryogenesis and can overcome the barriers to sexual hybridization resulting from apomixes, a step forward for breeding seedless scion cultivars of Nagpur mandarin.

biochemical parameters such as proline content, total chlorophyll content, osmotic potential, electrolytic leakage and relative water content.

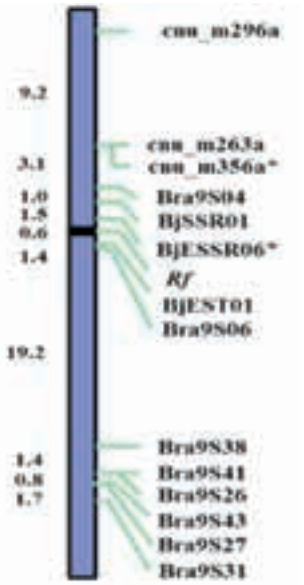
Castor SNP genotyping array: A newly designed 6K SNP (Single Nucleotide Polymorphic) array was validated by genotyping 318 diverse castor accessions (comprising core set of germplasm, trait-specific germplasm, elite inbreds/parental lines of hybrids etc.), representing fairly wide genetic diversity available in castor. A total of 4,098 SNPs were called successfully with high quality. The call rate of these SNPs ranged from 80 to 100% with an average of 98%. The reproducibility of all the SNPs across biological and technical replicates was 100%. Of the 4,098 informative SNPs, 2,690 (65.64%) have MAF >0.2 and can be considered as markers with normal allele frequencies. About 18% have a MAF of 0.1 - 0.2 while 291 SNPs have MAF of <0.05. In addition, 489 SNPs (12%) have showed almost equal allele frequencies (with MAF close to 0.5) for two alternative alleles. The polymorphism information content (PIC) suggests usefulness of markers for diversity and linkage analyses, which ranged from 0 to 0.5 for a bi-allelic marker such as SNP. The gene diversity ranged from 0.003 to 0.500 with an average of 0.351; indicating a moderate level of genetic diversity in castor as validated by SSR, ISSR and AFLP. Thus, the array developed is of superior quality in terms of performance, polymorphism and reliability, which can be readily used for any genome-wide research applications in castor.



Frequency distribution of polymorphism information content (PIC) of SNP markers (X axis: PIC values of SNP; Y axis: Number of SNPs)

Marker-assisted selection for high oleic acid in safflower: A point mutation in the candidate gene, *fatty acid desaturase 2-1* (*fad2-1*), which is responsible for high oleic acid content was detected in a set of high oleic safflower genotypes. A gel-based marker assay was designed to predict high and low oleic genotypes using mutation specific primer-pair. Marker-assisted validation of F_2 population (n=96), produced from low oleic (~20%) and high oleic (~80%) cross, showed segregation 3 (presence):1 (absence) ratio. As heterozygotes carrying *Olol* alleles could not be detected through this analysis, a 'sequencing based assay' was developed. Using this assay, perfect co-segregation of marker-genotype with high oleic acid trait was established by analyzing oleic acid content of F_3 seeds (n=64) through gas chromatography.

Fine mapping of fertility restorer gene of CMS (*Moricandia arvensis*) *Brassica juncea:* Closely linked markers were identified for fertility restorer (*Rf*) locus on chromosome A9 using differentially expressed anther transcriptome sequences in *B.juncea*. From 842 differentially expressed unigenes, 45 SSR markers and 22 STS markers were designed and used to genotype BC_1F_1 population. Two markers, one each of SSR and STS, were found very closely linked to *Rf* gene .



Fertility restorer gene map of CMS (*Moricandia arvensis*) *B. juncea*

Pulses

Genetic transformation of chickpea and pigeonpea: Explants of chickpea (41,217) and pigeonpea (22,309) were subjected to *Agrobacterium*-mediated genetic transformation with *Bt-cry1Ac* gene. Kanamycin -tolerant putative transformants were established in transgenic containment facility. Molecular analysis (PCR, RT-PCR, ELISA, Southern and Western blot) of putative transformants indicated presence and expression of *Bt* gene in progenies of selected events of chickpea and pigeonpea (T3, T2 and T1). Insect bioassay (detached leaf assay) of selected lines of chickpea (T3 and T4) and pigeonpea (T5, T3 and T2) exhibited larval (*Helicoverpa armigera*) mortality in the range of 20-100%.

Pod-borer resistant transgenic pigeonpea: Transgenic pigeonpea containing *cry1Aa* and *cry1EC* genes individually were characterized for expression of transgenes and levels of insecticidal proteins. A total of 6,800 embryo explants were subjected to *Agrobacterium*-mediated transformation with a transformation frequency of 0.05%. The concentration of insecticidal protein in *cry*1Aa events (804, DTS-43 and AK1304-PB-1) ranged from 0.16 to 0.978 ng/mg of fresh leaf tissue while that in *cry1Ec* lines (AMT-1, NBRI-PB-1), ranged between 0.192 and 2.4 ng/mg.

Allele-mining in chickpea and pigeonpea: Allele-mining of drought-responsive factors (DRFs) *CcCDP* (Acc. No. GU 444041.1) and *CcHyPRP* (Acc. No. GU 444042.1) and *CAP2* gene (homolog of the *DREB2A* gene, Acc. No. DQ 321719.1) was accomplished in selected set of chickpea and pigeonpea genotypes. Chloroplast transit peptide (cTP) sequence from chickpea and pigeonpea genomes was isolated. In addition, eleven stress-induced miRNAs including those responsive to heat stress in pigeonpea were identified.

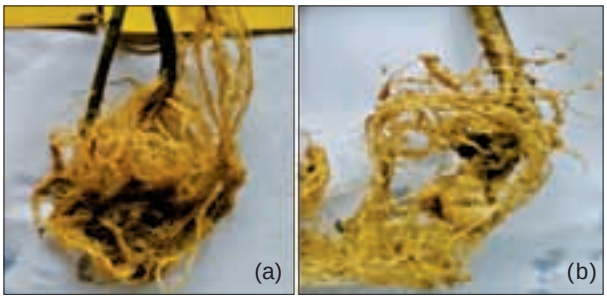
Molecular breeding in pulses: Marker-assisted backcross breeding generated five progenies with resistance to *Fusarium* wilt (*Fusarium oxysporum* race

2) in the background of chickpea variety Pusa 256. Similarly, seven SSR markers identified polymorphic between parental lines were used in molecular mapping of wilt resistant genes in pigeonpea, and these identified true F_1S were from a cross Type 7 × ICP 8863. In mungbean, 53 polymorphic SSR markers grouped 53 accessions of wild species into 5 distinct groups and one admixture group.

Commercial crops

Whole genome and transcriptome analysis of *Colletotrichum falcatum:* Using next generation sequencing (NGS) technology, whole genome (WGA) and whole transcriptome analysis (WTA) were done. Analysis of highly repetitive ~48.2 Mb genome and ~27Mb transcriptome assemblies of *C. falcatum* resulted in prediction of nearly 12,270 protein-coding genes. Global view of syntenic alignments between genome and transcriptome of *Colletotrichum falcatum* led to its delegation to linkage group of *C. graminicola* with about 93% similarity in base pairing and gene clustering. The WGA and WTA resulted in nearly all subunits of protein complexes like carbohydrate metabolism, putative proteins (characterized and uncharacterized), respiratory electron transport chains, the V-ATPase, and ubiquitin–proteasome systems. This is the first report on whole genome and transcriptome sequencing of *Colletotrichum falcatum*; red- rot pathogen of sugarcane.

Characterization of parasitism genes in root -knot nematode : More than thirty parasitism genes known in root-knot nematode *Meloidogyne incognita* were evaluated for their critical role in pathogenesis through RNAi -mediated silencing, using dsRNA specific to each gene. Two oesophageal genes – *MSP6* and *MSP13*– have been found to seriously affect parasitism and impair infectivity of root-knot nematode on cotton. As plant parasitic nematodes including juveniles of root-knot nematodes reduced oral uptake; four bio-molecules were evaluated for enhancing ability of second stage juveniles to acquired sRNA. Two molecules, Octopamine and



Uptake of *msp6 dsRNA* by root-knot nematode rendered it defective in infecting tomato (**a**) *dsRNA*-treated nematode; (**b**) healthy nematode

Resorcinol, have been found most effective as inducer of dsRNA uptake.

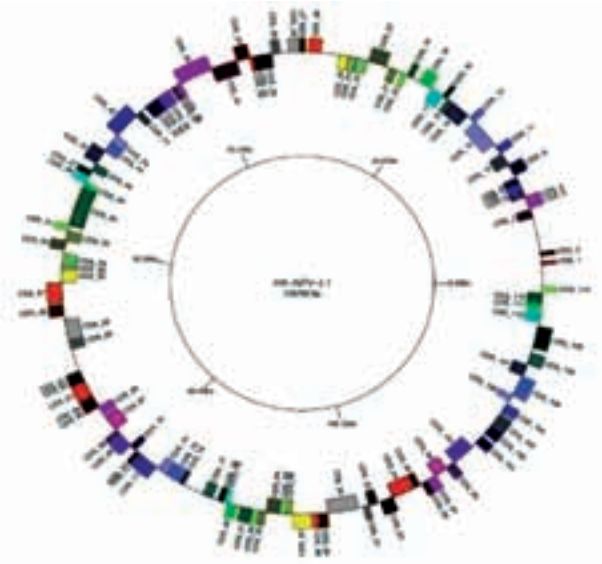
Pink bollworm resistance to cry toxins: Populations of pink bollworm were collected from 34 locations in Gujarat on Bollgard-II and non Bt cotton hybrids during 2014-2015. F_1 progenies of pink bollworm populations were subjected to diagnostic assays with Cry1 Ac and Cry2Ab toxin proteins at 10 ppm, 5 ppm, 1ppm and 0.1 ppm. Populations from Surat and Anand sourced from non-Bt were most tolerant as they recorded lowest corrected mortality of 62% and 69% at 10 ppm Cry 1Ac toxin compared to susceptible population. Pink bollworm collected on Bollgard-II hybrids in Junagadh and Vadodara were most tolerant as they recorded lowest corrected mortality (62% and 67%) as compared to susceptible population at 10 ppm Cry1Ac. Populations collected from Amerli Bt, Bhavnagar Bt and Surat NBt recorded lowest corrected mortality, 25.00%, 49.00% and 62.00%, respectively, on Cry2Ab at 10 ppm diagnostic dose. Resistance to Cry1Ac and Cry2Ab log dose probit assays with pink bollworm F_1 population from non-Bt cotton was monitored. Population from Jalna, Mansa, Bharuch, Amreli, Akola and Khandwa recorded 3, 4, 7, 9, 11 and 19 fold resistance to Cry1Ac over susceptible check. Population from Faridkot, Rahuri Sirsa, Mansa, Amreli, Junagadh and Khandwa recorded 26, 34, 35, 37, 125, 142 and 335 fold resistance over the susceptible

Pink bollworm infestation on Bollgard-II cotton hybrids in Gujarat

check to Cry2Ab.

Whole genome sequencing of economically important microbes: *Staphylococcus xylosus:* Genome sequence of psychro-tolerant bacteria *Staphylococcus xylosus* strain LSR_02N isolated from water (sediment) at the confluence of river Zanskar and Indus at Leh (Jammu and Kashmir) was deciphered. The 3.7 Mb genome sequence of the strain LSR_02N (JXAV00000000) contained 38 scaffolds and 2,971 total genes including 1,419 unique and 553 hypothetical genes. Presence of heat and cold shock protein encoding genes support its ability to survive under low temperature conditions.

Helicoverpa armigera: Nuclear Polyhedrosis Virus



Circos plot for gene arrangement in *Helicoverpa armigera* NPV whole genome [Different colours represent protein-coding genes. Gene arrangements are depicted counterclockwise]

(NPV) is a member of family Baculoviridae having high specificity to insects belonging to Lepidoptera. These rod-shaped, double-stranded DNA viruses are one of the most potent biocontrol agents of *Helicoverpa armigera*, particularly on pulses and vegetables in India. The genome of *H. armigera* NPV (GenBank accession number KT013224) from Ludhiana was sequenced. The whole genome sequencing comprises 136,760bp circular DNA, with a total of 113 protein-coding genes with four repeat regions. Altogether, 73 named proteins were identified. The gene arrangement and orientation of the assembled NPV whole genome were identical to the reported single-capsid NPV genome from G4 strain of China, NNg1 of Kenya and LB1 of Spain. All these starins are known for their enormous infectivity against Lepidoteran insects.

Virgibacillus: The whole genome sequence of *Virgibacillus* sp. bacterium known from Rann of Kutch, Gujarat, revealed presence of genes for 3,459 coding sequences and 910 hypothetical proteins. There are 26 genes for osmo-regulation and 37 for oxidative stress tolerance. Exploring genome has paved the way for understanding mechanism of osmotolerance. Genes critical for osmoregulation are potential candidates for engineering plants and microbes for stress tolerance.

DNA fingerprinting

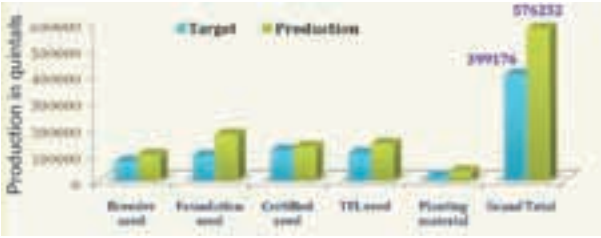
Genetic diversity analyses were done using SSR (Simple Sequence Repeat) and other markers in rice (6,984), wild *Oryza* (48), barnyard millet (94), kodo millet (96), prosomillet (16), sponge- gourd (45), bread wheat (48), pearl millet (90) and giloe (24). New markers were developed for cultivar identification and genetic diversity analyses in sesame (~70, 000 SSR and SNPs-Single Nucleotide Polymorphisms markers), bottlegourd (44,823 genome-wide and 108 SSR markers through cross-transferrability) and rice (129 SSR markers using conserved microRNA genes). Trait-specific markers were developed for terminal heat tolerance gene *HKT2:1* and rust and spot blotch resistant genes *Adc* and *AdoMetDC* in wheat, yield -related genes in rice, long-chain fatty acid genes *FAE1*/*KCS1* in Indian mustard, transcription factor families in giloe, and abiotic stress tolerance in horsegram and pigeonpea. Visual and real-time LAMP (Loop mediated isothermal amplification) assays targeting *cry* genes and glyphosate tolerant genes were developed using fourteen GM events in corn, cotton, eggplant and soybean. Adventitious presence of transgenes was monitored in cotton (*in- situ* collection) and okra (*ex-situ* collection) using multiplex PCR targeting genes.

Seed technology

Alternative areas for hybrid seed production: Considering uncertain weather owing to climate change and for ensuring steady supply of quality seeds, the alternative areas for economic hybrid-seed production of various crops have been identified.

Crop	Alternative areas for hybrid seed production
Paddy	Balaghat (Madhya Pradesh); Dhamtari, Mahasamund and Gariaband (Chhattisgarh); Chilkalurpeta, Guntur (Andhra Pradesh)
Sunflower	Gudibande and Gowribidanur, Sira (Karnataka)
Maize	Nandiyal (Telangana); Sira, Hiriyur and Siruguppa (Karnataka); Pathera (Haryana)
Pearl millet	Sriganganagar, Bharathpur (Rajasthan)
Castor	Surendranagar (Gujarat), Gadwal, Reddipalli, Nandyal and Banaganapally (Andhra Pradesh)
Jute	Tadikonda, Tulluru, Macherla, Sattanapalle, Chilakalurpeta and Marturu (Andhra Pradesh)

Quality seed production: During 2014-15, 978, 17,562, 12,847, 14,000 and 3,418 tonnes of breeder, foundation, certified, truthfully labelled seed and planting material, respectively, were produced. Further, 2,026 lakh of planting material and tissue-cultured plants were produced. The production of different classes of seed and planting material was higher than the envisioned targets.



Target and production of seed and planting material during 2014-15

Pollinators

Sunflower: Significant variations were observed among the genotypes for luring honeybees. Among genotypes evaluated significantly high honey production potential (36.60 kg/ha) was recorded in DK 3849, followed by SH 3322 (34.52 kg/ha).

Mustard: Honeybees and other pollinators exhibited significant role in enhancing seed yield of mustard-crop. Different modes of pollinations in mustard-crop revealed that number of siliquae/plant were highest in open pollination–(OP) (188), followed by bee-pollinated plants (155) and was lowest in case of pollinator exclusion (PE) treatments (132). The highest seed yield per plant was recorded in OP (8.50 g), followed by BP (6.37), and PE (4.37) plants

Bt Cotton: In Bt cotton hybrid RCH BG 11 open-pollination treatment recorded maximum number of pollinators, followed by *Aphis cerana indica* confined treatment and pollinator excluded plots. The seed-cotton yield was 38% higher in open-pollinated plot and 17.5% higher in *A. cerana* pollinated plots compared to pollinator excluded plots.

Horticulture

Fruit crops

Arka Udaya, a semi-vigorous mango hybrid (Amrapali × Arka Anmol) with medium-sized fruits (250g), firm and deep yellow pulp, 23-24% TSS was released.

Arka Udaya mango

Arka Rashmi, a guava hybrid (Kamsari × Purple Local), bearing round and medium-sized fruits (200-210 g) with pink pulp and moderately hard (9kg/cm^2) seed was released. Dhawal, a half-sib selection from Allahabad Safeda with round, smooth and medium to large fruits (200-250 g), white pulp, TSS 13%, acidity 0.42%, ascorbic acid (250mg/100 g pulp) was released.

Guava Dhawal

Lalima, a half-sib selection from Apple guava with attractive crimson fruits, good yield (50kg/tree) with higher shelf-life (5-6 days) at ambient was released.

Guava Lalima

The PDKV Bahar, an acid lime Clone 2, with 22% more fruit yield over the existing varieties was identified for high yield (143 kg/tree) and released for cultivation in Maharashtra.

Bael variety, Thar Divya, with compact canopy, semi-spreading growth, early-maturity (second fortnight of February), attractive dark yellow and high pulp (70.5%) content, TSS (pulp-37%, mucilage-49.5%) was released for cultivation in Rajasthan and Gujarat.

Thar Rituraj, a variety of khirni (*Manilkara hexandra*) with 12-14 kg fruit yield/tree, 5.2g fruits having 24-25% TSS and 0.3% acidity was released for cultivation.

Karonda, CHESK-2, with 5g fruit weight, 9-10% TSS, 0.64% acidity, 13.4 mg ascorbic acid/100g pulp and 13 kg/plant fruit yield was identified and released as Thar Kamal. The fruits of Thar Kamal are suitable for candy- and jelly-making.

Plantation crops

Kalpa Jyothi and Kalpa Surya, dwarf coconut lines, suitable for tender nut, were developed. Kalpa Haritha, a tall, dual-purpose variety suitable for copra and tender nut and; hybrid Kalpa Shreshtha (D × T); a high-yielding (167 nuts equivalent to 35.9 kg copra/palm/year), were accepted for release and notification by the Central Sub-Committee on Crop Standards, Notification and Release of Varieties of Horticultural Crops. Kodinar**,** a high-yielding (3.82kg/palm/year), arecanut selection, with recovery of 62.5% A-grade nuts was recommended for release.The coconut varieties Kalpa Pratibha, Kalpa Dhenu, Kalpa Mitra, Kalpa Raksha, Kalpa Sree and Kalpa Sankara, were registered with the Protection of Plant Varieties and Farmers' Rights Authority, Government of India.

Kalpa Shreshtha

A hybrid cashew line (H126) with jumbo nut (11-12 g), kernel weight (3.3 g) and kernel grade of above W150 was found promising at Puttur.

Fruiting in H-126

Vegetable crops

Of the 10 determinate F_1 hybrids evaluated, Hybrid 369 with Arka Vikas fruit type possessed triple disease resistance (ToLCV+BW+EB), whereas Hybrid 371 possessed combined resistance to ToLCV and early

blight and Hybrid 373 recorded the highest yield (24 tonnes/ha). Similarly of the 25 indeterminate F_1 hybrids evaluated, maximum yield was recorded in IIHR 2042 × IIHR 2834 (76 tonnes/ha), followed by IIHR 2042 × IIHR 2856 (76 tonnes/ha) and PH 4225 (73 tonnes/ha). Fruit firmness was highest in IIHR 2867 × IIHR 2834 (8.7 kg/cm^2). These hybrids possessed triple disease resistance (ToLCV+BW+EB).

Six promising populations of chilli with combined resistance to thrips, CMV and ChiVMV were identified and advanced. Four advanced breeding lines of brinjal, viz. IIHR 37-36-4-4, (38 tonnes/ha), IIHR 37-36-4-20, (35 tonnes/ha), IIHR 37-36-13- 7 (32 tonnes/ha) and IIHR 37-36- 3-4 (30 tonnes/ha) were promising for high yield and resistance to bacterial wilt.

A total of 116 advanced lines of okra were evaluated. Of them, IIHR 11-1-50 and IIHR 299-1 were identified for high yield (23.54 and 27 kg/3.4 m^2 plot, respectively) along with combined resistance to YVMV + powdery mildew (no incidence) during summer.

Kashi Vardaan (VRO-25) is an early, medium tall (120-125 cm) hybrid, taking 42-44 days for first flowering. Its fruits are harvested 47-100 days after sowing. It has yield potential of 150-155 q/ha, resistant to yellow vein mosaic virus (YVMV) and okra enation leaf curl virus (OELCV). It is recommended for cultivation in Uttar Pradesh, Bihar, Jharkhand and Punjab.

Of the 30 pole type photo-insensitive advanced breeding lines (F_6) evaluated, seven high-yielding and photo-insensitive advanced breeding progenies, viz. IIHR15-5, IIHR 15-7DG, IIHR 15-7G, IIHR 15-8, IIHR15-15, IIHR 15-21, IIHR15-23 with 30-35 tonnes/ha pod yield were selected. A ridge gourd variety, Thar Karni, with 3.5m vine length, light green and cylindrical fruits (95g) and 140-150q/ha fruit yield was released for cultivation in Rajasthan.

Of the 20 selective crosses of onion (four male sterile, disease resistant lines and seven male fertile disease resistant lines), two F_1 progenies, viz. PBRMS 319 × PBRC 339 (26.50 tonnes/ha and PDI 10.50%) and PBRMS 318 × PBRC 338 (24.80 tonnes/ha and PDI 12.20%) were found tolerant to purple blotch disease during rainy season. Bhima Safed (NRCWO-3), a white onion line with 22-25 tonnes/ha bulb yield was recommended for cultivation during *kharif* in Chhattisgarh, Gujarat, Karnataka, Madhya Pradesh, Maharashtra, Odhisa, Rajasthan and Tamil Nadu. Onion, Bhima Super, Bhima Dark Red and Bhima Shweta, with 500-600 sets/m^2 production were recommended for set production in *kharif* season in areas prone to heavy rainfall. These varieties have bulb yield potential of 22-25 tonnes/ha in *kharif*.

Onion Bhima Safed

Four advanced breeding lines of onion, viz. DOGR Hy-5, a F_1 hybrid with uniform, dark red and global bulbs and thin neck, 20.11% more bulb yield (387.25 q/ha) than the best check Bhima Dark Red (322.4 q/ha), matures 101 days after transplanting, free from double bulbs and bolters, suitable for *kharif* cultivation and; RGP-1, an open-pollinated line with red and flat-globe bulbs having thin neck and free of doubles and bolters, 17.5% more yield (328.6 q/ha) than the best check Bhima Shakti (279.65 q/ha), matures 118 days after transplanting and suitable for *rabi* cultivation; RGP-2, an open-pollinated line having uniform, global, dark red bulbs with thin neck and free of doubles and bolters, suitable for *rabi* season, with 32% more bulb yield (369.15 q/ha) than best check Bhima Shakti (279.65 q/ha) and matures 116 days after transplanting, were recommended for multilocational testing.

Potato

A potato variety, Kufri Lalit, with red peel and light yellow pulp was released for commercial cultivation in Bihar, West Bengal, Asom, Odhisa and Jharkhand. It is field resistant to late blight.

Patato Kufri Lalit

Ornamental crops

Arka Aayush, a gladiolus variety, with thick open-faced florets, slightly ruffled, double rowed, red (41.C) having red (41.A) margin, blotch red (46.B) with yellow (13.C) border and resistance to *Fusarium* wilt was recommended for release. Arka Manorama, another gladiolus variety with open-faced florets, medium, wavy, red-purple (65.B) having red purple (62.A) streaks, red-purple (67.B) splash was identified for release. Arka Agni, a petaloid male sterile (IIHRMGYP-1 × 9-2) marigold hybrid with medium plant height (80-85 cm), high-yielding (7-7.5 tonnes/acre), compact but large (7.5-8 cm) and orange flowers (RHS colour N25C, orange group). Flowering starts at 40-45 days after planting and continues for 60 days was identified for release.

Arka Alankara, another petaloid male sterile marigold hybrid (IIHRMGYP-1 × 9-2) with compact and large (7-7.5 cm), golden yellow (RHS colour 9A, yellow group) with high yield (6-6.5 tonnes/acre) was released. Flowering starts 40-45 days after planting and continues for 60 days. The *Zygopetalum intermedium*, a Brazilian orchid with scented flowers was observed to produce true-to-the-type apomictic progeny lines on hybridization with *Vanda coerulea*, *Vanda hybrids* and several species of

Arka Aayush

Arka Alankara

Gene pyramiding

For pyramiding tomato leaf curl virus (ToLCV) resistance genes *Ty-2* and *Ty-3* into elite tomato lines, Marker Assisted Selection (MAS) was done. Among four backcross progenies, four plants homozygous to both *Ty-2* + *Ty-3* were identified and advanced. In addition, for introgression of *ToLCV* resistance genes from *Solanum habrochaites*, 30 BC_1F_4 families derived from an inter-specific cross, 15 SBSB × *S. habrochaites* (LA-1777), were screened using *Ty-2* and *Ty-3* markers and 28 individual plant selections were made for the presence of *Ty-2* and *Ty-3* genes.

genus *Coelogyne*. However, there was marked reduction in vigour in second selfing cycle due to inbreeding depression.

Spices

Appangala 2 (NHY-35); developed through heterosis breeding (moderately yielding 'Appangala 1' × mosaic resistant 'NKE 19') and resistant to Cardamom Mosaic Virus (katte) with 9.3 q/ha dry capsules yield was recommended for cultivation in hilly zones of Kodagu, Hassan and Chickmagalur in Karnataka and North Wyanad in Kerala. Ajmer Fenugreek 4 (AFg-4) variety with 12.53% higher seed yield (19.25 q/ha) than Hisar Sonali (National check), moderately resistant to powdery mildew and root rot was identified and released for cultivation in Rajasthan. Ajmer Ajwain 93 (AA-93), an early-maturing variety, was released for cultivation in Rajasthan. This variety is erect in growth, lodging resistant, matures 40-45 days early (123-125 days) and yields 9 q seeds/ha at 40 cm × 20 cm plant spacing.

Ajmer Nigella 20 (AN-20), with 42-43% more yield (10.25 q/ha) than Azad Kalonji and Ajmer Nigella 1 was released for cultivation in Rajasthan.

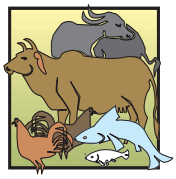
Medicinal and aromatic plants

A temperature sensitive, male sterile line (DWS-10) of Ahshwagandha (*Withania somnifera*) producing sterile pollens during cool seasons (December-January), which gets converted into male fertile during warm season (March onwards), was identified. Eight promising advance breeding lines of Ashwagandha with higher dry root yield (569.5 – 1624.3 g/4m row) than check (Arka Ashwagandha, 432.3g/4m row) were selected in F7 generation.

Two promising selections of Mandukaparni (*Centella asiatica*, viz. IIHR-CA-13 with higher dry leaf yield (303.63 g/plant), asiaticoside (3.72%) and total tri terpenes (8.94%) and IIHR-CA-1 with higher leaf yield (349.26g), ascorbic acid (69.11mg/100g) and total carotenoids (26.58 mg/100g) contents were identified.

Promising advanced lines of *Mucuna* spp., viz. IIHR PS 10-2 and IIHR PS 10- 1 with higher seed yield (310 and 275g/plant) and L-dopa content (5.38 and 5.03%, respectively) over the check Arka Dhanvantari (304g, 4.82%), were identified.

Coconut selection for Goa: Tender coconuts of Benaulimpani coconut selection were harvested at 6, 7 and 8 months of maturity, where the volume of the water was 300, 280 and 250 ml/nut, respectively. TSS of the water was 6.86, 6.66 and 7.36 degree Brix in 6, 7 and 8 month old nuts. Sodium content was 22–23 ppm and potassium content ranged from 1,267 to 1,366 mg/l. Orgnaoleptic test revealed the taste of the water with very good score. Annual yield of selected palm ranged from 67 to 74 nuts/palm. Fruit component analysis of mature nuts revealed that it contains water of 160 ml/nut with 6.53 degree Brix. Copra wet and dry weight of the fruits was 266 and 194 g/nut respectively. The nuts had minimal damage due to eriophyiid mite. Benaulimpani has good scope for cultivation in Goa for tender coconuts.



6. Livestock Improvement

AICRP on Cattle

Frieswal project: The number of Frieswal females was the highest at military farms Ambala (2,039) followed by Pimpri (1,633) and Meerut (1,141). The strength of elite cows at various military farms was 1,111 as compared to 951 in previous years. During the reported year, 337,485 doses of semen were frozen and 67,323 doses were distributed to military farms. The overall mean of age at first calving (AFC) in Frieswal cows was 973.25 ± 2.64 days. The least squares means of service period (SP), dry period (DP) and calving interval (CI) were 145.47±1.70, 104.43±1.31 and 424.29±1.68 days, respectively. The overall least squares means of 300 days milk yield (MY300), total milk yield (TMY), peak yield (PY) and lactation length (LL) were 3,284.78±17.73 kg, 3,320.47±16.29 kg, 15.11±0.07 kg and 326.56±0.88 days, respectively.

Genetic improvement of crossbred cattle under field conditions

Guru Angad Dev Veterinary and Animal Sciences University, Ludhiana: Female progeny (4,098) born from different sets have reached age at first calving. During the reported year, 6,188 artificial inseminations were carried out and the overall conception rate was 46.4%. Average first lactation 305 days milk yield of cows was 3,703.6 ± 31.3 kg and average age at first calving was 1,036.6±10.20 days.

Kerala Veterinary and Animal Sciences University, Thrissur: From the female progeny born out of different sets, 1,733 have reached age at first calving. During the reported year, 4,408 artificial inseminations were carried out and the overall conception rate was 37%. Average first lactation 305 days milk yield of cows was 2,678.3 ± 64.27 kg, while average age at first calving was 1,133.9±31.38 days. The milk yield showed an increasing trend among the progeny of different sets and average 305 days milk yield increased from 1,958 kg in first set to 2,604 kg in 10th set.

BAIF Research Development Foundation, Uruli-Kanchan, Pune: From the female progeny born out of different sets, 4,126 have reached age at first calving. During the reported year, 5,771 artificial inseminations were carried out and the overall conception rate was 43.04%. Average first lactation 305 days milk yield of cows was 3,206.64±60.98 kg, while average age at first calving was recorded as 956.88 ±0.49 days.

GBPUA&T, Pantnagar: From the female progeny born out of different sets, 192 have reached age at first calving. During the reported year, 3,310 artificial inseminations were carried out and the overall conception rate was 56.7%. Average first lactation 305 days milk yield of cows was 2,587.3±72.59 kg, while average age at first calving was recorded as 1,044 ±44 days.

Conservation and genetic improvement of indigenous cattle breeds

Gir breed: The Germplasm (GP) unit has 67 breedable females (including 28 heifers); and 15 Gir bulls were inducted in two sets. At the start of the reporting year, 14,676 doses were in stock and during the year 10,097 semen doses were produced out of which 3,928 doses were utilized for insemination and 758 doses were sold. During the year the conception rate was 46.12%;

and 587 daughters were born, taking the total to 3,346 daughters. The average first lactation length and first peak yield were recorded as 374.30 ± 20.60 days and 13.90 ± 0.60 kg, respectively. The overall age at first calving, first service period, first dry period and calving interval were 1,284.50 ± 31.30, 139.10 ± 9.30, 200.20 ± 33.70 and 552.00 ± 46.80 days, respectively. The wet and overall averages of the GP unit were estimated as 7.40 ± 0.60 and 4.70 ± 0.50 kg, respectively.

Kankrej breed: The number of breedable females in GP and Data Recording (DR) units was 67 and 3,058 (includes organized farm and field units), respectively. Seventeen bulls in two sets have been inducted so far. At the start of the year, 66,623 semen doses were available under the project and during the year 33,670 doses of frozen semen were produced and 3,975 doses of semen of second set of bulls were utilized for insemination and 2,410 were sold. During the reporting period 2,286 animals were inseminated, and conception rate was estimated as 39.06% against overall conception rate of 46.45%. The overall average estimates for age at first calving, first service period, first dry period, calving interval in GP unit were 1,398.75 ± 80.40, 187.00 ± 75.99, 299.25 ± 56.17 and 431.35 ± 21.42 days, respectively; while average estimates for first lactation milk yield, all lactation milk yield and first peak yield were recorded as 2,136.04 ± 195.61, 2,760.71 ± 134.67 and 10.59 ±

0.33 kg, respectively. The average first lactation length of the herd was estimated as 288.20 ± 15.96 days, while the wet and overall averages were 9.14 and 6.86 kg, respectively.

Sahiwal breed: The number of breedable females above two years of age in the GP unit was 214 and the corresponding number in the DR unit was 599. Fifteen Sahiwal bulls in two sets have been inducted so far. At the start of the reporting year 49,236 of semen doses were in stock and 23,840 doses of semen were produced. During the year, 1,406 inseminations were carried with an overall conception rate of 41.18%. The overall average estimates for age at first calving, first service period, first dry period, calving interval of Sahiwal cows maintained at GP unit were 1,238.22 ± 27.55, 138.75 ± 24.48, 123.13 ± 33.27 and 425.38 ± 25.41 days, respectively; while average estimates for first lactation 305-day milk yield, total first lactation milk yield and first peak yield were recorded as 2,054.92 ± 229.49, 2,437.79 ± 379.27 and 11.41 ± 0.69 kg, respectively. The average first lactation length of the herd was 316.53 ± 31.69 days; while the wet and overall averages were 7.17 and 3.47 kg, respectively.

Garima produced second calf Karishma

Garima, a cloned buffalo, earlier born at NDRI produced second female calf named "**Karishma**" through normal parturition. The weight of the calf at the time of birth was 35 kg and the newborn calf is keeping good health. Garima, born on 22 August 2010 through hand guided cloning technique using embryonic stem cells as donor cells, was inseminated and conceived with frozen-thawed semen.

Buffalo

Under field progeny testing programme (FPT), 4,129 AI with the 6 test bulls of XV set were performed in adopted villages. Monthly test day milk yield was recorded for 138 daughters, recording of 66 daughters is in progress.

Milk production performance of Murrah buffalo herd relating to overall wet average (8.25 kg) and herd average (5.77 kg) were the highest since inception of the project and revealed an improvement of 3.0 and 16.15%, respectively, as compared to the earlier records. Overall wet average and herd average were 8.48 kg and 5.98 kg, respectively, for Nili Ravi herd, which revealed an improvement of 2.79 and 12.41%, respectively, over the earlier performance.

Young Murrah bulls (15) were tentatively selected as future breeding bulls and 6 superior males were selected for test mating in 15th set. A total 127,209 and 31,474 semen doses of Murrah and Nili-Ravi bulls, respectively, were frozen.

Clone of Endangered Wild-buffalo of Chhattisgarh

A clone of the only alive wild-buffalo in Chhattisgarh in semi-captivity was born on 12 December 2014 through the 'Hand-guided Cloning Technique' at ICAR-National Dairy Research Institute, Karnal. The female calf named **"Deepasha"** weighed 32 kg at birth. This novel achievement of producing cloned calf from endangered species has opened up new windows of applications of cloning technology. Scientists are of the opinion that besides multiplication of superior germplasm through cloning, conservation of endangered species should also be initiated.

Buffalo cloning

A female cloned calf named **'Apurva'** was born on 5 February 2015 by normal parturition with birth weight of 37 kg. The calf is a clone of an elite Murrah buffalo (MU-5345) of NDRI Livestock Farm. Earlier, another cloned calf **'Lalima'** was produced from the same buffalo. In this case the donor cell was isolated from urine of the donor animal. This is the first report in the world across the species of cloned embryos produced using somatic cells isolated from urine.

Sheep

Increasing prolificacy in sheep: Prolific sheep strain developed at the Institute is being evaluated for its overall performance. GMM × P (Garole-Malpura-Malpura × Patanwadi) sheep at birth, 3, 6 and 12 months attained body weights of 3.35, 17.53, 27.51 and 36.01 kg, respectively. Tupping rate and lambing per cent on available basis in GMM × P ewes was 100.0 and 92.50%, respectively. Multiple births were 40.54% with litter size of 1.43. In field condition, the lambs born from GMM × P ewes at birth, 3, 6 and 12 months attained body weights of 3.18, 14.42, 24.00 and 28.20 kg, respectively. In total, 15 lambs were born out of 10 lambing from 5 prolific ewes till date with a multiple birth of 50%.

Prolific (GMM × P) sheep

Network Project on Sheep Improvement

Presently, there are six ongoing cooperating centres of NWPSI in the country with its coordinating unit at

Performance of sheep breeds under the Network Project

Breed	Average body weights (kg)					Annual GFY (kg)	Tupping (%)	Annual lambing (%)	Survivability (%)	Sale of rams
	Birth	3 m	6 m	9 m	12 m					
Marwari	3.19	16.45	23.03	28.33	31.09	1.48	97.5	87.2	97.7	77
Muzaffarnagari	3.60	17.03	26.84	33.34	38.34	1.29	97.3	88.3	97.2	125
Deccani	3.47	16.13	24.54	25.83	28.69	1.03	97.1	90.1	97.9	66
Nellore	3.01	15.20	21.03	25.21	29.01	-	95.2	84.1	96.1	70
Madras Red (field)	2.58	11.53	15.59	-	20.53	-	-	85.5	-	85
Magra (field)	2.45	16.29	23.19	-	30.34	-	-	79.7	-	98

GFY, Greany fleece yield.

ICAR-CSWRI, Avikanagar. Four of these units are farm based while two are field based.

Marwari, Muzaffarnagari, Deccani and Nellore sheep are maintained under Farm Units for improvement through selection and production of superior germplasm. Average fibre diameter, medullation and staple length of Marwari sheep wool were 37.28µ, 55.76% and 4.59 cm, respectively, whereas average fibre diameter, medullation and staple length of fibre in Magra wool were 36.17µ, 47.27% and 5.66 cm, respectively. Under field project, 11,296 Madras Red sheep and 8,212 Magra sheep were registered for performance recording and improvement. Identification and performance recording of progeny was strengthened and 810 Madras Red lambs were individually identified by tagging/tattooing during the year. In Madras Red field flock 85.50% lambing was observed. Artificial insemination (AI) with oestrous synchronization was implemented to accelerate superior germplasm dissemination and enhanced ewe coverage. AI Units were established at Magra and Madras Red Sheep Units.

Mega Sheep Seed Project

The major objective of the project is improvement of indigenous sheep breeds in their respective breeding tracts by providing genetically superior germplasm to the farmers in terms of distribution of elite rams as well as estrus synchronization coupled with artificial insemination of the ewes with freshly diluted liquid semen; the project has five cooperating units.

Chhotanagpuri Sheep Unit, BAU, Ranchi (715 Chottanagpuri sheep; including 433 breeding females), Mandya Sheep Unit, KVAFSU, Bidar (440 Mandya sheep including 257 breeding females); Mecheri Sheep Unit, TANUVAS, Chennai (nucleus flock of 749 Mecheri sheep; including 392 breeding females); Sonadi Sheep Unit, RAJUVAS, Bikaner (487 Sonadi sheep including 256 breeding females); Malpura Sheep Unit, ICAR-CSWRI, Avikanagar (730 Malpura sheep including 353 breeding females) were built up for production of high performing sheep seed. Superior rams were distributed to registered farmers for improvement of their flock.

Goat

Increasing production performance: Selective breeding of Jamunapari, Barbari, and Jakhrana goats

showed significant improvement in body weights, milk yield and wool production. The average body weights at birth, 3, 6, 9 and 12 month age in Jamunapari were 3.29±0.04, 12.78±0.14, 18.12±0.30, 23.55±0.38 and

Mandya sheep flock

Improving goat productivity in Farmers' flock

The implementation of goat husbandry technologies in the famers' flock across country through AICRP on Goat Improvement significantly affected conservation and improvement of goat genetic resources, as it increased population of goats true to the breed and productivity amongst 13 descript breeds and 3 lesser known genetic resources. Significant improvement in body weights (19 to 43%) at different ages, in milk yield (12 to 31%) and in prolificacy (8-17%) was observed in different breeds. Considerable improvement in survival rate due to adoption of health and management practices at farmers flock (e.g. mortality in Bengal kids at Ranchi Unit was reduced from 69 to 12.5% and in adults from 35 to 8.5% over the years) resulted in higher population growth. Annual income from sale of Black Bengal goats has increased from ₹ 8,000 to 14,500 (small frock <10 goats) and ₹ 15,000 to 28,000 (large flock >15 goats). Project has contributed significantly to biodiversity conservation.

28.31±0.48 kg and in Barbari goats 1.54±0.02, 8.55±0.09, 13.40±0.16, 19.14±0.33 and 22.69±0.41 kg, respectively. In Jamunapari goats 90 and 140-days milk yields were 78.08±2.376 and 110.68±3.79 litre and in Barbari goats 140 days milk yield was 85.16±2.32 litre. The body weights in Jakhrana goats were 2.74±0.09, 9.93±0.56, 15.80±0.18, 20.24±0.69 and 22.75±0.75 kg at birth, 3, 6, 9 and 12 months, respectively. The overall mortality in the institute flocks was less than 4%.

Pig

Pig for fattening purpose: Pure parental lines of Hampshire and Duroc (male), and Ghungroo (female) pigs were used as exotic and indigenous germplasm, respectively, for producing the triple cross ($D_{50}H_{25}G_{25}$). The productive, reproductive and adaptive characters of developed population of Variety-I ($H_{50}G_{50}$) were stabilized by few generations of *inter-se*-mating. Subsequently, selected Variety-I female pigs were crossed with Duroc males, which was used as terminal sire due to its high potential of lean meat production with superior growth rate. The crossbred animals showed significantly higher body weight and pre-weaning and post-weaning growth rate. Mass scale production of these animals was initiated at the institute farm for supply to farmers.

Triple cross pig variety developed at ICAR-NRC on Pig

Poultry

Rural poultry: Pure lines, viz. PD-1 (Vanaraja male line), PD-2 (Vanaraja female line) and PD-3 (brown egg layer line) were maintained for use in developing rural chicken varieties. In PD-1 line, the shank length and body weight increased considerably in the present generation. In PD-2 line, the egg production up to 52 weeks in S-12 generation showed an improvement of 1 egg over previous generation on phenotypic scale. In PD-3 line, the body weight at 4 and 6 weeks of age was 178.3±0.05 and 276.6±0.04 g, respectively. The shank length at 6 weeks of age was 54.0±0.5 mm. The ASM was 159.0±0.03 d and body weight at 20 weeks of age was 1,349.6±64 g. In the SL-4 generation of Gramapriya Male Line (GML), the shank length at 6 weeks improved by 3.23 mm over the previous generation.

Adult pair of PD-2 line

AICRP on Poultry Breeding

Under the AICRP on Poultry Breeding, ICAR Research Complex for NEH Region, Agartala; NDVSU, Jabalpur; AAU, Guwahati; BAU, Ranchi; CSKHPKVV, Palampur and MPUAT, Udaipur are involved in rural poultry production. At Agartala centre, the body weight at 8 weeks in Tripura Black, Dahlem Red and ND cross [(Tripura black × CSFL) × DR], egg production up to 40 weeks of age were studied. Hen housed egg production in Jabalpur color (JBC) and 40 weeks egg weight and egg production in Kadaknath (Kd) were studied at Jabalpur centre. Three-way cross, Kamrupa [(PB-2 × Indigenous) × Dahlem Red female] besides the native, Dahlem Red and PB-2 populations were evaluated at Guwahati centre. Annual hen housed egg production in the native population and BN (broiler × native) cross were studied at Ranchi centre. Native (G-2), Dahlem Red (DR), 2-way (DR ×Native) and 3-way [(Native × Dahlem Red) × Dahlem Red] crosses were evaluated at the CSKHPKV, Palampur centre. The egg weight was 59.0 and 45.8 g in Dahlem Red and native population, respectively, at 40

Poultry Seed Project

Improved poultry germplasm for rural poultry was supplied through six centres located across the country. Chicks (259,086) of improved germplasm were distributed to the farmers by the centres in their respective regions. The Patna centre distributed 45,864 improved germplasm; Kolkata centre 61,835 chicks; Durg centre, 16,996 improved chicken germplasm; and Jharnapani centre supplied 63,210 germplasm to the farmers. Gangtok centre distributed 36,401 improved chicken germplasm to the farmers across Sikkim. At Imphal centre, 34,780 improved rural chicks were distributed to the farmers in Manipur. The Seed Project has been strengthened during the XII plan with addition of five more centres.

weeks. The Dahlem Red produced 67 eggs up to 40 weeks of age, whereas native population recorded 40 eggs. The hen housed egg production in D×N cross was 54 eggs in farm.

At the MPUAT, Udaipur centre, G-4 generation of native germplasm was evaluated for body weight at 8 weeks of age, hen housed and hen day egg production up to 40 weeks. During the third evaluation (E-3), Pratapdhan was evaluated up to 72 weeks of age. The pullets matured 4 days earlier as compared to last generation. The hen housed egg production up to 72 weeks of age was 97 eggs in E-3 generation.

Poultry for eggs: Pure lines of White Leghorn chicken (IWD, IWF, IWN, IWP, IWH and IWI) were improved through intra-population selection under the AICRP on Poultry Breeding. At KVASU, Mannuthy centre, the egg production up to 40 weeks of age on hen-housed basis was 122 in IWN and 123 in IWP strains. The S-12 generation of IWN and IWP strains was evaluated at AAU, Anand. The egg production up to 40 weeks of age increased by 8.1 and 4.6 eggs, respectively, in IWN and IWP strains. The egg weights at 40 weeks of age increased by 1.36, 1.39 and 3.26 g as compared to previous generation in IWN, IWP and control populations, respectively.

The egg production up to 64 weeks of age was 230 eggs each in IWD and IWF strains during S-31 generation at SVVU, Hyderabad and up to 72 weeks of age it was 276 and 280 eggs, respectively. Egg weights at 64 weeks of age in IWD and IWF strains were 56.5 and 56.1g, respectively.

At DPR, four layer chicken lines (G-3 generation of IWH and IWI lines, S-11 generation of IWK line, and layer control population) were evaluated for the performance up to 52 weeks of age. As compared to previous generation, egg production up to 40 and 52 weeks increased in IWH population by 10 and 12 eggs, respectively. In IWI population, these increased by 8 and 1.5 eggs, respectively.

Poultry for meat: Under the Project, five synthetic coloured broiler populations were improved through mass selection for 5-week body weight in sire lines (PB-1 and CSML) and 5-week body weight along with egg production in dam lines (PB-2, CSFL and SDL). The Bengaluru centre evaluated PB-1 and PB-2 lines. The average 5-week body weight was 1,030 and 948 g in PB-1 and PB-2 lines, respectively. The Ludhiana centre regenerated S-39 generation of PB-2 and S-7 generation of PB-1 line along with control population. Over the last 10 generations, the genetic response for 5-week body weight in PB-2 line was 30.8 g/generation.

The CARI, Izatnagar centre evaluated CSML and CSFL and Control populations. Body weight at 5-week increased in all the populations. The Bhubaneshwar centre evaluated CSFL and CSML lines. Body weight at 5-week increased in both the selected populations as compared to previous generation. Colour broiler lines i.e. synthetic colour broiler male line (PB-1), synthetic colour female line (PB-2) and control broiler (CB) populations were maintained and evaluated. Genetic and

Adult pair of PB-1 line

phenotypic responses in 5-week body weight over the last 5 generations were 40.3 and 16.3g, respectively. In PB-2 line, 40 weeks part period egg production showed an improvement of 7 eggs over the last generation. The egg production up to 52 weeks improved by 8 eggs over the last generation.

Duck for farmers' field

Keeping in view the need of the farmers to have dual purpose (for both egg and meat production) colour plumage ducks with good adaptability and scavenging ability for their propagation in backyard system of rearing, crossbred were developed using males of White Pekin (meat variety) drake and females of Khaki Campbell (egg variety) duck through artificial insemination technology. The production, reproduction, body conformation and egg traits were evaluated in three management conditions, i.e. (i) intensive system (research farm of RC CARI), (ii) farmers' field through KVK, Khurda, and (iii) Integration with rice (CRRI, Cuttack). Crossbred ducks attained 1.60–1.80 kg (female) and 1.80–2.20 kg (male) by fifth month of age, sexual maturity at 18th week and 64 g of egg wt. The birds were best suited due to their colour plumage pattern and low mortality in all the three management situations.

Guinea fowl: A total of 33 lactobacilli isolates obtained from guinea fowl gut samples were screened for their probiotic potency through various *in vitro* tests. *L. plantarum* (LGFCP4) was identified as best probiotic candidate and selected for feeding trial in both guinea fowl and broiler chicken. The feeding of LGFCP4 was found effective in improving FCR and cell mediated immunity and showed competitive exclusion of *Salmonella* and *Escherichia coli.*

Fish

Captive breeding of *Rita chrysea:* *Rita chrysea*, an indigenous catfish endemic to Mahanadi river, Odisha,

Venn diagram showing shared and unique microbial species. GWG, Guinea fowl GIT in intensive system; GCR, guinea fowl crop in intensive system; IBG, broiler GIT in intensive system; ING, CARI-Nirbheek gut in intensive system

has good consumer preference and market demand fetching ₹ 250-300/kg. Captive stocks of *R. chrysea* were successfully induced bred in hatchery conditions. Fishes of 130-150 g were selected for induced breeding. The fecundity was estimated about 9,000-12,000/100 g body weight. The larvae hatched out in 24-26 h of incubation at 26-28 °C. Fertilization ranged between 70 and 80% and hatching rates 60 to 70%. Successful induced breeding would lead to hatchery seed production and grow out culture of this species.

Induced breeding of giant snakehead: Broodstock of giant snakehead, *Channa marulius* was raised in concrete cisterns and fishes of 700-950g were induced bred under hatchery conditions by hormonal treatment. Fishes spawned after 16-18 h. Eggs were floating, non-adhesive and light yellow. Its fecundity was about 2,000-6,000 eggs/kg body weight. Larvae hatched out in 40-44 h at 25-27ºC water temperature. Fertilization rate ranged from 75 to 85% and hatching 60 to 70%.

Induced breeding of milkfish: Milkfish has the ability to grow in brackishwater, seawater and even adapt

Modular farming system for mud crab

A three-tier modular farming system comprising three months nursery rearing, four months of mid grow out and three months of final grow out was developed for farming of mud crab. The three tier system is used in dividing the 10-month farming period into three groups, so that income could be generated by the farmer at each stage, in a short period of 3-4 months.

Mud crab instars on three months of nursery rearing attained weight of about 85g with survival rate of 45%. During mid-grow out of four months the crabs attained weight of about 280g with a production of 1,110 kg/ha. In three month final rearing, production was about 1,168 kg/ha with a survival rate of 80%. This form of modular production system enhances survival rate and production efficiency, and farmers are able to generate income at each stage of three to four months.

Success Story

Integrated multi-trophic aquaculture (IMTA) system

Integrated farming of cobia, *Rachycentron canadum* in cages along with raft culture of sea weed, *Kappaphycus alvarezii* was successfully accomplished at Mandapam, Tamil Nadu. The practice proved effective in increasing fish production in cages and alleviating adverse impact of organic load on the environment. Integration of seaweed rafts with cobia cages doubled the seaweed yield to 290 kg/raft. Cobia attained an average weight of 3.25 kg during culture period of six months. This is an initial step in developing an ecologically sustainable integrated marine fish farming system, where seaweed, mussel/oyster, lobsters, high value marine food and ornamental fishes could be farmed together.

Cobia sea cage farming along with seaweeds rafts; (*inset*) seaweed

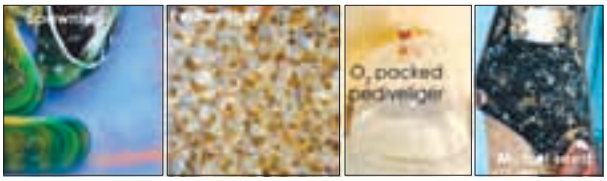
Milkfish (*Chanos chanos*)

to freshwater conditions. Fish consumes low protein formulated feed and grows up to 500-700 g size in 5-6 months. Fish were bred for the first time by ICAR-CIBA through hormonal manipulation. The fertilized eggs were hatched and reared to fingerling stage, which are suitable for farming. Milkfish with its ability to grow with other fishes and shrimp and also being disease resistant is an ideal fish suitable for polyculture, including pokkali farming practiced in Kerala.

Cost-effective feed: Pacific white shrimp, *Litopenaeus vannamei* covers almost 90% of the shrimp farming area in the country. The growth of *L. vannamei* was significant with the cost effective feed prepared by ICAR-CIBA. The feed gave FCR of 1.68 when tested in farmers' pond.

Litopenaeus vannamei produced using ICAR-CIBA developed feed

Seed production of green mussel: Mussel farming is practiced by collecting seed from natural habitat. ICAR-CMFRI developed commercial seed production technology to overcome the short supply of quality seeds for mussels and for expansion of mussel farming. Under this package of practice, about 1 lakh mussel spat can be produced in 1 tonne capacity FRP tank in 30-40 days and the same number can be nursery reared to seed size in small meshed nursery cages within 40-60 days with survival rate of more than 95%.



Various stages of green mussel seed production

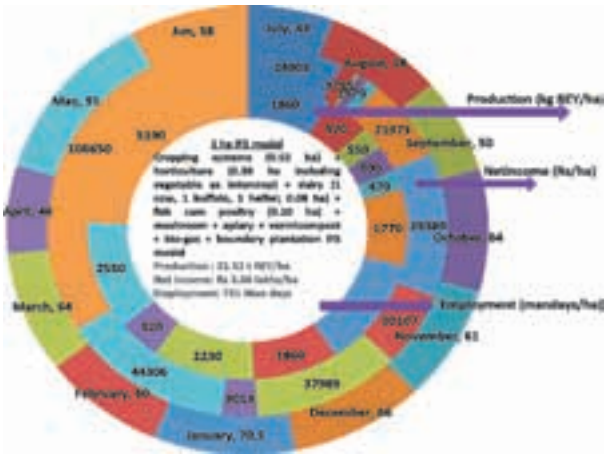
7. Crop Management

PRODUCTION

Food production can be increased substantially by upgradation of integrated strategies for cultivation of crop-plants and linking them to other disciplines.

Cereals

Integrated farming system model for round-the-year production: One ha integrated farming system (IFS) model comprising cropping systems (rice-wheat-mungbean, rice-potato-urdbean, rice-mustard-mungbean and berseem+oat-maize + sorghum with hybrid napier on bund) in 0.52 ha + horticulture (guava as main crop, lemon and mango (Amarpali) as boundary crop and



Integrated farming system model for round-the-year production (kg REY/ha), profit (₹/ha) and employment (man-days/ha) for the farm-family at Jammu (Jammu and Kashmir)

broccolii, knolkhol, cabbage, cauliflower, radish, okra as intercrops) in 0.30 ha + dairy (1 cow, 1 buffalo, 1 heifer) including biogas and vermicompost unit in 0.08 ha + fish-cum-poultry in 0.1 ha) + mushroom (dhingri and button) developed for the mid to high altitude plain zone (JK-1) in Western Himalayas provides round-the-year production (21.52 tonnes REY/year), profit (₹3.06 lakh/year) and employment (731 man-days/year). The maximum production and profit was realized in June while employment was generated in May month, suggesting opportunity of the work even during the lean period. The model also meets around 85% of the inputs required for different enterprises within the farm besides providing all the commodities (cereals, pulses, oilseeds, vegetables, fruits, mushroom, milk, egg, and fish) required for the farm-family.

IPM in rice: Adoption of IPM practice in over 100 acres of land in Mahanga block of Cuttack in farmers' participatory seed programme over a period of 3 years resulted in successful production of high-quality seed.

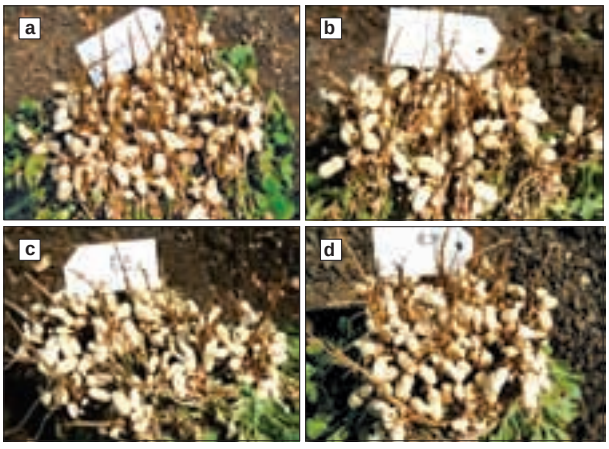
ITK-based botanicals for IPM in rice

ITKs of tribal farmers for the use of botanicals were validated scientifically for effectiveness against different insect-pests of rice. Neem (*Azadirachta indica*), karanja (*Pongamia pinnata*), water pepper (*Polygonum hydropiper*), parasi (*Cleistanthus collinus*), wild sugarcane (*Saccharum spontaneum*) and kochila (*Strychnus nux-vomica*) were employed through bio-intensive IPM in tribal area of Nilgiri block of Balasore district, Odisha. The ITKs were refined further before their implementation in farmers' fields for pest management in *kharif.*

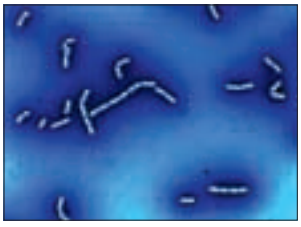
Seed treatment of Pooja and Gayatri varieties with 2% Carbendazim before sowing and need-based application of 0.5% neem oil + 2% detergent liquid or 0.05% Imidacloprid or 2% Chlorpyriphos as foliar spray for swarming caterpillar/case-worm/BPH/YSB kept the rice-crop pest- and disease-free. Monitoring of pests prevalence and their management at the initial stage of crop infestation/infection was the key factor for successful seed production.

Oilseeds

Moisture-deficit stress alleviation in groundnut: Endophytes *Bacillus subtilis* REN51N and *B. firmus*



Effect of application of endophytes on the pod yield of groundnut (cultivar TG 37A); cultivated without supplementary irrigations after sowing during summer 2015. (**a**) Control; (**b**) E2= *Pseudoxanthomonas mexicana* REN 47; (**c**) E3= *Pseudomonas pseudoalcaligenes* SEN 29; (**d**) E9= *Bacillus firmus* J22N.



Bacillus subtilis REN 51N, a root endophyte of groundnut

J22N isolated from seed, root and stem of groundnut were found effective in mitigating drought stress and enhancing growth and yield of the crop. Yield enhancement up to 40% in cultivar TG 37A was recorded over uninoculated control under extreme moisture deficit (soil moisture at 0-10-cm zone below 5%)

Conservation agriculture for groundnut-wheat system: Minimum tillage increased pod yield and net returns as compared to the conventional tillage. Wheat stubble retention + *Cassia tora* mulch increased pod yield and net returns compared to no residue application.

Plant-growth promoting rhizobacteria in soybean-maize: *Bacillus aryabhattai* MDSR 14 (JF 792521) and arbuscular mycorrhizal fungi co-inoculation significantly increased dry-matter accumulation, seed yield and phosphorus- use efficiency in soybean and maize intercropping. There was depletion of native organic-P and acid extractable-P and increase in inorganic-P in rhizosphere soil with co-inoculation; this indicates role of co-inoculation in mobilizing native unavailable organic-P and inorganic insoluble-P pool of soil to available-P.

Commercial crops

Cane yield enhancement through growth regulators: Application of ethrel, gibberelic acid (GA_3) and cytokinin at critical growth stages of sugarcane (90, 120 and 150 days after planting) in autumn-planted crop enhanced plant population to 11.6 lakh plants/ha against 3.83 lakh plants/ha in the control at 180 days after planting. Tiller survival of 61.8%, number of millable canes (NMC) 4.43 lakh/ha and cane yield of 330 tonnes/ha were recorded against tiller survival of 60.8%, NMC of 1.52 lakh/ha and cane yield of 129 tonnes/ha in control.

Enhancement of cane yield through growth regulators—(**a**) Control; (**b**) Ethrel+GA_3+cytokinin

Horticulture

Fruit crops

Variable response of different shoots on tree to the same environmental stimuli appears to be one of the major reasons leading to staggered flowering in old Alphonso mango trees. Observations on leaf net P_N, revealed that more than 70% of the older leaves (> 6-8 months) on trees were photosynthetically inefficient (-7.7 to 1.5 µ moles/m^2/s) as compared to relatively younger leaves (3-11.5 µ moles/m^2/s) irrespective of the month in a year. Complete defoliation of trees resulted in highly synchronized vegetative shoot formation with the primordia getting activated within 5-7 days in Alphonso mango.

Application of paclobutrazol from fourth year at 0.125 or 0.250 g/tree/year of age to alphonso mango on olour rootstock under high density (1,111 trees/ha) planting was stabilized by the tenth year. The orchards gave more than five-fold increase in fruit yield during the initial 15 years (93.95 and 94.99 and t/ha, respectively) over the conventional planting at 100 trees/ha (17.48 t/ha).

In mango, application of 50% recommended dose of fertilizers + 50 kg FYM + 5 kg vermicompost recorded higher yield (59.6 kg/tree) than the control (25.52 kg/tree) at Sangareddy in variety Banganapalli.

The sodium caloride induced salinity (3.83 ds m^{-1}) in papaya resulted in increased number of days to flower, higher percentage of male plants, and decline in pollen viability in cv. Red Lady as compared to cv.CO-4. The ultradried seeds of Arka Prabhat with 4.1% moisture, stored at ambient temperature and at 15 ^{0}C showed higher germination percentage (83 and 86) compared to those dried at 8% moisture content.

Application of black polythene mulch on sloping surface in interspaces of guava followed by 10 cm thick coir waste mulch in basin retained 41-50% more moisture than the control after 75 days of rainfall cessation. Application of 50% recommended dose of fertilizers + 25 kg FYM + 250 g *Azotobacter* recorded higher yield of guava at Sangareddy (36.26 kg/tree) and Udaipur (29.26 kg/tree).

Doubling planting density (500–1,000 plants/ha) in fig from increased yields in cv. Poona from 1.3 to 3 t/ha and in cv. Deanna from 2.5 to 4.8 t/ha.

In macropropagation of banana, application of sawdust + BAP (4 ml) + *Bacillus substillis* (30 g) produced more number (18.5) of plantlets in Grand Naine (24.3), Tellachakkarakeli (31.38) and Karpura Chekkarakeli (20.0).

Application of farmyard manure (FYM) @ 10 kg + neem cake @ 1.25 kg + vermicompost @ 5 kg and wood ash @ 1.75 kg/plant + triple Green manuring with sunhemp (one time) and cowpea (two times) along with biofertilizers, viz. AM (25g/plant), *Azospirillum* (50 g/plant), PSB (50 g/plant) and *Trichoderma harzianum* (50 g/plant) registered higher yield in Grand Naine (46.8 t/ha - 70.84 t/ha) and Nendran (24.44 t/ha) banana.

Mulching with black polyethylene paper in pomegranate resulted in improved fruits weight (273.91 g) and fruit yield (23.08 kg/tree) with low incidence of wilt (die-back) and fruit spots.

Application of 50% recommended dose of fertilizers + 50 kg FYM + 5 kg vermicompost recorded higher yield in Rose Scented (53%), Bombay Green (46%), Shahi (49%) and Mandraji (34%) varieties of litchi over the control. Foliar spray of K_2HPO_4 (1%) + KNO_3 (1%) in litchi resulted in early flowering by 6 days and increased fruit weight (23.27g), TSS (21.57°B), fruit yield (82.33 kg/plant) and reduced fruit acidity (0.341%).

Vegetable crops

In onion cv. Arka Kalyan and Arka Nikethan, both ultradried seeds (H"3% moisture) and seeds with 5.2% moisture maintained > 90% germination and vigour even after 50 months irrespective of storage temperatures (ambient and at 15 ^{0}C). Spray of 5000 ppm ethrel 45 and 60 days after planting resulted in reduced (55%) scape length in onion.

Mushroom

The technology for production of iron-fortified mushrooms was standardized. The iron content of fortified oyster mushrooms (*Hypsizygus ulmarius*) was increased by 143% over the control. By using short duration cultivation technology for shiitake mushroom the first harvest could be taken in 45 days as compared to 75-80 days in previous technology.

Spices

Based on soil test values, fertilizer recommendations for Appangala 1 and Green Gold varieties of cardamom were developed for fixed target yield. In both the varieties, the recorded yield were higher in target specific application (690–1140 kg/ha) as compared to general recommendations (470–690 kg/ha). Application of irrigation (9 litres/clump/day) with 100% RDF through drip in small cardamom recorded highest capsule yield (207.41 kg/ha), followed by 9 litres/clump/day with 75% RDF (201.23 kg/ha).

In turmeric, under integrated nutrient management system (50% organic + 50% chemical + micronutrient), variety Sudarsana recorded highest fresh yield (31.3 t/ha). The protray technology of rapid multiplication of turmeric through single bud rhizome was successfully demonstrated to farmers in Tamil Nadu and Andhra Pradesh.

Maximum saffron yield (5.43 kg/ha) and B:C ratio (4.63) was obtained by planting 10 lakh corms/ha on raised bed system with sprinkler/drip irrigation, while maximum propagation co-efficient (515.6%) was recorded in fifth year on raised beds with sprinkler irrigation and 5 lakh corms/ha plant population.

Medicinal and aromatic plants

In *Coleus forskohlii* variety, K 8, planted in September produced maximum dry tuberous root yield (18.5 q/ha) with improved forskolin content (0.7%), leading to 12.95 kg/ha forskolin yield, 180 days after planting. In ashwagandha (*Withania somnifera*) variety, JA 20, maximum root yield (272.46 kg/ha) and seed yield (227 kg/ha) were obtained with July planting. Under organic cultivation, kalmegh (*Andrographis paniculata*) planted in June produced maximum dry biomass (3848 kg/ha) with two cuttings (at 60 days interval) with a B: C ratio of 1.55.

Tuber crops

The low input management strategy comprising NUE genotype (Ac. No. 906) with low-cost soil fertility management involving soil test based application of fertilizers (NPK @ 106:0:83 kg/ha), green manuring *in situ* with cowpea as organic source and use of nutrient mobilizing biofertilizers resulted in a significantly higher tuber yield of 36.46 t/ha with a saving of 10-20% in cost of cultivation.

The green manuring *in situ* with cowpea in elephant-foot yam (EFY) yielded higher (31.9 t/ha) over application of FYM @ 12.5 t/ha (24.9 t/ha). Fertigation (RDF) (40 splits) at 4 days interval produced maximum corm yield (38.3 t/ha) in EFY. Flood irrigation over 1-24 weeks and drip irrigation at 100% CPE (cumulative pan evaporation) during 13-24 weeks yielded at par (41.9 t/ha).

Plantation crops

A soil-based AMF bioinoculant, *Ker*AM, was released. The bio-inoculant contains *Claroideoglomus etunicatum*, one of the dominant AM species isolated from coconut agro-ecosystem with high potential to increase the growth of coconut seedlings.

Application of borax@120-180 g/palm with husk burial resulted in amelioration of boron deficiency symptom in 65% palms.

In laterite soils, spraying of 0.1-0.3% $ZnSO_4$, or soil application of 10 g $ZnSO_4$/palm and skipping of nitrogen/phosphorus application in arecanut reduced disorder like crown choking, bending and cross nodes, with normal growth of emerging leaves in young palms of less than 10 years age.

A procedure for culturing oil palm (*E. guineenis* and *E. oleifera*) embryo in MS medium by excising fresh embryos to silica gel for 8-10 hours and storing in liquid nitrogen after desiccation to prevent contamination was standardized.

Floriculture

In China aster cv. Arka Kamini, seeds with normal moisture (5.9%) and stored in ambient conditions showed no germination, whereas seeds at 15 °C maintained original germination irrespective of seed moisture content. Ultra dried seeds gave higher germination (74%) and vigour even under ambient conditions but showed signs of decline compared to the controlled temperature storage (germination 79%) after 43 months .

Potting mixtures were standardized for commercial cultivation of *Cymbidium*, *Dendrobium*, *Vanda*, *Oncidium Phalaenopsis* and *Cattleya.* The standardized mixtures are: for *Cymbidium* = coco-chips + cocopeat + brick pieces (3: 1: 1v/v) + slow release fertilizer @ 5g/pot; for *Dendrobium* = cocopeat + brick pieces + tree bark (1: 1: 1); for *Vanda* = coco-chips + brick pieces + leaf fern (1:1:1); for *Oncidium* = coco-chips + brick pieces + leaf moulds (1:1:1) ; for *Phalaenopsis* = coco-chips + brick pieces + leaf moulds + green moss (1:1:1:1) and for *Cattleya* = coco-chips + brick piece + leaf mould/leaf fern (1:1:1)

CROP HEALTH MANAGEMENT

Crops are influenced by an array of biotic stresses, which need to be managed to sustain productivity. The year

witnessed a number of crop -pests like armyworm, white-fly, white grubs, pink bollworm etc. on cereals, vegetables, cotton and pulses. The invasive insect, *Tuta absoluta*, the South American pin-worm, affected many states after its first introduction into the country during the last year. All around prevailing threat of climate change is further adding to crop losses owing to pests and diseases. Incorporation of biofertilizers, particularly microbial, beneficial algae and bacteria in agricultural practices is now realized to have a vital role in promotion of soil- health. Biological control based IPM through deployment of parasitoids, predators and microbials has already gained visibility and can bring in holistic management of insect-pests and diseases.

Plant quarantine

A total of 136,257imported samples including transgenic and trial materials were processed for quarantine clearance. Of 14,374 samples infested/infected with different pests, 14,187 samples have been salvaged. Important interceptions include- **fungi-** *Rhizoctonia solani* and *Periconia hispidula* in paddy from the Philippines;*Stenocarpella zeae* and *S. maydis* in maize from Indonesia, Mexico, Columbia, Nigeria, the Philippines and Zimbabwe; *Lasiodiplodia maydis* in maize from Indonesia, the Philippines, Thailand and USA; *Colletotrichum graminicola* in sorghum from Argentina and Mali;*Drechslera setariae* on sorghum from Argentina; *Pseudoperonospora cubensis* in bottlegourd from the USA;*Peronospora manshurica* in soybean from Costa Rica and the USA;*Lasiodiplodia* spp. and *Rhizoctonia bataticola* in cotton from the USA; *Tilletia barclayana* on paddy from China and maize from the Philippines and Thailand; **insects-** *Bruchus ervi* on lentil from Lebanon; *Sitophilus oryzae* and *S. zeamais* in paddy from the Philippines; *Corcyra cephalonica* in maize from Nigeria; and *Trogoderma granarium* from the USA; *Cryptolestes ferrugineus* in sorghum from Mali; **viruses-***Arabis mosaic virus* in soybean and lima-bean; *Tomato ring spot virus*, *Peanut stunt virus* and *Tomato black ring virus* in soybean and cowpea; *Grapevine fan leaf virus* in soybean from Canada, Costa Rica, Nigeria, USA; **nematodes**- *Aphelenchoides besseyi* in paddy from China, the Philippines, Brazil, USA; *Tylenchorhynchus* spp. in blackberry from the USA; and **weeds-***Bifora testiculata*, *Galium aparine* and *G. tricornutum* on barley from Lebanon ; *Echinochloa colona* and *E. crus-galli* on paddy from Brazil.

Plant quarantine and biosecurity alert

A consignment of six metric tonnes of seeds of basil (*Ocimum basilicum*) imported from Germany was thoroughly examined for invasive as well as any other pests/diseases of quarantine significance. Based on thorough experimental procedure of testing of seeds and risk assessment, imported consignment was found contaminated with four species of weed seeds.

Taxonomic characterization led to identification as *Asphodelus fistulosus* and *Atriplex patula*, which were not known to occur in India and hence were of high quarantine risk. Based on the information, inactivation of the seeds through irradiation or heat treatment was advised. DPPQ&S, MOA and FW was advised to inactivate the seeds in the consignments through irradiation or heat treatment.

Pre-harvest crop-health monitoring

Wheat-crop health was rigorously monitored during normal as well as off-season in high hills of Himachal Pradesh (Lahaul, Spiti, Kullu), Nilgiri hills (Tamil Nadu) and jammu and Kashmir (Ladakh). Though the yellow rust was observed in early January 2015; however, due to resistance in cultivated varieties as well as proactive steps taken for the management, this could be managed well. In Karnataka, leaf rust was observed in Lokur area of Dharwad in January 2015 in Local bread wheat variety (parrot green colour ear-head).

In Maharashtra, leaf rust was observed in January 2015 in village Kenjal (Satara), on var. Lok1. Except for the yellow rust in NHZ and NWPZ, the overall crop health status was satisfactory in the country.

ICT-based pest surveillance and advisories

e-pest monitoring was implemented across 33 districts, 348 talukas and 43,000 villages under Crop Pest Surveillance and Advisory Project at Maharashtra on five crops– soybean, cotton, rice, pigeonpea and chickpea. Dissemination of pest management advisories using short message services numbering 9310, 14171, 15193, 8097 and 10594 were made for the crops, respectively, based on the economic threshold levels of different pests. A total of 36 forecast models were developed for predicting population levels of thrips and white flies on cotton for the North Western India.

Cereals

Pathotype distribution of wheat rusts

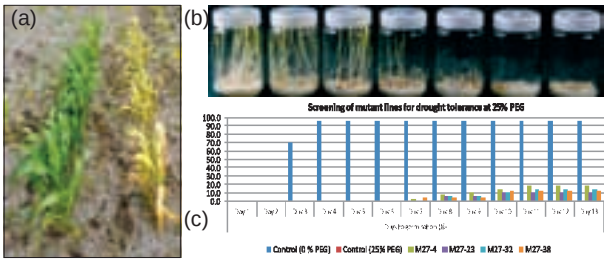
***Yellow rust of wheat* (Puccinia striiformis):** Prevalent races of yellow rust of wheat was avirulent to rust resistance genes: *Yr*5, *Yr*10, *Yr*13, *Yr*14, *Yr*15, *Yr*26, *Yr*Sp and*Yr*Sk. Pathotype 46S119, virulent against *Yr*9 and*Yr*A, was observed in more than 72% of the analyzed samples. Four new pathotypes with more virulence than the existing pathotypes were documented during the season. They appeared to have originated as a result of mutation in the existing pathotypes on Suwon × Omar and Riebesel 47/51. These new pathotypes were designated as 110S119, 238S119, 46S117 and 110S84.

***Black rust of wheat* (P. graminis tritici):** Virulence on *Sr*31 (Ug99 type pathotype) was not documented anywhere in India. Population of black rust of wheat was avirulent against a number of host genes including *Sr*26, *Sr*27, Sr31, *Sr*32, *Sr*35, *Sr*39, *Sr*40,*Sr*43, *Sr*Tt3 and *Sr*Tmp. Among the eight pathotypes of black rust, pathotype 11 was observed in more than 50% of the samples, followed by 40A and 21-1.

***Brown rust of wheat* (P. triticina):** There was a shift in virulence pattern with pathotype 77-9; becoming more frequent in occurence in Tamil Nadu, Karnataka,

Maharashtra, Madhya Pradesh and Punjab. Three predominant pathotypes, i.e. 77-9 (38%), 77-5(32%) and 104-2 (14%) constituted 85% of the flora. Population of brown rust of wheat in the region was avirulent to leaf rust resistant genes *Lr*24, *Lr*25, *Lr*29, *Lr*32, *Lr*39, *Lr*42 and *Lr*45. Two new pathotypes designated as 107-2 and 20-1 were documented. They were, however, less virulent than the existing pathotypes and do not appear to have any epidemiological significance.

Induced mutations in sorghum for herbicide tolerance: Induced mutant progenies of M35-1 (Maldandi) were screened for resistance to glyphosate herbicide (round-up) from M_2 onwards. Four mutant lines showed tolerance to glyphosate in M_2 and M_3 generations, when screened against 0.4% herbicide.



(**a**) M 35-1 mutant line showed resistance to 0.4% glyphosate compared to control; (**b**) Polyethyleneglycol (PEG); (**c**) PEC 17 derived mutant lines showed germination in 25% PEG compared to control

Identification of QTLs conferring resistance to diseases in wheat

Karnal bunt: A set of 75 wheat recombinant inbred lines (RILs) developed from a cross between Karnal bunt susceptible (WH 542) and resistant (ALDAN) genotypes were screened for two years with the pathogen populations prevalent in the north India. Parental genotypes were screened with 330 SSR markers; out of which 16% showed polymorphism. Analysis of variance revealed significant differences in disease severity among RILs (G), years (E) and G × E interactions over two years (2012-13 and 2013-14). A QTL (Qkb.dwr-5BL.1)-mapped between the marker *Xwmc235* and *Xbarc140* on chromosome 5B accounted for 16.9-18.0% of phenotypic variation.

Spot blotch: In 209 lines of a mapped population, derived from the cross involving Sonalika and BH 1146, two stable QTLs for spot-blotch resistance were identified on chromosome 7BS (QSb.iiwbr-7B) and 7DS (QSb.iiwbr-7B) at LOD score above 2.4, which explained phenotypic variation (R2) of 11.4% and 9.5%, respectively. These two QTLs were detected in three environments and for three years consecutively.

Oilseeds

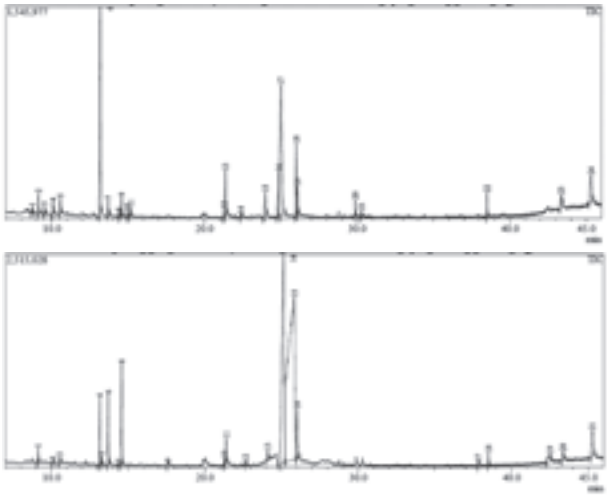
Managing insect-pests of groundnut: Intercropping *bajra* with groundnut (3:1) supported lowest population of thrips, hoppers and aphids as compared to other intercrop combinations. Among three bio-pesticides tested for efficacy on sucking pests, Ponneem (an organic preparation containing 45% neem oil, 45% pungam oil and 10% soap solution) @ 6ml/L and azadirachtin 1.5% @ 7.5 ml/L were found effective in reducing leafhopper population significantly. Azadirachtin 1.5% @ 7.5 ml/L and standard check of Monocrotophos 36 SL @ 1.2ml/L were effective for checking thrips.

Success story

Integrated pest management in rice

Integrated pest management (IPM) technology in rice-crop was demonstrated successfully in farmers' participatory mode in cluster of villages around Gautam Budh Nagar, Uttar Pradesh. Need-based single application of Buprofezin by IPM practising farmers in selected plots as against 2-4 sprays of one or more chemical pesticides (Carbofuran, Phorate, Cartap Hydrochloride, Monocrotophos, Malathion, Imidacloprid, Fenobucarb, Dichlorvos and Hexaconazole) in farmers' practice (FP) was compared. The post-crop analysis showed enhanced levels of organic carbon content (11%), increased natural enemy count (spider population 1.36/hill in IPM against 1.05/hill in FP), and reduction in yellow stem borer (*Scirpophaga incertulas*) and leaf folder (*Cnaphalocrocis medinalis*) infestations. No infestation of brown plant hopper (*Nilaparvata lugens*) and incidence of Bakanae foot-rot (*Fusarium moniliforme*) were documented in IPM plots.

Stem-rot resistance basis in groundnut: Stem-rot (*Sclerotium rolfsii*) tolerant genotype of groundnut (CS 19) showed higher constitutive level of pyrocatechol, which is a substrate for polyphenol oxidase enzyme, 2-furancarboxaldehyde 5-(hydroxymethyl) and l-(+)-Ascorbic acid 2,6-dihexadecanoate as compared to susceptible genotype TG 37A. Besides constitutive level, the genotype also retained higher level of characterized metabolite post infection along with linoleic acid, which is a substrate of lipoxygenase enzyme.



A. Metabolites of stem-rot tolerant genotypes of groundnut at 30 DAS (non-infected) Line no. 4: Pyrocatechol, 6: 2-Furancarboxaldehyde 5-(hydroxylmethyl), 18: l-(+)-Ascorbic acid 2, 6-dihexadecanoate. **B.** Metabolites profile of stem-rot susceptible genotype of groundnut TG 37A at 30 DAS (non-infected) Line no. 2: Pyrocatechol, 4: 2-Furancarboxaldehyde 5-(hydroxylmethyl), 16: l-(+)-Ascorbic acid 2, 6-dihexadecanoate. Peak area of these metabolites is higher in CS19 than that of TG37A. Metabolites were analyzed by GCMS.

Damage caused in tomato field by *Tuta absoluta* (*top*), Efficacy of NBAIR NML lure (*bottom left*), commercial lure (*bottom right*) on *T. absoluta*

Biological control

Ecofriendly management of *Tuta absoluta*: Destruction of infested tomato-plants and fruits; preservation of potential natural enemies like *Nesidiocoris tenuis*, *Necremnus* sp., *Orius* sp. and *Trichogramma* spp.; mass trapping of male moths both in nursery and main field (40 traps/ha) using nanomatrix lure trap; use of biopesticides (*Bacillus thuringiensis, Beauveria bassiana*) and entomopathogenic nematodes showed a great promise in management of this pest.

Predators documented: A new invasive mealybug, *Phenacoccus madeirensis* Green, known to occur in South American region, was recorded in severe form in Chamrajnagara (Karnataka) on cotton; infesting 80% plants. Some of the commonly affected host-plants are cotton, hibiscus, tomato, potato, brinjal, Acalypha, etc.

Predator of *Phenacoccus madeirensis*

A potential gnat predator, *Diadiplosis hirticornis*, was documented infesting invasive mealy bug *Phenococcus madeirensis*. Unique association was observed between predator gnat and mealybug, wherein predator lays eggs (5-22) on mealy bug females resulting in maggots crawling into the ovisacs to feed on pest eggs. Predation of eggs was recorded in more than 60% of the ovisacs, and 12-16 gnats emerged from each ovisac. Gnat lives for 5-6 days, with a developmental period of 12-16 days. The predator can be mass produced easily in laboratory on pink mealybug, and can be utilized as a potential biocontrol agent.

Detailed leaf assay screening for castor against grey mold

A detached leaf technique was standardized to screen castor genotypes against grey mold caused by *Botryotinia ricini*. Abaxial surface of the detached castor leaf was inoculated with agar disc (5 mm) cut out from margin of a 7-day-old culture. The inoculated leaf was incubated at 25° C and 90% RH with periodic wetting. in a petri-dish lined with moist blotting paper. The petiole of the infected leaf was covered with moist cotton-swab to maintain turgidity. The disease severity was recorded, starting from 3 days after inoculation. This technique can be used for rapid screening of castor genotypes.

Tuta absoluta: A New Invasive Pest

During October 2014 ,a new invasive pest was reported in Western and Southern regions of the country. *Tuta absoluta* also called South American pin-worm was observed initially in Pune on tomato-plants grown in polyhouses and fields. Subsequently, it was found infesting tomato in Karnataka in mild to moderate levels.

Survey carried out in five states and 15 places recorded up to 52.4% infestation of fruits and stems of tomato. The management of the pest was taken up with pheromone compound 3E, 8Z, 11Z -3, 8, 11-tetradecatrien-1-yl acetate on a nanomatrix for delivery. Field trials conducted at farmers' fields in Hosur (Tamil Nadu) and in and around Bengaluru (Karnataka) revealed that pheromone nanomatrix lure (NML) trapped 20% more moths than available commercial lure. The lure had a lower load of pheromone, making it highly cost-effective compared to conventional technology.

Biological control of pomegranate root-knot nematode

Successful biological control of pomegranate root-knot nematode, *Meloidogyne incognita*, was done in more than 100 acres of land where heavy infestation (480-760 J_2/200 cc of soil) of nematode had been causing losses since 2010. Field application of two bioagents, *viz*. *Trichoderma viride* and *Pseudomonas fluorescens*@ 20 kg/ha resulted in reduction of nematode population by 42.1 and 37.5% with concomitant increase in yield by 53.45 and 38.45%, respectively. Farmers were also demonstrated integrated nematode management strategies through the use of healthy seedlings, clean cultivation, application of organic amendments (FYM/compost and neem-cake), intercrops (marigold) and need-based application of nematicides (Carbofuran 3 G and Phorate 10 G).

White grub management

Lepidiota mansueta a biennial species of white grub is a severe endemic pest of multiple field crops in Majuli river island of Asom. Mass-emergence of beetles occurs following pre-monsoon showers during April-May. Beetles were trapped by operating light traps in endemic pockets (during premating hours from 6.30-7.00 pm) as well by hand collection of beetle pairs in copula from 7.00-8.30 pm. Bio-ecological and behavioural research led to the concept of Social

Whitefly infestation in cotton in North India

Whitefly, *Bemisia tabaci* (Gennadius), one of the common sucking pests infesing cotton, also feeds on about 600 plant species. The adults and the nymphs suck cell sap resulting in leaf yellowing, wilting and thus there is an overall decline in seed-cotton yield. It further damages cotton directly, as it acts as a vector for leaf geminivirus on cotton.

During *kharif* 2015, unprecedentedly heavy infestation of whitefly on cotton was documented in Punjab and Haryana. Significant damage to cotton-crop occured in Punjab where more than 75% of the cotton-crop was delayed in sowing owing to late harvest of wheat. In Haryana, relatively lesser damage was noticed where nearly 50% cotton area could be timely sown. Deficient rainfall coupled with hot, humid and cloudy weather during June–Jumy led to severe whitefly outbreak. The heavy infestation was also influenced by a number of other factors, including lack of field sanitation including weed control, cultivation of susceptible Bt cotton-hybrids, using high doses of nitrogenous fertilizers, indiscriminate and injudicious use of tank mixes of unregistered pesticides, faulty spray application technology, and failure of active flow and field-translation of advisories issued by the ICAR and other agencies.

Acomprehensive strategy to prevent reoccurence of the pest during the next season has been planned.

Engineering/Farmers Participatory Approach as community action programme for management of adult *L. mansueta*. This mass campaigning explored group approach of extension, involving 400 farmers from 40 endemic villages, mostly from flood and erosion prone areas. The endeavour led to massive collection and killing of about 307,450 number of beetles in Majuli during 2010-2015. These efforts would have the potential of cutting down on to losses due to white grubs by 40-50% during subsequent years.

Cooked/fried adults of *L. mansueta* are relished by tribal people in the Majuli area. The beetles serve as the source of protein-rich food, having nutritional and nutraceutical value. Food-value analysis revealed that beetles contain carbohydrate (10.93%), fat (4.10%), protein (76.83%), fibre (5.16%), ash (2.98%) and seven dietary elements.

Processing, refinement and value-addition of beetles resulted in two dishes viz., Beetle fry and Roasted beetles, which have become popular among ethnic tribes and other communities of Majuli. The efforts have potential to improve both livelihood and nutritional security of the affected farmers.

Management of mites

Mite-tolerant rice: Mite infestation is becoming widely significant across crop commodities including field and horticultural crops. Rice varieties , BR 2655, Thanu and IR 64, were found relatively tolerant to sheath-mite damage in Mandya region of Karnataka. Similarly, okra varieties Aruna and Susthira and chilli variety K2 were found reasonably tolerant compared to the popular ones.

Bio-acoustics for managing higher vertebrates

Bio-acoustic gadgets equipped with alarm and distress calls of different animals when installed effectively warded off birds and wild animals from feeding on crops. The device protected sorghum and groundnut from wild boars. The calls from a single device effectively scared monkeys from damaging crops in 6 acres of land.

Suction trap for whitefly management

The device was designed and evaluated for its efficacy in trapping adult whiteflies. The shoulder mounted, portable trap helps in sucking whiteflies present on the underside of the cotton-leaves with minimal harm to natural enemy fauna and to cotton-crop. The adhesive

aluminium/fibre board fixed on the upper side of the trap acts as a sticky trap for trapping whiteflies, which are dislodged from the plant canopy with fan fitted with the device. Under heavy adult whitefly pressure, the trap could reduce whitefly adult population by 40-52%.

Management of depredatory birds

Bird management through bioacoustics: The call sequences involving alarm and distress calls were worked out to formulate an effective strategy for bird management in sunflower and sorghum. A total of 4 call

Ecofriendly protocol for trapping melon-fly

Fruit-flies (*Bactrocera* spp.) are one of the biggest limitations to profitable cultivation and trade of fresh fruits and vegetables. An efficient protocol to trap melon-fly was developed. The formulation neither required alcohol for impregnation nor any insecticide (like DDVP) to kill trapped insects. The trap used cuelure {4[4-(acetoxy) phenyl]-butanone} to attract fruit flies. Field studies with this formulation resulted in trapping 2.5 times more fruitflies compared to those caught by conventional trap

sequences were constructed by recording and analysing alarm and distress calls of 25 birds under field conditions. Call sequence 1 (CS-I) with 43 minutes of duration resulted in 42% efficacy involving 7 species of predatory/depredatory birds, while call sequence 2 (CS-II) of 15 minutes duration involving 12 species proved promising resulting into 59% efficacy. On the other hand call sequence 3 (CS-III) of 14.4 minutes resulted into 66.3% efficacy involving 17 species, while call sequence 4 (CS-IV) of 17.36 minutes duration gave maximum efficacy of 80-89% involving 17 species of birds. Call sequences constructed and tested at several locations were documented to provide protection to crop from the birds up to 25 days. CS-IV was found most effective in *rabi* with 89% efficacy and in monsoon with 70% efficacy.

Pea-fowl management through physical barrier (jute rope) in maize, groundnut and soybean: Fixing jute rope at 1 feet height around the sprouting crop with the help of pegs arranged at 1 metre distance and also making a checkered pattern forming 1m × 1m

squares above the crop with the same jute rope was found promising in containing entry of pea-fowl into crop fields. The pea-fowl damage was reduced up to 98% in maize, groundnut and soybean. The economics of this technique worked out to be ₹ 600 per acre (₹ 300 for jute rope and ₹ 300 for labour) thereby proving it to be cost-effective for practical application.

Fruit crops

The incidence of banana skipper, an invasive butterfly pest (*Erionota torus*) was recorded across Kerala in monsoon. For the management of *Fusarium* wilt on banana, dipping of suckers in Carbendazim (0.2%) for 30 min + drenching Carbendazim (0.2%) + 2% Carbendazim injection (3ml) at third, fifth and seventh MAP recorded least incidence of *Fusarium* wilt at Coimbatore (18.5% PDI, with 76.9% reduction in disease over the control) and Jorhat (29.6% PDI, with 53.5% reduction in disease over the control).

Complete genomes of three Banana Streak Virus (BSV) species were amplified and cloned. Complete genomes of Banana Streak Mysore Virus (BSMYV) and Banana Bunchy Top Virus (BBTV) were obtained. Transgenic banana plants resistant to BBTV were generated using BBTV replicase gene construct and the resultant 52 plants tested negative to BBTV. Multivirus resistant transgenic plants were generated using RNAi construct from 8 embryonic cell suspension (ECS) lines. The *Trichoderma asperellum* was effective in extending shelf-life of banana fruits by 28 days at 23°C and 55 days at 13°C. A protocol for the detection of Trizteza virus in citrus aphids (*Aphids citricola*) was validated.

Isolates of three *Pseudomonas* species (*P. geniculate, P. plecoglossicidia* and *P. fluorescens*) reduced pomegranate bacterial blight incidence by 58-66% and severity by 22-33% over the control. Silicon, salicylic acid and chitosan based formulations reduced pomegranate bacterial blight incidence by 75.5%, 74.5% and 71.5%, respectively, over the control.

The PCR amplification of Bhagawa, Nana, Daru and Ganesh pomegranate using the *in silico* revealed the presence of the *Xanthomonas* interacting gene homologous sequence in six out of eight genic primers.

Arid crops

Spinosad 2.5 SC @ 1 ml/litre and Indoxacarb 14.5 EC @ 1 ml/litre were effective in controlling ber stone weevil (8.8–9% damage) at Rahuri, Anatapur, Bawal and Jobner. Fruit rot on date palm was effectively controlled using *Trichoderma viride* + Azadirachtin (0.3%) + date leaf cover.

A real-time PCR protocol was developed at CPCRI, Kasaragod, for specific detection of *Phytophthora meadii*, causing fruit rot of arecanut. Self-grown *Colocasia* in arecanut garden was identified as an alternate host for *P. meadii* for initial establishment of inoculum in arecanut garden. A real-time LAMP (RT-LAMP) assay using the Genei II LAMP system, Optigene, was developed for detection of phytoplasma associated with root wilt disease of coconut and yellow lead disease of arecanut using the phytoplasma 16Sr DNA as target for amplification.

A tablet shaped botanical cake (each weighing 1.9 g) for the prophylactic leaf axil filling for management of adult rhinoceros beetles of coconut was developed. Y-tube response of rhinoceros beetle towards essential oils, viz. basil oil, ginger oil, citriodora oil, thymol oil and ajowan

oil showed 70–75% repellency. Area-wide bio-suppression of rhinoceros beetle indicated significant reduction in leaf damage by rhinoceros beetle (65.2–85.5%). A pest- weather regression model (PWRM) between log values of monthly rhinoceros beetle (RB) infestation and weather variables during 2010-2014 was established.

A prototype of red palm weevil detector based on acoustic system, which could be linked to mobile phones, was developed in association with Centre for Development of Advanced Computing (CDAC), Thiruvananthapuram. Evaluation of the entomopathogenic fungi on red palm weevil revealed that placement of three filter paper sachets containing 12–15 *Heterorhabditis indica*-infected *G. mellonella* cadavers on the leaf axils after application of 0.002% Imidacloprid could recover 60% of infested palms. Studies on effect of EPN on root grub population in coastal sandy soils showed that root zone drenching of EPN liquid formulation of *S. carpocapsae* (100-200ml solution) containing 0.5 x 10^6infective juveniles per palm during June-July and September - October resulted in 61% reduction of root grub population.

The leaf webworm on oil palm was identified as *Acria meyricki* (Depressariidae: Lepidoptera) which is a new species infesting on oil palm in India. The Mitochondrial Cytochrome Oxidase based DNA barcode was also generated.

Spices

Two strains (GRs-SIK and GRs-MEP) of *Ralstonia solanacearum* infecting ginger were sequenced using Illumina Next-Generation Sequencing Platform and the raw data was assembled using 'A5-miseq'; both the strains were also annotated using the software tool 'Prokka'. Reference based alignment with GMI1000 showed that 83% of reads properly paired with the reference genome. SNP calling indicated that there were 4,368 and 4,648 SNPs in GRs-MEP and in GRs-SIK, respectively. A total of 74 Type 3 effectors were present in IISR strains compared to those of 11 other strains of *R. solanacearum.*

Vegetables

Explorative surveys carried out in Bengaluru (Rural and Urban), Kolar, Chikkaballapur, Ramanagara and Tumkur districts in Karnataka indicated the presence of south merical tomato leaf minor in all the areas surveyed. The species identification was confirmed by both morphometric and molecular methods. The infestation of *T. absoluta* ranged from low to high in different tomato fields surveyed (up to 15 mines/plant). In some of the fields up to 87% of the tomato plants were infested.

Detection of seed borne tobamoviruses in vegetable crops

Seeds collected from infected plants (cucumber, capsicum and tomato) were tested for different tobamo viruses by ELISA and RT-PCR. There was externally seed borne infection of CGMMV (8%), PMMV (12%) and ToMV(14%) and none of the viruses were detected in embryo and cotyledon indicating absence of internal seed transmission of CGMMV, PMMV and ToMV in cucumber, capsicum and tomato.

Sequences of S-RNA and M-RNA of Indian isolate of Iris Yellow Spot Virus (IYSV), a tospovirus affecting seed onion crop were determined that showed > 95% identity with other known isolates and occurrence of intra- and inter- species recombination at intergenic region.

Orchids

An encyrtid wasp, *Anagyrus* sp. (Howard) as a parasitoid of long tailed mealy bug, *Psuedococcus longispinus* and mealy bug, *Pseudococcus* sp. infesting orchids was reported for the first time.

RNAi or gene silencing technology

The RNAi constructs were made for actin gene and also for vATPase gene isolated from tea mosquito bug *Helopeltis antonii*, a pest of cashew. Delivery of cognate dsRNA through sponge mimicking the cashew stem elicited feeding by the adults. The effect of RNAi was validated using RT-qPCR, which showed a 50% down regulation of these target genes. Silencing of OBP2 resulted in delayed host recognition based on the electro antennogram readings. Similarly, silencing of both vATPase and JHBP genes resulted in 80% mortality of treated aphids at 12.5 µg.

8. Livestock Management

Animal nutrition

Deconstruction of ligno-cellulosic biomass: Lignolytic enzymes (MnP manganese peroxidase, LiP lignin peroxidase and laccase) were produced from white rot fungi. PUF (polyurethane foam) cubes were the most effective biocatalyst for producing heat and pH stable enzymes with superior kinetic properties. *In vivo* and *in vitro* studies in sheep and cattle revealed that the enzyme treatment significantly improved the digestibility of the treated straws.

The laccase enzyme gene of *Schizophyllum commune* was cloned into *Pichia pastoris*, which was used to produce recombinant laccase enzyme. The bioactive recombinant enzyme could be produced extracellularly in the culture medium.

Canine-origin probiotic

A canine-origin probiotic (*Lactobacillus johnsonii* CPN23; cPRO) improved fibre digestibility, antioxidant level, cell mediated immunity and favourably altered the hind gut fermentation in dogs. It was superior to the dairy-origin probiotic. The cell-mediated immune response improved in the probiotic fed group. Evaluation of this probiotic in rats yielded similar results.

Cattle

Feeding of sugarcane mud up to 20% level in the concentrate mixture to growing calves as a feed ingredient had no adverse effect on growth, nutrient utilization, nutrient balance, rumen fermentation, microbial protein synthesis and blood biochemical profile of growing calves. Its inclusion in the feed, therefore, would further reduce feeding cost of both pre- and post- ruminant calves.

Supplementation of specific mineral mixture developed for temperate hills of Uttarakhand in oak leaves (*Quercus leucotricophora*) based diet (concentrate: roughage:: 40:60) improved nutrient utilization especially protein, fat and fibre in lactating crossbred cows. The milk yield and FCM yield in cattle improved by 8 and 10%, respectively.

Buffalo

In vitro rumen fermentation studies indicated that both sesame oil and mustard oil can reduce ruminal methane production; however, mustard oil exerted greater inhibitory effects on feed degradability and microbial biomass production. Hence, sesame oil proved better than mustard oil as methane inhibiting agent. Chelates of zinc, copper and manganese using different physio-chemical conditions were prepared to be tested for their *in vivo* effect on growing buffalo calves.

A feeding module on economic calf starter was developed using precision feeding approach. The precision feeding of calves improved growth rates and saved ₹ 10.40 on cost of feed/kg weight gain.

Sheep

Supplementing milk replacer: A milk replacer powder was developed (dried skim milk,350g; sesame cake,70g; groundnut cake, 80g; soy flour, 100g; wheat flour,100g; corn flour,100g; rice flour,100g; soybean oil,30g; linseed oil, 30g; mineral mixture, 20g; citric acid, 2g; butyric acid, 0.2ml; and Hyblend, 200mg). The cost of milk replacer powder and liquid milk comes to ₹ 115/kg and ₹ 19.50/litre. The milk replacer is fed to lambs @ 250ml/day from 15 to 90 days of age. Average daily gain in lambs was 170g and feed efficiency 2.13 in milk replacer supplemented lambs compared to 156g and 2.40 in lambs on conventional system. Cost of feed for 1 kg of body weight gain in milk replacer fed lambs was ₹ 51 compared to ₹ 68.10 under conventional system.

Deficiency biomarker: Copper chaperone for SOD (CCS) was evaluated as a sensitive biomarker of copper deficiency in sheep.

Goat

Methane production potential: Azolla *(Azolla microphylla)*, full fat mustard *(Brassica juncea)* seed, gram *straw (Cicer arietinum)* and concentrate mixture used for goat feeding were evaluated for methane production potential. The net gas production (ml/0.2g substrate) was the lowest in azolla (11.33 ml) and was the highest with concentrate mixture (44.0 ml), however concentration of methane in gas was almost similar among feed resources. The azolla produced lowest methane 1.52 ml/100 mg truly digestible substrate, followed by mustard seeds (2.29 ml), gram straw (4.33 ml) and concentrate mixture (4.89 ml).

***Moringa olifera* biomass based feed:** The biomass production of *Moringa* under cultivation is much higher than any other fodder crop. Complete feed was prepared using dry biomass of wild type *Moringa* tree (leaves and twig portion) and concentrate mixture for feeding of goats. The units of antioxidant property of plasma were higher and serum cholesterol level lower in moringa biomass based pelleted feed group than that in the goats fed traditional ration. The feeding of moringa based diet to goats, was cost effective and depended upon the production cost of moringa biomass.

Camel

Pelleted complete diet: Male camel calves fed on iso-caloric (65% TDN) complete feed pellet diets (50:50::R:C; 8.34% CP) showed better growth and nutrient utilization compared to normal feeding.

Rumen microbes in camel: From the C1 compartment fluid collected from camel, 4 microbes were isolated. Based on morphological, biochemical characteristics and on nucleotide homology and phylogeny, three were identified as *Bacillus subtilis* strain B11(1297 bp), *Bacillus subtilis* strain FS2 (1283 bp), *Bacillus subtilis* strain WZ3 (1299 bp), *Bacillus subtilis* strain FS2(1279 bp) and *Clostridium bifermentans* strain E051 (1323 bp).

Assessment of work efficiency in yak

Yak is used as pack animals by the highlanders. The work efficiency of yak was evaluated in different seasons through experimental study, besides recording of quantifiable parameters namely rectal temperature, pulse rate and respiration rate. During summer these parameters were the highest when animals carried load up to 20% of their live body weight. On the contrary during winter there was shift of quantifiable parameters when animals carried 34% of their live body weight. This could be concluded that during winter threshold level of yaks pertaining to carry load increase, which may be attributed towards fall of ambient temperature.

Mithun

Keeping-quality and shelf-life of the feed blocks containing different combinations of grass, tree leaves and fodders were studied up to 24 months. Comparatively a higher microbial i.e. fungus and bacteria, load was observed in the feed blocks containing either congo signal grass or tree leaves than those containing either napier or green maize.

Poultry

Linseed oil: Significantly higher total body weight gain was observed in the birds fed linseed oil and natural antioxidants. Linseed oil feeding improved the omega-3 content of meat by more than two folds and the supplementations of curry leaf, turmeric and commercial antioxidant enhanced the meat shelf life.

Coconut xylo-oligosaccharides: Xylo-oligosaccharides were produced from green coconut husks, which mainly comprised higher degree oligomers such as xylopentose and xylohexose. The supplementation of the coconut xylo-oligosaccharides (0.5%) in the diet of broilers increased the abundance of beneficial microbes in the caecum.

Fungal phytase: Phytase enzyme was produced from fungal isolate *Aspergillus foetidis* (MTCC 11682). Incorporation of partially purified fungal phytase in the diet (1000FTU/kg) of broiler chicken was effective in replacing 0.12% non-phytate phosphorus.

Processed protein meals: Processed rape seed meal (RSM) with 80% reduction in glucosinolate concentration could be safely used in commercial broiler chicken diet at 10% level, partially replacing soybean meal. Srinidhi chicks could tolerate raw RSM up to 5% level in diet. *Guar* meal in diet at graded levels (5 to 20%) progressively reduced feed efficiency in commercial broilers. Dimethyl carbonate treated *karanj* cake showed no adverse effect at 3% level in diet, but significantly depressed performance of broiler chicken at higher levels (6 or 9% in diet), even with late introduction at 11 or 21 days of age. Isopropyl alcohol treated *karanj* cake could be used in the feed of Vanaraja chicks at 6% during 5 to 6 weeks of age.

Value addition of chicken meat: Dietary incorporation of fish oil at 3% level during finisher phase improved the bird's performance and enriched the meat with n-3 fatty acid without affecting the sensory attributes of meat. Conjugated linoleic acid (CLA) accumulation in meat significantly increased with increasing CLA level in the diet.

Utilization of alternate feed resources: Inclusion of rice DDGS (dried distillers grains with solubles) up to 10% level did not exert any adverse effect on growth, feed conversion ratio, carcass traits and development of immune organs of broiler chickens. Similarly, high protein *guar korma* could be effectively and economically used up to 10% level in broiler diet replacing costlier soybean meal. Further, irrespective of source of protein commercial protease incorporation in diet was beneficial for improved feed utilization and reduction in feed cost.

Precise nutrient supply: A dietary concentration of 0.35 and 0.25% available phosphorus during starting (0-21 d) and finishing phase (21-42d), respectively, and 1,500 IU/kg vitamin D_3 with supplementation of phytase (500FTU/kg diet) was optimum to obtain maximum growth performance, immune response and leg bone mineralization in broiler chicken.

Turkey

Dietary energy level of 2,600 kcal ME/kg was found optimum for growing turkey poults during 8-16 weeks. Similarly, supplementation of selenium (Se) @ 0.4 mg/kg basal diet was beneficial for lowering age at sexual maturity, improving egg production, egg quality traits, parthenogenetic characters in females and physio-biochemical characteristics of semen in male turkeys.

Animal Physiology and Reproduction

Cattle

Genetic polymorphism of heat shock protein genes: The expression pattern of ATPase beta subunit genes (ATPase B1, ATPase B2, and ATPase B3) among the crossbred bulls under different ambient temperatures (20–44°C) was studied and compared with the relationship of HSP70. Among beta family genes, transcript abundance of ATPase B1 and ATPase B2 was significantly higher during the thermal stress. The expression of ATPase B1, ATPase B2, and ATPase B3

is highly correlated with HSP70.

OAS1 gene related to establishment of pregnancy: PCR-SSCP method was used to scan for mutations within the amplified regions of four exons of 2,5-oligoadenylate synthetase 1 (OAS1) gene 240 animals, comprising 81 Sahiwal and 159 Frieswal animals. Variations were identified in SSCP patterns of OAS1, 5, and 6A exonic regions, whereas monomorphic pattern was detected in OAS4 and OAS6B regions.

Buffalo

Expression and localization of the ghrelin and receptor GHSR-1a in ovarian follicles increases with ovarian follicle development and maturation. Ghrelin had inhibitory effect on estradiol secretion, aromatase expression and apoptosis and stimulatory effect on cell proliferation on GCs in bubaline species.

Pregnancies established from cloned embryos: Transferable stage cloned embryos were produced from somatic cells of a superior bull and established 2 pregnancies in recipient buffaloes. Calvings for the same completed in November 2015. A protocol was tested for superovulation of anoestrus buffaloes that are otherwise normal and have a good body condition score.

For the first time endogenous level of osteopontin in buffalo seminal plasma was estimated, which ranged from 6- 30 pg/ml. Liposome was found to be a better alternative to egg yolk as buffalo bull semen extender.

Sheep

Supplementation of ITS (insulin-transferrin-selenium) and FGF2 (fibroblast growth factor 2) in the maturation medium improved the maturation and cleavage rates of sheep oocytes. GDF9 (growth differentiation factor 9) was crucial for the maturation of metabolically active sheep oocytes. Poor development of the metabolically active sheep oocytes was attributed to disrupted activin/BMP (bone morphogenetic proteins) signalling. Whole transcriptome analysis revealed 914 and 945 significantly up-regulated and down-regulated genes respectively, in the metabolically active compared to silent sheep oocytes.

Production of 3 lamb crops in 2 years: The accelerated lambing system was adopted in Malpura ewes. Ewes were bred at 8 monthly intervals. Ewes not shown estrus in time were induced for estrus with progesterone impregnated intra vaginal sponges and PMSG protocol. It was found that 75% of ewes lambed at every 8 month (i.e. 3 lambs in 2 year).These lambs attained puberty at the age of 337 days and mated within 360 days. The adoption of accelerated lambing system in Malpura sheep produced 32.58% more lambs in comparison to one lamb in a year under conventional system.

Reproduction in ruminants: An attempt was made to develop pregnancy associated glycoprotein (PAG) based immunodiagnostic in buffaloes. The PAG7 is expressed predominantly during early pregnancy in buffaloes. The recombinant protein and synthetic peptide corresponding to PAG7 were generated and used for anti-sera production, which were suitable for immunoassay development.

Mithun

Study on expression profiling of *KiSS1R* genes revealed a higher relative abundance of the transcripts encoding *KiSS1* and *KiSS1R* genes in mithun that were in the transition phase from prepubertal to pubertal phase than those in pre-pubertal stage. A trial was conducted to determine the optimum osmolarity of hypo-osmotic solution to assess the functional membrane integrity of mithun sperm. Osmolarity of 150 mOsm was the most suitable for hypo-osmotic swelling test in mithun.

Poultry

Effect of bisphenol-A (BPA) on reproduction in quail: Evaluation of effect of endocrine disruptors (ED) such as bisphenol-A (BPA) on reproductive function of male Japanese quail revealed that it has adverse effect on reproductive functions.

Quick detection of *Brucella melitensis*

A Taqman probe based OMP-31gene realtime PCR assay was developed for the diagnosis of *Brucella melitensis* in vaginal washings/swab, aborted contents, preputial swab, milk etc. The oligos and probes were designed in the coding region of the OMP31 gene specific to *B. melitensis*. The assay has a very high sensitivity that detects positive *B. melitensis* DNA spiked to clinical samples with concentration as low as 100 femtograms. The advantage of this assay is that it is specific to *B. melitensis*, which is the most common abortion causing agent in small ruminants and can be assayed approximately in 30 minutes using the suspected DNA sample.

LIVESTOCK PROTECTION

Epidemiology and disease informatics

During period under report, forecasts for the 15 economically important animal diseases were released. Records (5,577), originating from 30 states pertaining to various diseases were reported to the National Animal Disease Referral Expert System (NADRES); and 2,151 serum samples received from Jharkhand, Madhya Pradesh, Maharashtra, Meghalaya, Odisha, Punjab and Tamil Nadu etc., were catalogued in the National Livestock Serum Repository.

The economic analysis in cattle and buffaloes in selected endemic states of India revealed that estimated mortality losses due to haemorrhagic septicaemia (HS) was ₹ 27,647 and ₹ 31,901 per animal, respectively. A cluster map of HS and FMD outbreaks in Tamil Nadu and Kerala, was prepared. The socioeconomic impact study revealed that total estimated direct loss due to FMD was ₹ 23,193 crore in the reported period. A parametric regression model with threshold for southern and eastern region of the country for *peste des petitis ruminants* (PPR)

outbreak was developed. At the optimum incremental level of 10%, the estimated loss due to PPR in sheep and goats in India was ₹ 1,611 crore.

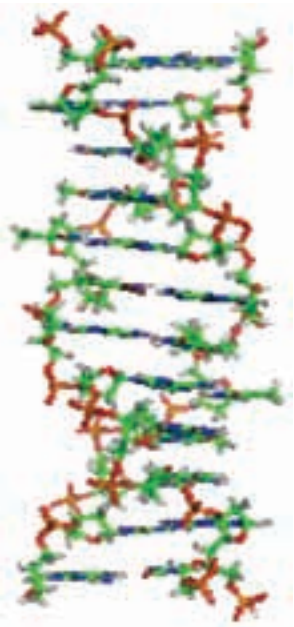
The hemagglutinin (H) and nucleocapsid (N) protein of PPR virus were expressed in prokaryotic system and on evaluation of indirect ELISA based on recombinant N and H antigen showed 97.97% sensitivity and 99.49% specificity. A total of 391 serum samples were collected from sheep and goats in seven states of NE region. On screening for PPRV antibodies, 17.90 and 63% of seroprevalance was recorded in suspected and random population of goats. Phylogenetic analysis carried out with 24 E2 gene sequence revealed that all the recent CSFV 24 E2 sequence could be grouped into subtype 2.2, which is now gradually dominating the traditional 1.1 group. The porcine tissue samples from Udupi, Karnataka, screened for TTV gene groups 1 and 2, were found positive for gene group 2. Out of 1,022 bovine samples from 14 states of the country, 31.5% cases were positive for IBR antibodies; Arunachal Pradesh had the highest (90%) and West Bengal the lowest (43.30%). In yak, a high percentage (95.23%) was found positive for IBR antibodies.

Under epidemiological study of rabies in livestock, out of 124 samples taken from animals from Uttar Pradesh, Gujarat, Karnataka and Kerala, 45 were found positive by fluorescent antibody technique. The N gene sequences of the rabies-positive samples revealed that all the isolates belonging to gene type 1 of rabies virus are of arctic lineage. Analysis of pox outbreak records revealed that, there was an increased trend from 2005-13 followed by a declining trend. The highest number of outbreak was reported from Andhra Pradesh. The number of deaths is directly proportional to number of outbreaks and number of attacks in each year. The outbreaks were mostly recorded during Dec-May. In goats, 70.31% morbidity and 46.87% mortality were reported.

Risk path analysis of notifiable avian influenza (NA, HPNAI, LPNAI) was identified for the import of chicken, meat and by-product and also live birds; the process includes the hazard identification, release, exposure and consequent assessment. Previously, reported HPAI outbreaks were mapped based on GIS coordinates as point dot maps. Temporal data analysis suggested three different introductions of disease in 2008 in different places. Majority outbreaks were recorded in the adjoining districts with Bangladesh and Nepal, which are endemic to H5N1 avian influenza. The outbreaks in crows reported during 2011-12 from Jharkhand, Maharashtra, Odisha and Bihar. This study suggested the spreading of the disease in different places/locations since, the crows are found near human habitations.

Under the All India Network Program on Blue Tongue (BT), screening of 562 serum samples for antibodies of BTV from 9 districts of Maharashtra, revealed 87.54% prevalence. The age-wise analysis of the prevalence showed that the number of affected animals increase with the increase in age.

Whole genome shotgun sequencing was completed for one each of field isolate, *Brucella melitensis* ADMAS-G1 (Accession # NZ_ AUTT00000000) and reference strain *Brucella abortus* S99 (Accession # AWTU00000000); and genome sequences are available in NCBI GenBank. Among 1,360 samples collected from different species of animals, more than 10% were found positive by screening through RBPT and ELISA. A newly developed lateral flow assay (LFA) kit for detection of brucellosis in animals showed 87.1% sensitivity and 92.6% specificity. The recombinant proteins of *Brucella* namely rBLS (36 KDa) and rBP26 (44 KDa) were expressed and analysed, which showed immunoreactivity of the proteins. Standardization of ELISA using such recombinant proteins also carried out. Standardization of fluorescent polarization assay for detection of brucellosis in animals was carried out and it showed 90% sensitivity and 78.33% specificity. Besides, 3,459 animal serum samples received from seven AICRP collaborating centres were screened for brucellosis. Out of them, 0.54% cattle, 0.33% buffalo and 0.97% goat were found positive for the presence of *Brucella* antibodies. In a questionnaire survey, 86% veterinarians opined in favour of brucellosis vaccination in animals whereas, 14% were against the vaccination.



Brucella abortus S19, whole genome shotgun sequencing

On the study of methicillin-resistant staphylococci organism, out of 97 goat samples, two isolates showed amplification for *mec*A gene by PCR. The antibiotic sensitivity test (ABST) showed one of the isolates as intermediate resistant to cefoxitin but another isolate was sensitive to both methicillin and cefoxitin. One of the *mec*A positive isolate was identified as *Staphylococcus epidermis*. The study on *in vivo* pharmacological properties of membrane- active glycoprotein antibiotic (YV11455) against MRSA (methicillin-resistant *Staphylococcus aureus*), revealed that effective dose response of the drug in 50% maximal bacterial killing (ED_{50}) was 1.43% mg/kg. The beta lactamase producing *Enterobacteriaceae* organisms were also studied.

Leptospira serovars (19) were used for MAT (macroscopic agglutination test) screening for the detection of *Leptospira* antibodies in the samples. For sero-epidemiology of leptospirosis, this year 887 animal serum samples from Odisha, West Bengal and Karnataka were screened and overall 36.87% seroprevalence was recorded with 36.45% in cattle, 54.28% in buffalo, 28.33% in goat, 44.44% in sheep and 31.37% in horse. Among human, 5.55% cases of leptospirosis were

detected by MAT screening. A lateral flow kit for the diagnosis of *Listeria* species was designed using listerolysin-o (LLO) and colloidal gold conjugated protein G and the test was evaluated with 405 serum samples showing 100% agreement with LLO based indirect-ELISA.

Serum samples (2,093) from cattle, buffaloes, horse, donkey and camel from Karnataka, Odisha, West Bengal and Rajasthan, screened for *Trypanosoma evansi* by ELISA, revealed that, 586 samples were positive for *T. evansi* antibodies. The buffalo showed highest seroprevalance (36%) followed by cattle (28-31.25%), camel (31%), donkey (6.89%) and horse (5.10%). Analysis of faecal samples (222) collected from cattle, buffalo, sheep and goats form Karnataka, showed that 19.81% were positive for parasitic infections; *Fasciola* 17%, Strongyles 12%, Amphistome 15%. On screening of *Lymnea* species snails, an overall 13% were found positive for *Fasciola* infection. During this year, 148 human samples collected from West Bengal, Karnataka and Andhra Pradesh were screened for the presence of *Toxoplasma gondii* antibodies by agglutination test. An overall 12.16% seroprevalance was recorded with 25.49% in Andhra Pradesh and 17.85% in Karnataka.

Development and improvement of diagnostics

Molecular diagnostics developed for animal diseases include real-time PCR assay for detection and quantification of porcine circovirus 2 load in tissues; DNA bar-coding of *Brucella* using *rpo*B gene; PCR for VNTR analysis of *Brucella* isolates; multiplex PCR for detection and differentiation of *Salmonella* serovars; and PCR assays for detection of *Clostridium difficile.*

Recombinant antigen based diagnostics for animal diseases include ESAT6-CFP10 fusion protein based indirect ELISA for differentiation of *Mycobacterium bovis* and non-tuberculous mycobacteria in cattle; listeriolysin O (rLLO) and recombinant phosphatidyl-inositol phospholipase C (rPI-PLC) based indirect ELISA for listeriosis; and BgP12 protein based indirect ELISA and dot-ELISA for diagnosis of *Babesia gibsoni* infection in dogs.

Surface plasmon resonance (SPR) biosensor assay for detection of *B. abortus* specific antibodies was developed using a recombinant p17 kDa protein (6, 7-dimethyl-8-ribityllumazine synthase-2). The SPR assay was used to record interactions between recombinant p17 protein and *Brucella* specific antibodies in real time. Since, SPR is a label-free technique and does not require any species specific conjugate or fluorophore, this assay using may be employed for providing rapid, real-time and label-free serodiagnosis of brucellosis in different species of animals.

Diagnostic vigilance

Avian influenza (AI): The avian influenza viruses were detected and isolated from poultry which included H5N1 (17 from Kerala, 6 from Uttar Pradesh and 1 each from Chandigarh and Odisha), H9N2 (2 from Kerala), H6N2 (1 from Kerala) and H3N8 (4 from Kerala) from a total of 45,980 morbid materials received from various parts of the country. Eighteen sera (14 chicken and 4 ducks) were positive for antibodies to avian influenza virus (subtype H5) and 20 sera were positive for H9N2 AIV antibodies (17 and 3, respectively, from Kerala and Chandigarh) of the 5,496 serum samples tested.

Bovine viral diarrhea (BVD): Out of 713 sera of mithun, cattle, buffaloes, sheep and goats from NE region, only five animals were positive for BVDV neutralizing antibodies indicating a low BVDV prevalence in this region.

Malignant catarrhal fever (MCF): The causative agent of MCF, ovine herpesvirus -2 (OvHV-2), was confirmed in blood samples of pigs from Mizoram for the first time in India. Twenty-two samples were positive for OvHV-2 genome of the 179 blood samples of cattle, buffalo and sheep tested from various parts of the country.

Porcine reproductive and respiratory syndrome virus (PRRSV): Out of the 495 porcine whole blood/ serum samples received from North East India, 238 (48%) were positive for PRRSV antibodies. Two sera (one each from Mizoram and Meghalaya) out of 163 inoculated on PAM cultures were positive for virus isolation and were confirmed by immunoperoxidase monolayer assay on MARC-145 cells using PRRSV specific polyclonal serum.

Swine influenza viruses (SIV): Sera samples (162) from pigs from different parts of the country were tested with HI test and 43 samples were found positive for antibodies against H1N1.

Diagnostics for exotic and emerging diseases

RT-PCR ELISA for pestiviruses: A reverse transcription polymerase chain reaction ELISA (RT-PCR ELISA) was developed for detection of ruminant pestiviruses and its diagnostic performance was evaluated on clinical samples obtained from cattle, sheep and goats. The assay had high analytical specificity, good reproducibility with 95.9% diagnostic sensitivity, 98.6% specificity and a strong agreement (97.5% concordance) with the reference virus isolation method.

PCR-array based multiple pathogen diagnostic: PCR arrays for the detection of 17 prioritized exotic and emerging viruses, viz. Crimean-Congo haemorrhagic fever (CCHF), Rift Valley fever (RVF), West Nile fever (WNF), vesicular stomatitis (SV), Japanese encephalitis (JE), Aujeszsky's disease, Ebola virus disease, Marburg, Eastern equine encephalitis (EEE) and Hantaan fever, bovine viral diarrhea (BVD), caprine arthritis encephalitis (CAE) and Schmallenberg virus infection, African swine fever (ASF), Nipah, swine vesicular disease (SVD), transmissible gastroenteritis (TGE), using molecular beacon (MB) and SYBR green realtime PCR chemistry were developed. This technology offers the simultaneous detection of various pathogens by running a panel of real time PCR in different wells of a single PCR plate under uniform reaction and thermal conditions.

AGID test kit for avian influenza: A kit for agar gel immunodiffusion (AGID) test for detection of avian

influenza antibodies in chicken serum samples was developed and evaluated against reference test. The sensitivity is 94.28% and specificity is 94.96% compared to HI test. The intra-laboratory validation on lyophilized antigen was conducted successfully by three independent scientists.

Molecular characterization of pathogens

- Molecular and genetic characterizations based on B2L gene of parapox viruses, ORF 19 of swinepox virus, UL 0.5 gene of bovine herpesvirus 1, VP2 gene of BTV, N and F genes of PPR viruses and omp 16 gene of *P. multocida* isolates, were carried out.
- Complete genome sequencing and phylogenetic analysis of PCV2 revealed presence of natural recombinants arising from PCV2a and PCV2b.
- Methicillin resistant *Staphylococcus aureus* (MRSA) was isolated and characterized from milk samples collected from bovine and caprine mastitis.
- The current phylogenetic analysis of avian influenza viruses showed that the H5N1 viruses isolated till early 2014 grouped with clade 2.3.2.1A, whereas, the recent H5N1 viruses isolated from Kerala, Chandigarh and Uttar Pradesh grouped with a new clade 2.3.2.1 C, which has not been detected so far in Indian poultry. Detailed phylogeny indicated role of migratory birds in the spread of H5N1 virus, although trade of poultry/poultry products cannot be ruled out.
- H5N1 isolates (46) from the year 2007 to 2014 were screened for drug resistance for Oseltamivir and Zanamivir, revealed drug resistance in 3 Indian isolates and decreased susceptibility for two isolates. These findings indicated emergence of antiviral resistance in avian influenza viruses isolated in India.
- The phylogenetic analysis of the 5'-UTR sequence identified five clusters within the BVDV-3 virus clade and demonstrated that Indian BVDV-3 isolates were grouped into two distinct clusters separate from the previously reported BVDV-3 viruses from South America, Europe and Australia. IndBHA5309/12 group of viruses was the most divergent BVDV-3 strain reported so far. Based on phylogeny of N^{pro} gene, three BVDV-3 virus lineages could be identified globally with two from India.
- Genetic analysis of the complete ORF 5, ORF 7 and nsp2 coding regions showed that the Indian PRRSV isolate grouped with genotype-2 viruses reported from China. Analysis of deduced amino acid from ORF 5, ORF 7 and nsp2 (within ORF 1a) sequences showed the presence of 2, 1 and 14 unique amino acid changes, respectively, as compared to the PRRSV genotype-2 currently existing in various parts of the world.

Success story

New indigenous sheep-pox vaccine

Sheep and goat rearing contributes significantly to the livelihood of >75% of small and marginal farmers of the country. Sheep-pox is endemic in India and outbreaks are reported regularly from almost all the states and the high rate of death (50%) causes heavy economic losses. ICAR-IVRI initiated the vaccine development programme using an indigenous isolate (SRIN-38/00 strain) of sheep-pox virus by adapting the virus to Vero cells. The attenuated vaccine strain can be used to produce large quantity of vaccine on commercial scale. Small quantity (1 ml) of virus may yield ~10,000 doses of vaccine. The vaccine was tested for its safety and protective efficacy in >90,000 sheep. A single dose of the vaccine provides immunity up to 4 years, which is sufficient for life time protection. Sheep-pox control is vital enhanced productivity of small ruminants through effective disease control programme using this indigenous vaccine.

Vaccine development and delivery

FMD: Immunization trial in cattle using recombinant Ad5-FMD constructs with and without adjuvant against three Indian FMDV strains (O, A and Asia-1) showed 100% protection against type O and A when booster vaccination was done. The efficacy of Ad5-FMD Asia-1 vaccine was lower than O and A.

Two new generation adjuvant formulations were evaluated for formulating trivalent FMD vaccines (Type O, A and Asia-1). Cattle were immunized with single 2 ml dose and challenged with homologous type O FMD virus. One of the proprietary formulations protected 100% of animals.

IBR: A mutant BoHV-1 (gE) gene deleted BoHV-1 marker vaccine candidate against infectious bovine rhinotracheitis (IBR) was developed. Guinea pigs immunized with oil-adjuvanted vaccine showed virus neutralization (VN) titer $>2^6$ which increased to $>2^9$ with booster dose and maintained up to $>2^{10}$ till 90 days post-immunization.

Clostridium: The protective efficacy of expressed recombinant immune-reactive proteins of *C. chauvoei* tested in guinea pigs. Enolase elicited better protective

immunity followed by Flagellin, Ribosomal L10 and glycosyl hydrolase proteins.

Trypanosoma: Immunization of rats with gamma irradiated *Trypanosoma evansi* at 450-500 Gy, induced 100% protection against homologous challenge.

Therapeutics

- Atorvastatin showed potential to ameliorate arsenic-induced hypertension.
- Polyherbs containing extracts of *Eclipta alba*, *Solanum nigrum*, *Macrotyloma uniflorum*, *Murraya koenigii* and *Phyllanthus niruri* have potent antioxidant, diuretics and hepatoprotectant effect in compromised liver condition.
- Pre-treatment with alcoholic extract of *Dalbergia sissoo* leaves showed cardioprotective effect in isoprenaline-induced myocardial injury in rats.
- The supplemental feeding of leaves of *Aegle marmelos* and *Murraya koenigii* augmented fertility in delayed pubertal heifers both at farm and field conditions.

Foot and mouth disease

During the year 2015-16, no major outbreak of FMD was reported and only 47 incidences were recorded in the country. Among them, serotype O dominated with 45 incidences while serotypes A and Asia-1 caused only one incidence each. The majority of the incidences were recorded in Karnataka, Kerala, Asom, Odisha, Madhya Pradesh, Uttar Pradesh and Bihar. A few incidences were also recorded in Gujarat and Rajasthan. Serotype A was reported from Gujarat and serotype Asia1 was reported from West Bengal. No disease was reported from Haryana, Himachal Pradesh, Maharashtra and Delhi during this period, while sporadic incidence was recorded in Punjab.

Phylogenetic analysis, carried out to assess genetic variations, inter-strain relationship and to track the movement of the virus in the country, revealed exclusive presence of Ind2001 lineage of serotype O in the field, while presence of PanAsia lineage was also recorded in state of Asom. Vaccine matching exercise revealed that the currently used vaccine strains of serotype O (INDR2/

Success Story

Development and launch of foot-and-mouth disease-decision support system

Foot and mouth disease- decision support system (FMD-DSS), an online decision support system for near real-time surveillance and monitoring, was developed and hosted at www.fmd-dss.res.in. The principal objectives of the system were to compile and automatically analyze the huge data generated from day-to-day activity related to FMD epidemiology in India and to provide refined information and reports to the concerned persons. The system archives the entire information of the samples and handle the raw data sheets of the various serological assays to reduce the manual errors, the system is having application to; map the disease (by GPS mapping up to the village level), map the serological status and analyze the FMD epidemiology, sero-monitoring, and sero-surveillance data using parametric and non-parametric assays. Various activity reports to be submitted to different departments for administrative purposes will automatically be prepared on start of the month, saving valuable time.

An online database management system for FMD in India

will produce a unique bar-coded accession number, through which the associated information of the samples can be accessed. The information of the FMD-DSS was used to generate FMD alerts in the country. For faster transmission of the information, the system is equipped with tools to— handle both emails and text messages; Various data sets such as, livestock demography, species, breed, GIS maps, meteorological parameters, districts, sub-districts and villages (>600,000) were procured and integrated with the system that may also help to build similar systems for other animal diseases in the country.

Success story

Understanding FMD viral ecology and landscape epidemiology towards control and eradication

The possible role of ruminants persistently infected with FMD virus in initiating new outbreaks remains to be understood. With generation of disease free zones in the country, understanding the role of the carrier animals in spreading the disease is crucial. Moreover, determining the probability of the animal becoming a carrier post infection and the time-dependent probability of clearing persistence is very important. A study was carried out in collaboration with Plum Island Animal Disease Centre (PIADC) and USDA. As pilot project three study sites were established having the natural FMD outbreaks in 2013. Regular sampling consisting of serum and oro-pharyngeal fluids were collected and examined. In the clinically infected category, both the farms in Uttarakhand, revealed comparable non-structural protein-antibody (NSP-Ab) positive animals, whereas considerable difference was noticed in the asymptomatic in-contact category despite showing similar proportion of genome PCR positive results. This may be due to older animals having more mature immune systems and seroconversion with more robust response following infection. Overall, the high prevalence of NSP-Ab in asymptomatic animals is important because it indicated that many animals that never show disease are actually infected. From 3 animals in the dairy farm, virus could be isolated and clustered with the O/ME-SA/Ind2001d lineage. In dairy farm at Chhattisgarh, in cattle only up to 7 months after outbreak, while in buffalo up to 13 months virus could be isolated. Virus clearing with time in all the three sampled farms was evident from the gradual decline in the proportion of viral genome positive samples and virus isolation.

1975) provided optimal antigenic coverage to the field isolates. Some isolates were found divergent from the vaccine strain; emergence of such antigenic variants in the field is a regular phenomenon and is not a serious concern at present. In serotype Asia-1, the field isolates analyzed had perfect match with the currently used vaccine strain (IND63/1972).

During this period, 160,243 serum samples collected as per the sampling frame from the states covered under FMDCP were tested by single dilution liquid phase blocking ELISA for estimation of antibody titers against the three serotypes. The percentage protective antibody titre in the serum samples collected at random from FMDCP states were higher when compared to the non CP states. Currently, 88, 77 and 89.1% animals tested are having protective antibody level ($\log_{10}$ 1.8 and above) against serotypes O, A and Asia-1, respectively, in post-vac serum samples in the first phase FMDCP districts, however, the remaining samples are still under testing. Under national sero-surveillance programme, 19,697 serum samples collected at random were tested for the presence of antibodies against non-structural proteins 3AB3 of FMD virus which is an indicator of FMD virus exposure regardless of vaccination status. The test revealed seropositivity in ~ 25% samples/animals.

Sheep

Genetic improvement of resistance to *Haemonchus contortus:* The increase in anthelmintic resistance in gastrointesinal nematodes of small ruminants necessitates identification and adoption of suitable worm management strategy with minimal dependence on anthelmintic. The identification and establishment of genetically resistant animals could be a sustainable non-chemical based option for worm management. Divergent lines (R - resistant and S - susceptible) were created in Malpura and Avikalin sheep through screening of lambs and evaluation of sire for low and high faecal egg counts (FECs). Challenge study in progenies from divergent lines was also conducted and it showed relative resistance to infection in R line.

Camel

Trypanosomiasis in camel: Persistence of low parasitaemia in camel due to development of Quinapyramine resistance was confirmed by RFLP. Alternative drugs prepared from local trees/herbs are being tested for management of drug resistant *Trypanosoma* infection.

Equines

Surveillance, monitoring and control of diseases: The country had no active case of equine influenza after 2009; the seropositivity in few cases is under investigation. EHV-1 is endemic in the country with an overall incidence of 2.53%. All samples tested for EIA were negative for antibodies. The incidence of piroplasmosis in 2014-15 was as high as 32.67%, while that of trypanosomosis was 3.54%. Amongst bacterial diseases, outbreaks of glanders, though of limited scale since 2006, were reported from Uttar Pradesh, Himachal Pradesh and Jammu and Kashmir.

Expression and characterization of expressed recombinant glycoproteins of EHV-1: Abortions due to EHV-1 cause huge economic losses. In quest to develop better immune-prophylactics, glycoprotein D (~48kD) and gM (~52kD) of EHV-1 were expressed in eukaryotic system by transfecting sf9 cells transfected with recombinant bacmid, and the expression of protein is being further optimized with various conditions. For construction of EHV-1 bacterial artificial chromosome (BAC), gene 71 (g71) was selected as targeted region to clone EHV-1 isolate, and transfection of RK-13 cells with virus and linearized plasmid showed desired results.

Neuropathogenic and non-neuropathogenic variants of EHV-1 and associated latency: A real-time PCR assay was standardized for detection of SNP at position 2,254 of ORF30 for differentiation between neurogenic and non-neurogenic EHV-1 infection. The existence of neurogenic EHV-1 was reported in the country. Genetic diversity based on the sequence analysis of partial ORF68 gene of 7 EHV-1 isolates revealed that the Indian isolates belonged to group 4 and group 5.

Equine influenza virus (H3N8) and vaccine efficacy: The continuous drift in equine influenza viruses requires harmonization of vaccines and strains

substitution. The studies were undertaken to develop mouse model for studying pathology of H3N8 influenza A virus (Sublineage Florida clade 2 virus) and to elucidate the protective efficacy of inactivated indigenous H3N8 vaccine eliciting protective immune response in mouse model.

Evaluation of synthetic drug molecules against *Theileria equi:* Equine piroplasmosis is a tick-borne haemoprotozoan disease of equids and there is no drug, which can completely eliminate *T. equi* infection from carrier animals. The target specific drug molecules were tested in MASP culture of *T. equi* in the *in-vitro* system. Of nine drug molecules tested, *in-vitro* growth of *T. equi* was significantly inhibited by HHD, HDTAB, HMC, decamethonium bromide and dodecyltrimethyl ammonium bromide molecules. On *in-vitro* cytotoxicity trials harmaline, decamethonium bromide and NBCN salts were found the most promising drug molecules in inhibiting *T. equi* growth with least cytotoxicity.

Diagnostic assays for *Trypanosoma evansi* infection: A highly sensitive real time PCR with detection level of 0.15pg of genomic DNA of parasite was developed and compared well with gold standard TBR-PCR. Both the techniques could detect the infection after 24 h post infection. Another approach for diagnosis of *T. evansi* using serological assay based on Hsp70 recombinant protein could detect antibodies against *T. evansi* at 10 dpi.

Success story

Eri silkworm: A non-mulberry silkworm as a bioreactor for expression of recombinant proteins

Insect larvae or insect cells that are permissive to baculoviruses are used as host to produce recombinant proteins, for use in diagnostic/pharmaceutical application. There are limited species of insect larve that are naturally susceptible to AcMNPV (Autographa californica multicapsid nucleopolyhedrovirus). The Eri silkworm (*Samia ricini*) is reared in many states of India, Japan and China. It feeds primarily on leaves of the castor plant (*Ricinus communis* L.). Eri silkworms are susceptible to infection by AcMNPV or recombinant AcMNPV (such as the one expressing GFP marker protein) leading to productive infection in larvae when injected by intrahemocoele route. The larvae were exploited for production of FMD virus non-structural protein 3ABC, when infected with recombinant baculovirus. Each larva yielded recombinant protein nearly equivalent to the quantity of protein recovered from 1×10^7 Trichoplusia ni 5 (Tn5) cells infected with the virus under stationary culture conditions. This systematic study demonstrated the experimental infection of the Eri silkworm (*Samia ricini*) larvae by AcMNPV and its utility as a potential bioreactor for expression of heterologous recombinant proteins.

Healthy silkworm larvae

Pig

Rapid detection of mithicillin-resistant *Staphylococcus aureus* (MRSA): Presence of mithicillin-resistant *Staphylococcus aureus* (MRSA) in food-producing animals and retail meat has increased the concern about the exposure of humans through the food chain, and hence, there is a need to use rapid method for its quick detection. The PCR protocol for rapid detection of MRSA from pigs was standardized for routine screening of pigs.

Yak

Sero-prevalence studies, carried out for detection of bovine hepesvirus-1, bovine viral diarrhoea virus and *Pasteurella multocida* in yak breeding tract of Arunachal Pradesh, revealed that percentage positivity was 37%, 21% and 2.4%, respectively. A survey revealed that yak farmers generally use albendazole as dewormer when the animals migrate downwards in winter. Out of 55 samples processed, only 9 (16.36%) samples were positive for albendazole residue. The range of concentration was 4.563 ppm to 19.999 ppm with an average of 14.502 ppm. A primary culture of yak skin fibroblast was established from the biopsy of ear pinna of yak calf. Fibroblasts were cryopreserved for conservation of yak germplasm and for preparation of feeder cell layer for yak spermatogonial stem cell culture.

Mithun

The IgG and IgA concentrations were higher in all the physiological stages of mithun than Tho-Tho cattle. However, IgE was higher in Tho-Tho cattle than that of mithun. Comparatively higher concentration of IgG suggested that mithun might have a better humoral immunity potential. However, a significantly higher concentration of Granzyme B and PRF-1 in Tho-Tho cattle than the mithun suggested a better CMI response in cattle.

In North-Eastern region, the overall seroprevalence of BVDV infection was 13.70% (111/810) in mithun. Clinical case of BVDV infection could not be detected. Further, in all the tested samples including aborted foetuses, neither BVDV nor its genome could be detected by virus isolation, PCR, RT-PCR, real time RT-PCR and IHC.

Differences could not be observed in the partial sequences of MHC (DRA, DRB1, DQA1 and DYB genes) and NRAMP1 gene of mithun with and without FMD and *Brucella* infection.

Genetic characterization of mithun isolate of *Fasciola gigantica* showed polymorphisms in ITS-2 sequence, which can be used as a marker for differentiating *F. gigantica*, *F. hepatica* and intermediate forms of the parasite.

Based on the sequence analysis of ITS-2, ribosomal DNA and Cox 1 gene, *Setaria digitata* was identified first time in mithun.

Based on mitochondrial gene NADH1 sequencing, genotype of the hydatid cyst, isolated from mithun

was characterized as *Echinococcus granulosus* and *E. ortleppi* for the first time.

Poultry

ALV and *Mycoplasma* surveillance: Pure line chickens (4,436), tested for avian leukosis virus (ALV) using group specific antigen ELISA, revealed 5.07% incidence. The genome of ALV-A isolate (DPRE32) was sequenced. Furthermore, the virus was detected in infected CEFs by transmission electron microscopy (TEM). Sequence analysis of *mgc2* genes of *M. gallisepticum* showed similarity ranging from 93.8–100% among 13 field isolates. Identity between field and reference strains was 89.1-100%. Sequence analysis of *vlhA* genes of *M. synoviae* showed identity ranging from 94.6–100% among 19 field isolates. Identity between field and reference strains was 91.6-100%. The chicken RBCs treated with two *M. synoviae* isolates examined under scanning electron micros (SEM) and TEM failed to show invasion of RBCs. *HaeII* PCR-RFLP using *HaeII* enzyme could be used to differentiate field and vaccine strains in our country.

Fish

Marine fish harvests: Marine fish landings estimated for the mainland of India in 2014 amounted to 3.59 million tonnes, registering a 5% decline compared to production in 2013. Gujarat, Tamil Nadu and Kerala have been the top three marine fish producing states in the country, since 2006. These states represented 54% of the total marine fish landings, with Gujarat and Tamil Nadu holding the first and second positions respectively. All the maritime states except Andhra Pradesh, Karnataka, Odisha and Goa recorded reduced landings in 2014 compared to 2013.

Management of hilsa: Hilsa (*Tenualosa ilisha*) is a trans-boundary fish species inhabiting the rivers of India, Bangladesh and Myanmar in Bay of Bengal region. Application of Thompson and Bell bioeconomic model in West Bengal waters, showed that the current fishing effort, has already exceeded maximum sustainable yield (MSY), indicating 20% over exploitation of the stock at Hooghly estuary and near shore areas. There is 40% over exploitation of spawning stock biomass (SSB) of >250-260 mm total length. Further, increase in the exploitation levels might cause serious decline in the fishery.

Gill nets are the major gear used for exploitation of hilsa in both inland and marine sectors. Use of small mesh sized gill nets and large scale capture of spawning stock during breeding period reduce the scope of breeding and recruitment of the fish. Henceforth, about 20% reduction in fishing effort, restriction on use of small mesh sized gill nets and banning of fishing during breeding season may be implemented.

Effect of plant extracts on aquatic leech

Aqueous and methanolic extracts of *Nicotiana* spp. and *Zanthoxylum alatum* showed effective hirudinicidal activity with mean dead time ranging between 2.11±0.111 and 20.56±2.298 min at different concentrations in comparision to the levamisole @ 333µg/ml (12.60±1.348). The methanolic extracts of *Solanum khasianum* showed mean dead time ranging from 24.89±2.342 to 113.67±20.996 at 500 and 50 µg/ml, respectively.

Fish age determination: A well-equipped fish ageing and imaging analysis laboratory was established at ICAR-CMFRI, Kochi. Age of Indian oil sardine (*Sardinella longiceps*), Indian mackerel (*Rastrelliger kanagurta*), Silver pompano (*Trachinotus blochii*) and Mahi mahi (*Coryphaena hippurus*) were determined using hard parts. Otolith morphometric studies for species/stock confirmation were also standardized for tropical marine species.

9. Mechanization and Energy Management

Several need-based and region-specific mechanization and energy management tools, implements, machines and technologies were developed for enhancing productivity and profitability of different farming systems.

Tillage implements

Animal-drawn implements for he-buffaloes: The implements comprise Tendua plough, clod breaker-cum-puddler and *biasi* plough. The average draught requirement for Tendua plough was 683 N for 98-mm width as compared to 556 N for 75-mm width. Field capacity of Tendua plough of 98-mm width was 0.014 ha/h with a field efficiency of 75%. The modified clod breaker of 7 rings performed better as compared to existing one of 5 rings, and field capacity of the modified clod breaker was 0.34 ha/h. The field capacity of 5-tyne *biasi* plough was 0.16 ha/h, and by using this plough, farmer could save ₹ 2,025 per ha and 356 MJ/ha energy in comparison to the indigenous plough. The weeding efficiency with *biasi* plough was 66%.

Biasi operation with 5-tyne *biasi* plough

Tractor-operated check-basin former: The new tractor- operated check- basin former scraps, collects and distributes uniformly collected soil to form side and cross bunds at regular intervals of 6 m in a single pass. It forms a check basin of 2m × 6 m with an effective field capacity of 0.15 ha/h. The cost of operation of the former was ₹ 3,070/ha; resulting in 96% saving over conventional manual method.

Tractor-operated check-basin former

Tractor implements performance with tillage equipment: An instrumentation system for measuring tractor-implement performance in the real field condition has been developed. With the system and set-up, performance of 11 different types of commercially available primary, secondary and conservation tillage implements was evaluated with 60-hp and 35-hp tractors in Vertisols with average cone index varying within 2,000 to 3,000 kPa in working depth and moisture content of 15 to 22% (d.b.). Performance was measured as per the BIS recommended speed with varied number of gear and throttle position combinations. All required data were recorded through universal data acquisition system.

Based on various performance parameters, it could be concluded that operating 2 bottom MB plough, 3 bottom MB plough, 1.8 m rotavator, large rigid shovel cultivator, subsoiler, sweep cultivator and spring shovel cultivator with 60-hp tractor would be economical; and operating small rigid shovel cultivator and zero-till drill would be economical with 35-hp tractor within the tested field and implement conditions.

Evaluation of tillage equipment in field

Planting implements

Evaluation of a multipurpose drill in ratoon sugarcane: *In-situ* retention of sugarcane trash can play an important role in replenishing soil quality and reducing environmental pollution. A prototype of multipurpose machine for operations like stubble shaving, off-barring, root pruning and drilling of basal fertilizers was developed and evaluated through on-farm trials. Cane yields improved by 16 and 11% over trash burning (farmer's practice) and chopping, followed by recommended practices of fertilizer application (0.45,

0.45 and 0.10 N as basal, at earthing-up and on-set of monsoon rains, respectively), and nitrogen-uptake efficiency (NUE) improved by 9.9%. Band placement of double the basal dose of N (0.9 N) further boosted initial growth, and improved cane yields and NUE by 22 and 11% over farmer's practice. Therefore, the fine tuning of this prototype should offer a practical and economic solution for trash-burning problem in sugarcane cultivation.

Ridge fertilizer-cum- seed planter: A tractor- drawn ridge fertilizer-cum- seed planter attached to three-point linkage of the tractor places fertilizers at a desired depth below the seed and mitigates effects of dry spells as well as waterlogging. The machine has provisions to change depth and angles of tynes besides altering row- to- row distance.

Modified furrower-type sugarcane cutter-planter: Tractor-operated sugarcane planter with modified furrow opener has been developed, which opens furrows of 20-25-cm depth and maintains loose soil-bed at the bottom of the furrow. The planter operation in sugarcane planting varies from furrow opening, sett cutting, sett placement in furrows, fertilizer and insecticide application(s) and soil covering over setts and its tamping simultaneously in a single pass.

Tractor-drawn bed former-cum-onion seeder: A tractor-drawn unique bed former-cum-seeder for onion was designed and fabricated. The bed former forms a broad bed of 90-cm wide and 15-22.5 cm high, while seeds are sown by seeder on the bed.

Animal-drawn seed- drill for intercrops: The seed drill consists of a rectangular frame mounted with four seed boxes. Two pneumatic wheels one on either side of the main-frame through axles are for transportation. One of these wheels supplies power to the metering mechanism through a chain drive and counter shaft. A clutch is on the counter shaft to engage or disengage

Animal drawn seed-drill for intercrop

power to seed -metering device. Plastic discs with different size grooves are fitted in individual boxes as per the required intercropping pattern. The seed rate is governed by adjusting opening between storage and feed box through rack and pinion arrangement. The draught requirement was observed as 230 N with effective field capacity of 0.17 ha/h at 82% field efficiency.

Bullock-drawn ridge-type drum-seeder: The seeder was developed and evaluated with a pair of bullocks of

Bullock-drawn drum-seeder

smaller size (body weight of 500 kg per pair). The seeder average row- to- row spacing and seed rate was 18.6 cm and 29.6 kg/ha. Its output was 0.2 ha/h with a field efficiency of 68%. The unit cost of the drum seeder and cost of sowing of pre-germinated paddy seeder were ₹ 13,500 and ₹ 118/ha, respectively. Heart rate, respiration rate and body temperature of bullocks were recorded at 90 bpm, 55 bpm and 37.8ºC respectively. The draught requirement was 9.13% of their body weight, which indicates that the drum-seeder can be operated sustainably by a small pair of bullocks.

Planting system for small seeds: Manually operated seed planter-cum-fertilizer applicator consists of a vertical rotor-type metering mechanism for seed and fertilizer (slot size of 10 mm × 10 mm), seed-cum-fertilizer box, chain-and-sprocket type power transmission system, ground wheel, shoe-type furrow opener, seed delivery tube, seed covering and firming-cum-transportation wheel, handle and frame. Metering mechanism is operated by a ground wheel of 400-mm diameter through chain and sprocket. The field capacity and field efficiency of the machine for sowing little millet was 0.04 ha/h and 68%, respectively, at an average operational speed of 2 km/h. The cost of operation for sowing kodo and little millet was ₹ 29/h. This machine costs ₹ 2,500 and is useful for small and marginal farmers of tribal areas of Madhya Pradesh, Chhattisgarh, Andhra Pradesh and Maharashtra to promote production and productivity of millets.

Manually operated multi-millet planter

Tractor-operated garlic planter: Six- row garlic planter is with actuating-spoon (23 mm diameter and 2.5 mm depth)- type metering mechanism for planting at 150- mm row spacing to suit local seed varieties and agronomic practices. It consists of seed-metering plate, seed hopper, agitator and seed-covering device. The power to metering mechanism is provided from ground wheel with the help of chain and sprockets. The field capacity of plants was 0.18-0.21 ha/h at a forward speed of 2.0 to 2.25 km/h. The percentage of missing and multiples was 9.1 and 26.7%, respectively. There was saving of 82% in labour requirement and 57% in operation cost as compared to conventional manual planting. The approximate cost and operation cost of the machine were ₹ 150,000 and ₹ 6,168/ ha, respectively.

Tractor-operated garlic planter

Power-operated sugarcane sett-cutter: The power (0.75 kW, 1440 rpm, single phase electric motor)-operated sett-cutter cuts single eye bud or double eye bud setts. Its capacity is 3,360 setts/h and time required to cut setts in a hectare is 8.24 h. The cost of machine, operation cost and time saving over conventional manual operation were ₹ 75,000, ₹ 98/h and 80%, respectively.

Sugarcane sett-cutter

Tractor-operated small seed planter: The tractor (26.11 kW)-operated six- row planter consists of inclined plate-type metering mechanism, seed-hopper for each

Tractor-operated small seed planter

row, shovel-type furrow openers and three-point hitch system. Its capacity is approximately 1.5 kg. Its metering plate of 130 -mm diameter is made of plastic. Machine's row- to- row spacing is 150 mm, and its plant- to- plant spacing can be changed by changing plate with different number of notches or by changing sprockets. The planter was evaluated for seeding onion (variety: Punjab Naroya) in the field using 24-groove plate at forward speed of 2.0 km/h. The avarage number of plants/m^2 was 88. The avarage percentage of single, multiple and missing was 59.7, 35.0 and 5.3%, respectively. The average yield of onion-crop was 38 tonnes/ha. There was saving of 50.4% in operation cost and 81.1% in labour requirement as compared to conventional method of onion cultivation. The field capacity and cost of operation of the planter were 0.16 ha/h and ₹ 5,090/ha, respectively.

Micro-controller-based variable rate granular fertilizer applicator (VRFA)**:** The prototype of the applicator consists of a differential global positioning system (DGPS), micro-processor, micro-controller, DC motor, 12 V DC power supply, threaded screw arrangement and fluted roller fitted metering mechanism. Digital nutrient availability maps and fertilizer decision GUI have been developed for major crops based on the target yield. For their development, synchronization of DGPS, micro-processor, micro-controller, actuator and metering mechanism was done using visual studio platform. The programme for varying rates of fertilizers was installed in Arduino-Uno micro-controller board. Based on the micro-controller decision four relay switches actuated DC motor clockwise and anticlockwise

GPS-based variable rate fertilizer appllcator

based on its output, which varied fluted roller exposure length according to the fertilizer requirement at the grid point. The VRFA was tested in research field at different speeds (3, 4, 5 km/h), grid sizes (4m×5m, 5m×6 m and 8m×8 m) and fertilizer application rates (10 rates). Forward speed of tractor and fertilizer application rate had no significant effect on the application rate using VRFA. It was observed that the applicator met closely the target fertilizer application rate for grid size of 8m×8m.

Harvesting implements

Crop-yield monitoring using indigenous combine: To create yield variability maps, yield-monitoring system consisting of optical sensor, moisture sensor, GPS, controller unit and display fitted with an indigenous combine (make: Crop Tiger 30, CLAAS) was used. The calibration factors were determined as 6.59 for wheat, 5.62 for soybean and 4.60 for paddy. Yield maps were created for 11 field plots for wheat harvesting during 2013 to 2015. Yield data of all the plots were classified in five yield groups. Yield legend showed that about 63.9% area belonged to 3,910-4,950 kg/ha yield group and 24% to 2,840-3,910 kg/ha. Spatial and temporal variabilities were observed across various field plots. The study also confirmed that yield-monitoring system can be retrofitted with indigenous combine(s) for effective monitoring of spatial and temporal variabilities.

Indigenous combine

Pineapple harvester: Convenient and safe harvesting device of 250-280 fruits/h capacity, and with 70% efficiency has been developed. When the operator pulls the lever of the cranking wheel which is connected to the cutting wheel through a transmission belt, the wheel starts rotating and cuts stalk just beneath the pineapple. The cut pineapples lands on the small collecting tray, which is fixed close to cutting blade and finally shifted to a basket kept on to ground. A single operator is required for cutting and putting pineapples in the basket as well.

Pineapple harvester

The unit reduces drudgery and is cost-effective and energy-efficient.

Potato combine harvester: A 2-row, tractor-operated, trailing-type potato combine harvester with a provision for inspection and simultaneous collection of tubers in bags/crates with the help of 4-6 workers was designed and fabricated. It can be operated with the help of a 45-hp tractor and has a capacity of potato digging @ 0.21 ha/hr.

Improved sugarcane detrashing tool: This tool has a weight of 290 g as against 430 g of the original model to detach yellowish green, dried leaves and sprouted side shoots on the cane-stalk. It has two 'U' shaped stainless-steel knives fitted with a ring of 3-mm thickness of SS rod to adjust diameter of detrashing cane. Its field capacity was 0.1 ha/day.

Tractot-cab and soil-bin

Ergonomically designed tractor-cab: A cabin layout of a tractor was designed based on the anthropometric data of the Indian tractor operators. The cabin was mounted on the tractor (Standard DI 475) with CRC pipes and CRC sheets fitted with silicon rubber fittings. One door on LHS, two windows (one on RHS and one on the rear side) were mounted, and one step at entrance of door was provided. Front headlights, front and rear indicators, rear-side view mirrors were also provided on each side of the cabin. Air-conditioning system was installed inside the cabin. Adjustable rear view camera was provided along with lighting arrangement and monitor inside the cabin.

Tractor-cab

Automation of soil-processing trolley of soil-bin: Soil-processing trolley of the rectangular soil-bin has been automated to prepare uniform test beds at different soil compaction levels in the soil-bin. The trolley comprises rotary tiller, levelling blade and roller for tilling, levelling and compacting soil, respectively. Hydraulic power is used to engage and disengage rotary tiller and leveler, lowering and raising as well as loading roller to achieve desirable compaction level and adjusting depth of operation of the implement. For this, mobile open loop system with tandem circuit has been designed and developed. Individual double acting cylinder is mounted on suitable frame to operate

Mechanization package for value- addition of banana central core stem

About 5 to 7 tonnes of central core stems can be extracted from a hectare of banana- garden. The core has many medicinal values and can be utilized for preparing curries. But the removal of fibres from the central core is cumbersome and time- consuming process. This discourages households and restaurants using curries based on banana pseudostem. A package of equipments for value-addition of banana central core has been developed. These include the following:

Banana central core slicing and dicing unit

This is very unique where banana central core is sliced by a blade and diced by a dicer which has nylon wheels and a punching arrangement. Feeding is automated using a cam arrangement. Its capacity is about 50 kg/h.

Banana central core slicing unit

Banana dicing unit


Banana central core fibre removing unit


Water-removing unit


Juice squeezer

Juicer

Diced banana central core fibre removing equipment

This helps in removing fibres from diced banana central core by rotary action of the attachment.

Central core surface water-removing unit

The surface water is removed by centrifugation technique. Its capacity is 7 kg/batch.

Banana central core juice-extraction unit

A high capacity grinder is used to smash central core into fine pieces, and juice is squeezed out of the smashed banana central core and is collected by a tilting arrangement. Its capacity is about 50 kg of sliced banana central core per hour. The juice extraction efficiency is between 70 and 75% of the weight of the central core.

The whole pacakge of equipment costs about ₹ 1.75 lakh,and is suitable for a cottage-level enterprise.

Automated soil-processing trolley and cone penetrometer

various units of the soil-bin.

A hydraulically operated instrumented cone penetrometer has also been designed and installed in the soil- bin. Double acting cylinder was used as driving unit for cone penetrometer. Accordingly, penetrometer shaft and cone have been fabricated with stainless steel AISI 416 and machined to a smooth finish. The cone has base area of 323 mm^2 and cone angle of 30^o. External threading is done at one end of the probe to have provision for replacing worn out cone as per the requirement. The other end of the probe is also threaded externally for fixing it with the load cell. An 'S' type load cell of 2 -kN capacity mounted between the probe and the piston rod is used to measure cone-index value up to 300 -mm soil depth. For measurement of profile depth, a linear potentiometer is used. Flow rate of the system is adjusted to achieve constant penetration rate of about 30 mm/s.

Implements package for hill mechanization

Single animal-drawn improved wedge-plough: Improved plough is suitable for terrace land of hilly track due to its light weight. Its work rate was 0.02 ha/h at an average draught of 450 N, corresponding to the depth of operation of 100 mm. The cost of operation of the plough was ₹ 2,500/ha; lesser by ₹ 800/ha to traditional plough.

Plough on terraces

Two row zero-till seed-drill: The seed- drill was fitted with inverted (T)- type furrow opener.Its field capacity was 0.027 ha/h at an operating speed of 1.77 km/h. Average draught of the machine was 296 N at a seed

Two row zero-seed drill

sowing depth of 4.4 cm. The machine costs ₹ 8,000, and its cost of sowing was ₹ 2,409/ha. Zero tillage seeding in single pass at residual soil moisture content of 20.4% on the dry basis and 51.8% saving in cost of operation proved advantageous to farmers in terms of timeliness and cost economics compared to traditional practice.

Bullock-operated potato-digger: Light weight potato- digger comprises extension rods, shank, mainframe, harvesting blade, hitch, handle and beam. It was tested with a pair of bullocks on terraces and valleys at an average bullock speed of 1.7 km/h and depth of operation of 120 mm. Size of harvested potato varied from 40 to 60 mm. The digging efficiency and field efficiency of the potato-digger were 93% and 88%,

Field trials of animal-drawn light weight potato digger

respectively. Its draught was 320 N. The effective field capacity and cost of operation were 0.03ha/h and ₹ 1,250/ha, respectively. The labour requirement was 35 h/ha for digging and 150 h/ha for picking of potatoes. It saved

Mechanization Index of Madhya Pradesh

Data for mechanization index with respect to seven districts (Raisen, Dewas, Khandwa, Chhindwara, Seoni, Mandla and Ashok Nagar) of Madhya Pradesh were collected from 280 farmers and analyzed. Average power availability was 1.80 kW/ha, which ranged from 1.63 to 2.05 kW/ha across the selected villages. Mechanical power contribution was in the range of 80 to 88%. Input-output data were converted into monetary terms and the cost of cultivation for crops grown in each district was calculated. Mechanization index for seven districts ranged from 52 to 68% (average - 58%) for wheat, 35 to 46% (average - 40%) for soybean, 34 to 41% (average - 37%) for maize and 41 to 46% (average - 44%) for chickpea.

60% in labour and 61% in cost of digging over traditional digging on terraces.

Alternate energy equipment

Solar PV pumping systems for micro-irrigation systems: Two solar PV pumps have experimentally been tested at different solar irradiations with mini-sprinkler, micro-sprinkler and drip systems. Field performance of micro-irrigation systems with 1-hp capacity solar pumps with 3-4 m suction head revealed 2.1 kg/cm^2 operating pressure with 9 mini-sprinklers under the AC pump and 1.1 kg/cm^2 operating pressure with 50 micro-sprinklers under the DC pump. Pressure-discharge relationship of both AC and DC pumps was developed and a discharge of 45-50 litres/min was observed with 9 mini-sprinklers in the solar AC pump.

Solar aerator for fish-pond: In view of solar energy potential (6.4-4.3 kWh/m^2/day with clear sunny days 250-300/year), a spray-type solar aerator was tested for dissolved oxygen in a fish-pond. By operating the aerator for 6 to 7 hr in a day, an increase of 30-35% of dissolved oxygen in the bottom layers was observed.

Performance evaluation of solar PV power plant (25 kW$_p$): A cold-storage facility for fresh horticultural produce (6-8 tonnes), powered by solar photovoltaic (25 KW$_p$ capacity) with battery back-up (240 V, 900AH capacity), has been fabricated and installed. The PUF insulated walk-in -type cold storage chamber (Lenght × Breadth × Height: 5m×4.4m×3 m) was constructed and fitted with a vapour compression refrigeration system (2.5 TR capacity) and a humidifier. Temperature and relative humidity (RH) controllers were fitted in the chamber to maintain temperature at 5-15°C and relative humidity at 65-95%. Energy output from the solar panel ranged from 75 to 115 KWh/day, which was sufficient to operate the storage unit.

Fresh matured unripe mangoes (Dasheri and Bombay Green varieties) were stored in June in the cold storage chamber at 12±1°C temperature and 90-93% relative humidity. Based on the different physico-chemical parameters, it was found that Dasheri mango could be stored safely up to 15 days and Bombay Green up to 8 days as compared to 4 days and 3 days, respectively, at ambient storage.

Low-tunnel solar-dryer: A solar-dryer with 7 m^2 collector area has been developed for non-electrified regions. The PV module produces electricity and also heats ambient air passing beneath it. The PV panel output is used to power brushless DC fans to produce forced convection drying. The system was tested at full load (40 kg tomatoes) at an average solar radiation of 790 W/m^2. The moisture content of the tomatoes was reduced from 95.5 to 5% (wet basis) in 20 solar hours (8 h/d). The total cost of the PV integrated dryer has been estimated at ₹ 95,700.

Solar steam generation system: This system has been developed with three solar collectors each with an aperture area of 1.90 m^2. Each collector has 15 heat- pipe-type evacuated tubes with outer diameter of 59 mm and length of 172 mm. A heat exchanger connected to solar

Solar steam generation system

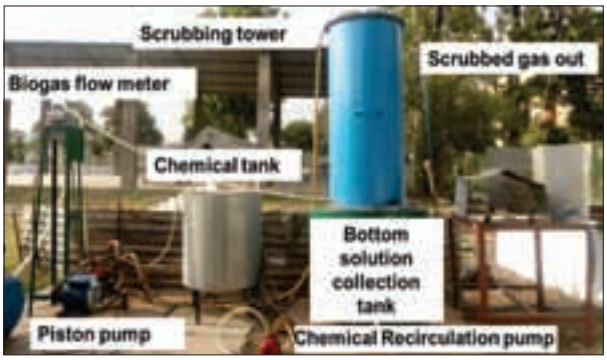
collectors was installed in the storage tank. The heated thermic fluid (Hytherm 600) from solar collectors is circulated through heat exchanger. The steam generation system has thermal efficiency of 15.4%. The approximate cost of the system has been worked out at ₹ 80,000.

Hydro pre-cooler for fruits and vegetables: The pre-cooler (100 kg/batch) has been developed for fruits and vegetables. It consists of an insulated water tank (L×B×H : 0.82m×1.6m×1.0 m), evaporative cooling tower with 0.37- kW motor and 0.45 m diameter axial fan,and an inclined trough for holding products submerged in the tank, belt conveyer and surface moisture drying unit. Cold water is recirculated from the evaporative cooling tower

Hydro pre-cooler

to water tank. Surface moisture drying unit is fitted with an axial fan below the perforated tray. The system cooled 1,060 litres of water in the tank from 38.5°C to 25.1°C in 4 h at the ambient temperature and relative humidity of 37-39°C and 38-51% RH, respectively. A batch of 100 kg fresh mangoes could be cooled from 35°C to 29°C in 20 minutes.

Purified biogas storage system: This has been developed by using a biogas scrubber, moisture-absorption unit (filled with 3A molecular sieves), compressor and purified biogas storage cylinder. Storage tank is provided with a molecular sieve- holder to remove moisture. Gas from the biogas plant was scrubbed inside



Purified biogas storage system

the scrubbing tower by counter-current principle; the gas was supplied from the bottom by using a compressor and the chemical solution was sprayed from the top by using a piston pump. Scrubbing is done using an aqueous solution of NaOH (0.5 M). For every cubic metre of biogas, 14 litres of chemical solution is used. The chemical scrubbing was effective in increasing methane content of biogas up to 92.3%. Prior to biogas storage, moisture of scrubbed biogas was removed by passing purified biogas through adsorption unit. The purified biogas stored in the cylinder is 0.5 m^3 at a pressure of 1.5 bars.

Bioreactor for accelerated biomass composting: A rotating drum-type bioreactor (100-kg biomass/batch) of 1.25m diameter and 1.5 m length has been developed for accelerated composting. The rotating drum is made of double-wall with outer one insulated with 50- mm glass-wool. Heating is provided using four strips of heating element of 1-kW each. The water is filled between double-walls for uniform heating. A temperature indicator -cum -controller is used for controlling temperature of substrate. The bioreactor is mounted on a three-wheeled structure for easy transport. Soybean -straw mixed with

Rotating drum-type bioreactor

biogas slurry @ 1% indicated that micro-organisms were most active during 6-9 days of composting. There was complete decomposition of cellulose, hemicellulose and lignin in 21 days. Significant mineralization of the straw was under thermophillic phase. The temperature of biomass was maintained between 60 and 70°C in the reactor.

Energy auditing of biomass gasification

Energy audit of biomass gasification based power plants in the Punjab State was conducted. Seven plants having total capacity of 67.5 MW were installed at different locations. Malwa Power Plant at Gulabewala village in Muktsar district purchased around 55,000 tonnes of paddy- straw covering nearly 20,000 acres from nearby village at ₹ 1,200/tonne. With an area of nearly 28 lakh hectares under paddy, the state produces and burns nearly 175 lakh tonnes of paddy-straw worth ₹ 2,100 crore every year. If biomass gasification plants are set-up, the straw can generate electricity. Transporting and using paddy- straw is possible in the radius of 20–25 km around the power plants. Beyond this it is uneconomical owing to higher transportation cost. By straw collection, an additional income of around ₹ 3,000 per acre worth ₹ 25,000-30,000 from 10 to 12 acre fields in a day and a net profit of ₹ 3-4 lakh can be earned during paddy season that lasts for six weeks. To promote paddy-straw use, the Government is offering 50% subsidy on baler and reaper. The venture is fairly profitable with a payback period of three to four years for farmers and even others who can invest and earn extra income from collecting and selling paddy-straw.

Briquetting of jute-sticks: In India, approximately 4 million tonnes of jute-sticks (after removing fibre) are produced annually. These sticks contain higher lignin (18%) and lower ash (1.7%), and thus are suitable for briquetting. They were ground below 2- mm particle size

Briquetting of jute sticks

to produce briquettes using die- and- press- type briquetting machine (500 kg/h) with tapered die of 60-mm diameter. The true density and moisture content of the briquettes are 900-950 kg/m^3 and 6.2% (weight basis), respectively. The calorific value of the briquettes is 18.59 MJ/kg. These briquettes can be used as domestic fuel, at brick kilns and in boilers.

Pilot plant for glycerol refinement: Crude glycerol, a by-product of transesterification process, contains 9.4% soap of *p*H 10.8, 4.3% ash, 4.2% free fatty acids and 21.5% methanol. The pilot plant consists of a neutralization chamber of 25 -l -capacity with a

Plant for glycerol refinement

removable lid and an agitator set -up. Neutralized glycerol is passed by gravity flow into a double-jacketed methanol and moisture distillation reactor of 35-l capacity with an agitator set-up, and heat is supplied through a steam generator. A water-cooled glass condenser is used to condense methanol and moisture. Vacuum distillation is conducted in the same chamber, and the distillate is collected in a chamber of 6-l capacity. Vacuum distilled glycerol is drained into a decolourization chamber of 2-l capacity. Refined glycerol yield from 100g of crude glycerol by this process was 39%.

Biomass gasifier cook-stove: A community-size gasifier cook-stove has been developed. It is made of mild steel cylinder of 540- mm outer and 400- mm inner diameter and a height of 960 mm. Refractory cement and cera-wool are used as insulation material to reduce heat losses and risk of burn injury. The stove consumes 3.0 kg of fuel-wood (100mm×30mm) per hour. Thermal efficiency of the stove is 36.38% with power rating of 5.0 kW.

Biomass gasifier cook-stove

Processing equipments

Power-operated onion detopper-cum-grader: The newly developed power-operated onion detopper-cum-grader consists of feeding, detopping and grading mechanisms. Onions after detopping are graded in five grades of < 35 mm, 35-50 mm, 50-60 mm, 60-85 mm and > 85 mm. Grader's feeding rate, detopping capacity and efficiency were 277 kg/h, 238 kg/h and 86%, respectively. The average power requirement at load was 0.9 kW. The average onion leaf neck length before and after detopping was 314.8 mm and 23.4 mm, respectively. Onions (in percentage)1.88, 44.73, 33.08, 20.29 and 0 were graded in < 35, 35-50, 50-60, 60-85, > 85 mm, respectively. The average output capacity of manual onion detopping and grading was 30 kg/h and 100 kg/h, respectively. The approximate cost of power-operated detopper- cum- grader was ₹ 85,000 and its operation cost was ₹ 256/tonne compared to ₹ 813/tonne of the manual onion detopping and grading.

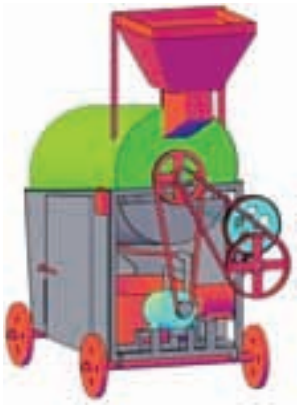
Onion detopper-cum-grader

Pedal-and power- operated arecanut dehusker: Pedal-operated arecanut dehusker was developed using anthropometric data of workers and agronomical principles as well as mechanical design parameters for

Pedal-operated arecanut dehusker

better man- machine system efficiency. Mean value of the heart rate of male workers operating it was 127 beats/min; indicating that the unit can be operated comfortably by workers over a longer time. The dehusking efficiency, kernel breakage and dehusking capacity were 97%, 6.7% and 15kg/h, respectively. The weight of the unit is 110 kg, and is mounted on wheels for mobility. The unit costs ₹ 15,000 with an operating cost of ₹ 3.70 kg/h as compared to ₹ 5.10/kg by manual dehusking in conventional method. The dehusker can also be operated by one hp electric motor with minor modifications.

Potato peeler-cum-washer: It is a two- in -one machine, suitable for small- scale processors for making potato-chips and other value-added products. The machine works on the principal of abrasive peeling. Its main components are abrasive roller (356-mm diameter), power transmission system, water spray system and water-lifting pump. The peeling drum with protrusions on the inside surface rotates and detaches peel from potatoes. The water spraying unit washes potatoes and simultaneously the peel is removed from the drum through perforations along with water flow.



Potato peeler-cum-washer

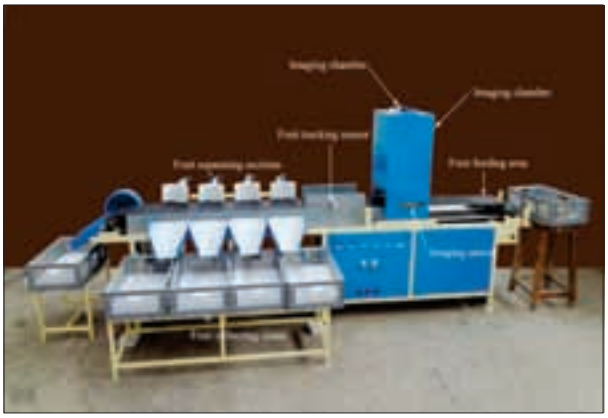
Taro peeler: This machine consists of five brush-rollers mounted over a shaft, a power transmission system and a water spraying system. Overall dimensions of the prototype are 470mm × 750mm × 960 mm. Its capacity is 200-250 kg/h with peeling efficiency of 95-97% with negligible breakage. The machine is easy to use, safe to operate, easy to repair and maintain, of low operating cost, small in size, has low weight, and low noise and vibration.

Taro peeler

Pneumatic-assisted coring device for oblong fruits: The prototype machine consists of a hopper,a moveable wooden roller, a extended fruit dropper, a coring plunger and a stone remover outlet. Wooden roller has a capacity of 6 fruits at a time and it drops fruits through dropper in specific groove on the wooden fruit-holding base for stone removal. All power transmission is controlled by pneumatic air- cylinders. Coring- plunger unit of stainless steel is attached to the main frame. The wooden frames of 470 mm × 50 mm are mounted on an individual mild steel sheet at equidistance on a circular movable unit that rotates only clockwise. The machine is also suitable for coring of fresh date-palms.

Coring device for oblong fruits

Automatic mango grader: The graders of 620 to 650 fruits/h or 200-300 kg/h capacity have been developed with five sections feeding, conveying, imaging, fruit separating and process controlling. Mango fruits are fed manually. The conveying section conveys fruits from feeding section to separating section via imaging section. Imaging section consists of shade- free imaging chamber, imaging device and fruit-detecting sensor. The fruit-detecting sensor is fixed perpendicular to the conveyor axis on the side wall of the imaging chamber at 15mm height from the surface of the conveyor belt. In the fruit separating section, five outlets are given for five grades. Process control section consists of a computer with data I/O card (Arduino Mega 2560, Italy), 5V-four channel



Mango grader

relay, PLC, rotary shaft incremental encoder and a fruit tracking sensor. Camera is connected to the computer with the GIGE Ethernet port. The data I/O card is attached with computer via USB port. The fruit detecting sensor is attached with Arduino board. The machine was evaluated for grading three mango varieties. Higher effectiveness of 98.6% was observed in Alphonso, followed by 96% for Banganapalli and 93.3% for Neelam. This machine would be more suitable for online grading of mangoes based on the external as well as the internal qualities. The operating cost of the machine was ₹ 0.60/kg fruits.

Walnut bleacher-cum-washer: The conventional washing of walnut is done under running water from streams and with tap-water in water drums, troughs or woven vicker-baskets. Nuts are stirred by wooden logs or trampled by feet under running water. Such practices break shell seal resulting in moisture ingress that subsequently leads to microbial growth, darkening of kernel and may cause rancidity, despite the method being laborious and time-consuming.

Walnut bleacher-cum-washer

To overcome these problems, a walnut bleacher-cum-washer (capacity: 150-180 kg/h and efficiency: 95%) has been developed. The unit consists of a rotating drum with meshed surface,and a cylindrical and horizontal and rectangular pyramidal hopper. There is well designed proper output mechanism fitted with lever which lifts drum by 9 degrees. The estimated cost of the machine is ₹ 50,000.

10. Post-harvest Management and Value-addition

An essential component of the agriculture in achieving food security for all is preserving, processing and value-adding produce in the post-harvest chain. Huge losses occur of the produce in the post-production systems; estimated to range from around 4% for foodgrains to 18% for fruits and vegetables. The total monetary value of these losses as on 2014 price level was ₹ 98,000 crore per annum. Value-addition and preservation in post-harvest chain would help making greater and healthier food choices for the consumers throughout the year.

Cottage-scale pilot plant for probiotic soy-cheese spread and soy-milk powder: Probiotic soy-cheese spread was developed using starter cultures prepared on the sterilized tofu- whey culture medium. Different ingredients (cow milk, sucrose and okara) were added to soymilk as substrate for growing probiotic lactic acid bacteria, and coagulation process was optimized.

A cottage- scale pilot- plant with a capacity of 10 kg per batch for preparation of probiotic soy-cheese spread has been developed. Fermented soymilk with appropriate doses of probiotic bacteria was spray-dried as well as freeze-dried to obtain probiotic soymilk powder; at 4°C, all the samples were stable during 6 months of storage with a viable cell count of 10^7 - 10^8 CFU/g. Probiotic soymilk powder exhibited antioxidant and antimicrobial properties and tolerance to bile and acid.

(a) Cottage-scale pilot plant for preparation of probiotic soy-cheese spread; (b) Probiotic soy-cheese spread; (c) Probiotic soy-milk powder

Hybrid dryer for pigeonpea *dal:* A solar biomass hot- air dryer was developed for drying 350-kg soaked pigeon- pea (whole). The dryer unit is covered with UV-stabilized solarization sheet for absorption of solar radiation during the day time. External heating arrangement for operating during night and in cloudy weather conditions has been provided using two downdraft inverted gasifier stoves and conduction tubes placed in the plenum chamber. Dehydration chamber has six partitioned double tray racks. The plenum chamber is equipped with fans and blower for air circulation and uniform heat transfer. During testing, temperature in solar tunnel area was recorded as 70±10 °C and 50±10°C was at the plenum chamber while ambient temperature was 34±2°C. Approximate cost of the unit is ₹ 1.20 lakh. This unit will be very useful to milling industry.

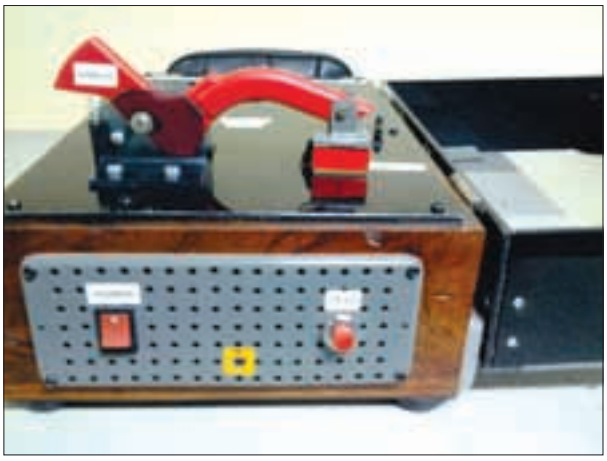
Hybrid dryer for pigeonpea

Heat treatment and ripening chamber for banana: To enhance the shelf-life of banana and for product safety, a set of equipment for post-harvest treatment of banana has been developed. This includes a hot-water treatment chamber and a collapsible ripening chamber. Hot- water treatment at 45°C for 45 min in a chamber of 20 kg per batch capacity retarded fungal growth and increased shelf-life of bananas by five days. The collapsible ripening chamber of one-tonne capacity resulted in uniform ripening of bananas. Temperature in the ranges of 15 to 17°C, relative humidity in the range of 85-90% and pre-determined ethylene concentration can be maintained in the chamber with domestic air-conditioner,

Collapsible ripening chamber for banana and other fruits

humidifier and ethylene generator, respectively. Five days were required to fully ripen banana at 17°C and 90% RH. Bananas ripened using this technique had two days longer shelf life than those ripened using traditional methods.

Testing electrical insulation of technical textiles: Technical textiles have come up worldwide in a big way. Measurement of electrical insulation properties of the fabric is essential especially when that fabric is to be used in the electrical field. An instrument has been designed and developed to measure electrical insulation of jute and allied fibre- based technical textiles. The digital instrument measures resistance in terms of Mohm/Gohm in the transverse direction of textile material up to 2-cm thickness. The measurement shows 99.6% accuracy. A safety measure has also been incorporated as the instrument works at high voltage and not in the open condition. Repeatability of the measurement was found good with deviation between minimum and maximum values insignificant at 1% confidence level in a sample of 30 measurements. This instrument is user friendly, is of low cost, is precise and easy to calibrate. It is useful for assessing suitability of fabric for electrical insulating products like gloves, jackets, floor covering etc.



Instrument for testing electrical insulation of jute and allied fibre-based technical textiles

Electronic colour meter for jute and mesta fibres: Following two types of colour measurement instruments for jute have been developed.

A very low-cost handy-type instrument: This uses indications for three major colour ranges of the fibre sample. Only 3 LEDs have been used for the indication of the colour range. Its main features are as follows.

- It is an automatic type and works on Light Reflectance technique.
- No expertise is required to operate it.
- It is a very low-cost device.
- It is portable and can work with rechargeable cells/solar cells/primary cell.

Electronic meters for jute and mesta fibres

A laboratory type colour meter for quantitative measurement: This has a digital 7-segment display, indicating colour properties of the fibre. Its main features are as follows.

- It is an automatic type and would work on Light Reflectance and Specular reflectance methods.
- The values of colour in terms of whiteness and lustre are displayed digitally.
- No expertise is required to operate the instrument.
- It can work both on AC 230V, 50Hz supply and from battery supply.
- Computer interface is present and can be used for stored data transfer in the computer.

Production of nano-cellulose on pilot scale: The process protocol for large-scale production of nano-cellulose from cotton-linters was optimized in Nano-cellulose Pilot Plant at Mumbai. The final product dimension was less than 100 nm with a consistency of 2% and the product can be produced both in a slurry form and in a powder form. This product can be a potential candidate for use as reinforcing agent in polymeric composites, concretes, natural rubber composites; as rheology modifier in paints; and as a carrier for pesticides and micronutrients.

Nano-cellulose production process (*inset*: AFM image of nano-cellulose)

Biosynthesis of aleuritic acid in Indian lac insect: Aleuritic acid is one of the widely used starting materials for producing musk-odour compounds at perfumery industry. Its natural source is a lac resin from which it is isolated by alkaline hydrolysis. Biosynthesis of aleuritic acid in Indian lac insect has been understood based on the fatty acid profiling, enzymatic analysis and inhibitor studies. According to this, four enzymes (fatty acid desaturase (FAD), epoxygenase, epoxide hydrolase and monooxygenase) are involved in the pathway; using hexadecanoic acid as the starting material. The hydroxylation at 9^{th} 10^{th} and 16^{th} position is achieved through a four step biochemical process. This is the first report regarding biosynthetic pathway of aleuritic acid.

Lac mud utilization in vegetable and flower production: Lac mud is a waste of lac- processing industry. Analysis of lac-mud revealed higher content of

organic carbon (23.3%) and organic matter (40.2%). It also contains 0.65% N, 0.31% P_2O_5 and 0.12% K_2O. Sulphur, copper, zinc, iron, boron and molybdenum content in lac mud was also found quite high. Substitution of 25% of the recommended nitrogen through lac mud, 25% through vermin-compost and 50% through chemical source gave 36, 23 and 16% higher fruit yield in brinjal and tomato, and fresh leaf yield of spinach, respectively, compared with application of only chemical fertilizers. Application of fortified lac mud (0.2% N + 0.2% P_2O_5 + 0.2% K_2O) was found to be a better option as substitute for other organic manures for higher flower yield of rose and chrysanthemum.

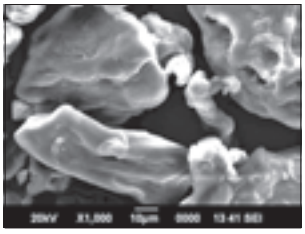
Carboxymethyl derivative of guar gum: India is the largest producer of guar gum in the world, and this gum is one of the best thickening, emulsifying and stabilizing agents. Guar gum hydrates well in aqueous solutions. Solution clarity, alcohol solubility and low thermal stability were the problems that led to the development of a number of chemically modified guar gums. Carboxymethyl derivative (anionic) of guar gum was synthesized, reacting guar gum with suitable reagents

Carboxymethyl derivative of guar gum

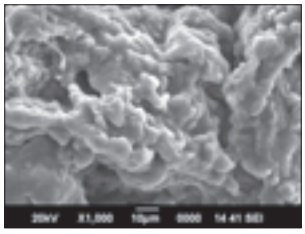
Solution clarity of carboxymethyl derivative of guar

using semi dry and non-aqueous method. The key physico-chemical parameters such as viscosity, time of hydration and degree of substitution (Ds) of the synthesized derivative were estimated for confirmation of derivatization. The viscosity and solution clarity of aqueous solution of carboxymethyl guar increased with higher Ds of the derivative; it finds its application in fabric printing, oil well fracturing, mud drilling and industrial application and preparation as stabilizer, thickener and suspending agents.

Hydrogel from guar gum: Hydrogels have been synthesized using grafted co-polymer of modified gum with vinyl substituents. The optimization of reaction parameters for synthesis of hydrogel for concentration of monomer, cross linker and initiator has been completed. Guar gum shows a tight structure while its hydrogel is a porous structure due to interpenetrating network formation.



SEM image of guar gum



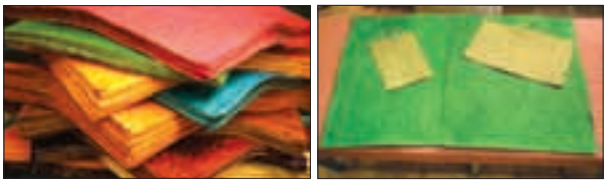
SEM image of guar gum based hydrogel

Nail polish formulations: Nail polishes are synthetic resin and pigment based and can reach stomach along with food materials while eating, during feeding children and due to nail-biting. A natural nail polish formulation (IINRG-NPL-05) has been developed based on the lac resin (a natural material). It gives very glossy, hard, smooth and durable finish on nails, and is quick drying and non-hazardous to health. It conforms to requirements of BIS standard (IS: 9245:1994).

Natural nail shine

Lignocellulosic fibres for pulp and paper: Removal of lignin from lignocellulosic raw materials requires pulping. This required many chemical treatments with caustic, sulphide, sulphate-based chemicals. These treatments result in huge effluent production. An eco-friendly process has been developed where bio-treatment of lignocellulosic fibres produces a raw material that requires very low chemicals, and pulping can be carried out at a lower temperature. Even production of effluents is minimum with this, and paper produced was with improved optical and physical properties.

The fibres are first treated with cellulase-xylanase combination, followed by laccase treatment and low chemical Alkaline Sulphite Anthroquinene Methanol (ASAM) pulping at 115°C for 3 hours. The pulp thus produced requires minimum of mechanical beating. The pulp is bleached by environment-friendly hydrogen peroxide bleaching process for whitening. The pulps thus produced are being utilized for making handmade papers of different arial density to produce drawing paper, carry-bag paper, visiting card and file- cover paper, crack paper and writing paper.



Lignocellulosic fibres raw material for pulp and paper

Eco-friendly printing of jute with natural dyes: Printing of designs on mordanted-bio-scoured-bleached jute-fabric was carried out by screen printing method using 40-mesh size. Curing of prints was done by steaming, followed by soaping and washing.

The printed jute-fabrics thus produced are of very high design sharpness and fastness properties like washing

Printed with natural dye extracted from annatto seeds

Printed with natural dyes extracted from roots of manjistha

and rubbing. The eco-friendly printed jute can be utilized for production of fashion-bags, home- textiles, and fashion- garments.

Design and development of jute- based decorative fabrics: Thirty designs suitable for jute with silk and jute with cotton union blended fabrics have been developed. Also ten jute-based decorative fabrics (₹ 120 to ₹ 170 per sq. m) with minimum jute content of 55% for light weight winter jackets, slippers, and some ladies outerwears were developed. Fancy jute covered yarn/mat stick-based ornamental fabrics have also been developed, which may be used for floor-mats and as different value-added products. Slippers and office bags have been developed from jute-based ornamental fabric and file folder and shopping bag have been developed from jute/ mat-stick fabric. In an effort for commercialization, one MOA has been signed with Miltex Eco-fibres, Coimbatore, Tamil Nadu. About 50 metres of jute/silk lightweight fabric was supplied to Miltex Eco-fibres; total revenue generated through this was ₹ 40,000.

Jute-based decorative fabrics

Flame-retardant finishing of jute textile: Nano ZnO can be easily synthesized by wet chemical methods such as alkaline hydrolysis of respective metallic salts at ambient conditions. Considering the ease of synthesis and yield, ZnO is selected as a suitable nano particle for jute textiles to impart flame-retardancy. Chemical synthesis of flame-retardant nano-particles was done by adding sodium carbonate 0.12 M solution slowly to 0.1 M of zinc nitrate hexa hydrate solution in ten minutes, followed by continuous stirring for 60 minutes using magnetic stirrer. After 60 minutes, zinc nitrate was converted into $Zn(OH)_2$. The nano $Zn(OH)_2$ solution was then dried at 90°C for 2 hours to remove water, followed by calcinations at 400°C for 2 hours. The yield of nano ZnO was 48%.

Indian pineapple leaf fibre (PALF) for apparels: Pineapple leaf fibres were extracted and softened by decortication and subsequent water-retting. Decorticated-cum-retted fibres have showed better physico-mechanical and surface appearance properties than the decorticated ones. The fibres developed by this method are fine (10.2 micron), soft (flexural rigidity, 3.2) and have excellent natural surface appearance. Whiteness and brightness indices of retted fibre are 60 and 41. Balanced coefficient of friction between fibre to fibre (44, 64), moderate strength (19g/tex) and low flexural rigidity indicates its spinnability for yarn formation in automated spinning system. Fine yarn (38 tex) can be spun in the silk spinning system and the property performance has been found suitable to make eco-sustainable novelty fabric. Yarn properties such as breaking tenacity (22.5), flexural rigidity (3.2), moisture absorbency (8.0) are found good for making apparel-quality fabric. Fabric was developed using cotton as warp yarn and pineapple leaf fibre as weft yarn in a handloom. High initial modulus of fabric indicates very good dimensional stability of the fabric. The abrasion resistance is notably high, showing weight loss value 3.35%, even after 3,700 cycles, indicating its high durability. Water-wicking property of PALF is almost similar to cotton, and high rate of absorbency of PALF shows its ability to absorb perspiration within a short time. Its crease recovery angle is nearly similar to that of commercial cotton. Thus, pineapple leaf, an agro-waste, can be successfully utilized for making green-fashion fabrics.

Decorticated and retted PALF

Electrospun fibre mat from cellulose acetate: A novel electrospinning process for production of nano-fibre mat from Cellulose Acetate (CA) has been developed by which nano fibre of diameter 100-220 nm could be produced. The optimized process parameters included 25 kV DC voltage, 15 cm distance between needle and collector and 0.03 ml per minute of polymer flow rate. This electrospun fibre mat can be used as matrix for the development of nanosensors.

Jute fibre reinforced polypropylene composite: DREF- friction spinning process was used for the preparation of jute reinforced polypropylene composite. Nine different Jute core polypropylene wrapped yarns were produced with varying core yarn twist level and jute: polypropylene proportion. The core spun yarns were converted into fabrics in both plain and twill weave and finally fabrics were converted into a total of 18 different composite

Jute polypropylene composite

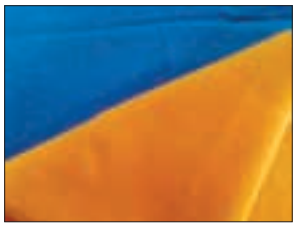
materials using compression molding process. It was found that with increase in jute reinforcement, the composite tensile strength either increased or remained constant. It was noticed that the plain weave structure had a little advantage over twill weave for this type of composite material. These types of composites can be used as an alternative to plastics, especially for high-strength applications.

Ginning of long-staple cotton on rotary-knife roller gin: Double roller (DR) ginning technology is widely used in India despite low ginning rate and there is limited scope for improvement in its productivity. The rotary-knife roller ginning technology is used in the USA and Turkey as a higher-capacity option in comparison with the double roller (DR) gin. It gives better fibre-spinning quality compared with saw ginning. Advanced rotary knife-roller ginning technology has not been practised in India because of higher fibre neps and seed cuts while

Rotary-knife roller gin

ginning Indian cotton. Hence, a commercial rotary knife-roller gin was evaluated and optimized for efficient ginning of Indian cotton. The efficient ginning was obtained at a roller speed in the range of 200-225 rpm, rotary-knife speed of 400-450 rpm, feeder roller speed of 18-20 rpm and at a pressure of 80 bar between the roller and the rotary-knife. The rotary-knife roller gin has a capacity of 425 kg lint per hour and is a higher-capacity option compared with DR gin, which has only 90 kg lint per hour. Hence, to increase profitability of ginning business and to ensure timely processing of cotton, rotary knife-roller gins can be used successfully.

Cotton-rich/bamboo viscose blended functional fabric: Yarns (30s Ne) from cotton, bamboo and their blends (65:35) were produced using compact ring spinning technology. They were woven into plain weave construction (GSM- 144, 82 ends × 72 picks per inch) on a sample loom. The fabrics were then subjected to scouring and bleaching through chemical and enzymatic methods. The enzymatically scoured cotton/bamboo blended sample gave better softness and whiteness (Index: 61) than alkali scoured samples (Index: 64). Subjective assessment showed that the cotton/bamboo viscose blended fabric has better softness compared to 100% cotton-fabric.



Cotton: Bamboo: viscose blended functional fabric

Functional and nutraceutical food products

Composite flour eggless cake: This contains 8.3-12 g protein, 19-22 g fat and 4.7-8.4 mg iron per 100 g and is made of banana with yoghurt, chia seeds, soy-milk, refined oil and composite flour; replacing egg, fat and refined flour, respectively. The composite flour; contains wheat (33%), malted fingermillet (41%), sprouted soy (8.5%) and sprouted amaranth (17.5%).

Composite flour eggless cake

Multigrain tortilla chips (Nachos): Baked multigrain tortilla chips have been made from a combination of corn, wheat, rice, sorghum (plain and nixtamalized) soybean, greengram (sprouted and unsprouted) and skim milk powder. Nixtamalized and sprouted chips had an overall acceptability of 8.6 on a 9-point hedonic scale. Nixtamalized and multigrain-based tortillas have significantly higher calcium content of 466 mg per 100g compared with the plain corn chips. Nixtamalized and sprouted multigrain tortillas make a tasty snack and are healthy and nutritive.

Nixtamalized and sprouted multi-grain tortillas

Antioxidant-rich pasta from vegetables and buckwheat: Capsicum incorporated pasta was developed using 18% groundnut meal and 82% refined wheat flour in food formulation with 27.3 mL per 100g capsicum juice as a liquid portion. The total protein, phenolic content and antioxidant activity of this pasta were 17.81%, 341.68 mg per 100g and 18.11%, respectively. The overall sensory acceptability was 8.53 on a scale of 10. Beet root incorporated pasta was also developed.

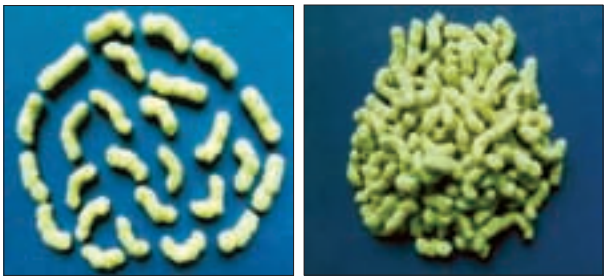
Protein and antioxidant-rich pasta with capsicum

Protein and antioxidant-rich pasta with beetroot

White ragi-malt-based designer food: In the backdrop of requirement of designer foods for targeted group of 2-5 years age, millet-malt-based food, which is 'Ready-to-Cook' and 'Complete One Meal Dish' has been developed. The process involves blending malted white

ragi flour at different levels with malted greengram flour (11.5%) and sugar (18.5%). Further, processes were optimized by incorporating skim milk powder (SMP), replacing greengram; whey protein hydrolyzate (WPH) up to 75% replacing SMP; and supplementation with honey and probiotics for enhancing consumer acceptability. Shelf-life of the developed product was 2 months.

Extruded snacks from broken walnut kernels: Nutritious extruded snacks from broken walnut kernels and rice have been developed with co-rotating twin-screw extruder. Storage studies revealed that the extrudates can be safely stored up to 3 months in LDPE bags under ambient conditions.



Extruded product from broken walnut kernel and broken rice

Pre-harvest field operations for improving post-harvest life of fruits: Bagging of litchi fruit bunches with white butter paper bags and non-woven polypropylene bags reduced sunburn and fruit cracking by about 30-35% and increased fruit weight by 6-16% over the control.

In litchi, *Bacillus subtilis* @ 1×10^8 cell/ml, potassium silicate @ 0.5%, chitosan @ 1%, Carbendazim @ 0.2% as post-harvest dip were effective in controlling fruit-rots up to 6^{th} day compared to 3 days in the control. Fruit dipping in chitosan (1%) + *B. subtilis*@1×10^8 CFU or Carbendazim (0.1%) maintained quality and increased shelf-life of fruits up to 18 days at freezing temperature.

Pre-harvest spray of GA_3 (100 ppm) + potassium sulphate (1%) significantly reduced fruit cracking (14%) and increased fruit weight by 15% in litchi cv. Shahi.

Extension of shelf-life: Treating the minimally processed pomegranate arils with salicylic acid, *Aloe vera* gel and ascorbic acid/citric acid extended shelf-life up to 19 days at 5°C.

Processing and value-added products: A processes for total utilization of commercially unmarketable pomegranate fruits (mature fruits with spots, slight cracking and over-sized) into juice, wine, pomegranate seed oil, organic mouth wash and bio-colour from rind was standardized. Litchi pulp could be preserved up to 10 months at 6±1°C with a treatment involving pasteurization and addition of 1500 ppm potassium meta-bisulfite. A probiotic drink having 5.7×10^8 CFU/ml *Lactobacillus* load, 4.8°B TSS, 0.61% acidity and 12.2 mg ascorbic acid/100 ml was developed from raw mango fruits through lactic acid fermentation. Similarly, a probiotic drink using mature unripe bael fruit having 6.4^0Brix TSS, 0.52% acidity, 0.7 mg/100 ml ascorbic acid and 312 mg/100 ml total phenolics was developed through lactic acid fermentation. A process for making ready-to-drink carbonated acid lime and Nagpur mandarin juices was developed and commercialized to an entrepreneur in Mohpa, Maharashtra.

Extending storage life of onion: During *rabi*, pre-harvest spray of 600 ppm IAA at 90 DAP and 400 ppm $CoCl_2$ at 105 DAP in Bhima Kiran, Bhima Shakti and Bhima Shweta varieties of onion reduced rotting and weight loss during storage.

Processing and value-addition: A combination of edible coating (pectin or PVA) and modified atmospheric packaging of minimally processed carrots extended its storage life upto 21 days at 8^0C without significant deterioration in quality. Lycopene enriched tomato soup and juice exhibited good retention of nutritional and sensory quality till 2 months of its storage in glass bottles under ambient conditions (28.72- 35.58^{0}C). In potato, microwave processing at 600 W for 2.5-3 minutes, produced potato chips with acceptable sensory scores (7.6 on 9 point hedonic scale) and low fat content (~3.57% vs 35.5% in commercial preparation). A fortification technique with whey protein concentrate for making enhanced protein (19.43%) starch noodles from sweet potato was perfected. For production of a low glycaemic flour *spaghetti* and *starch*, NUTRIOSE®, a commercial Resistant Starch source with a high dietary fiber content (85%), was observed an excellent additive to sweet potato flour and starch.

Coco-sap chiller: A device 'coco-sap chiller', which can easily be connected to spadix of coconut palm, and retains low temperature for longer duration while tapping the sap for collection of fresh hygienic coconut inflorescence sap (*Kalparasa*) was developed in partnership with a farmer. Quality evaluation revealed the superiority of the product over the traditional *neera*. When pasteurized and packed in plastic bottles with 0.1% Nisin, the product stored well with good keeping quality (15 days) both at ambient and refrigerated conditions. The technology was transferred to 12 firms in south India.

Value-added product of coconut oil cake: Virgin coconut oil cake (a byproduct in virgin coconut oil production) rich in proteins, phenolics and antioxidants was successfully utilized for sweet snacks and extruded value-added products production.

Milk

Detection of *E. coli* in milk: Two-stage test was developed for detection of *E. coli*. The developed test can be used in dairy industry for routine detection of *E. coli* in milk and milk products for regulatory compliance. The novel features of the test is rapid detection within 15.0 ± 1.15 h as against 3-5 days protocol in conventional method and selective inhibition of contaminants like *Salmonella, Shigella, Citrobacter, Enterobacter, Proteus, Serratia, Yersinia, Staphylococcus aureus, Bacillus cereus.*

Detection of oxytetracycline antibiotics residues in milk: A rapid and semi-quantitative lateral flow assay (LFA) was developed to screen oxytetracycline (OTC) antibiotics residues in milk samples. The assay was validated by spiking OTC to antibiotic free milk samples and results were accomplished within 5 min without the need of any equipment. The visual detection limit was 30 ppb. The developed LFA can be used as a rapid screening method at farm to fork level.

Extraction of antibiotics from food matrix: Imprinted polymers against oxytetracycline, cephalexin and cefquinome were prepared over the surface of iron magnetite and evaluated for extraction of antibiotics from food matrix. These polymers could extract 62 to 94% of the antibiotics from water, milk, honey and egg white.

Quality evaluation of dairy products: Machine vision system (MVS) was designed and developed and successfully evaluated for colour measurement of plain *burfi*. The developed system can be used for improving quality control and providing a highly useful color measuring tool for the food industry.

Technology of cheese dip: The technology for the manufacture of cheese dip was developed using sodium caseinate, WPC-70, Cheddar cheese and milk fat with the addition of unique combinations of stabilizer and emulsifiers and to enhance the palatability of cheese dip, four different spices were tried at different levels. The process developed for the manufacture of cheese dip has great industrial potential.

Value-addition: Processing techniques were standardized for Mozzarella cheese, Paneer, Gulab Jamun etc. From sheep milk.

Camel milk for treatment of autism in children: Camel milk consumption by 41 autism children as an adjunct to other form of treatment for 3 months resulted in improvement in 78% cases by having better scores on Autism Treatment Evaluation Sabel (ATES) scales.

Meat

Time temperature indicator: Total volatile basic nitrogen (TVBN) sensitive indicator sensor and on-package sticker type time temperature indicator was developed for monitoring meat quality and safety during storage conditions. A strip type indicator sensor based on bromophenol blue coated nitro cellulose membrane was developed, which when kept inside the packaged meat reacts with the TVBN released from the meat and changes colour from yellow to blue upon quality deterioration.

Shelf-life of pork products: Addition of *kordoi* (*Averrhoa carambola*) fruit juice and bamboo (*Bambusa polymorpha*) shoot extract significantly affected the instrumental colour values of the nuggets. Estimation of TBARS (thiobarbituric acid reactive substance) value, which indicates the oxidative stability of products, revealed that nuggets with *kordoi* fruit juice and bamboo shoot extract had significantly lower TBARS values on the day of processing compared to the control. Antioxidant components present in bamboo shoot extract and *kordoi* fruit juice significantly slowed the oxidation process of fat in pork nuggets during the storage period.

Poultry

***Sous-vide* processed chicken sausages:** *Sous vide* processing technology was developed, which is efficient in prolonging the shelf-life of chicken sausages to more than 90 days under refrigeration temperature (4 ± 1 °C) as compared to a shelf life of only 20 days wider aerobic processing.

Standardization of process for development of instant emu egg noodles: Process for development of instant egg noodles was standardized using emu eggs (60%) in combination with cereal flours, table salt and other seasonings. Emu egg noodles showed yield up to 60% with very good water absorption index and shelf-life of over 6 months at ambient temperature in air tight PET jar. The noodles contained moisture, protein, fat, ash and carbohydrate @ 8.3, 18.7, 14.6, 4.26 and 54.08%, respectively. The product was well accepted by the sensory panel members.

Thermal death time modeling of *Salmonella* Typhimurium using antimicrobials on dressed chicken: Decontamination study was carried out for thermal inactivation of *Salmonella* Typhimurium on dressed poultry carcasses. Acidified sodium chlorite (100, 200 and 300 ppm) or carvacrol (0.02, 0.04 and 0.06%) at 56, 60 and 64ºC was used to design a mathematical model to show the efficacy of these antimicrobials in combination with thermal treatment for effective inactivation of *Salmonella* Typhimurium on dressed chicken carcasses.

Wool and hair

Biophysical characterization of pig hairs: The thermal conductivity studies indicated that the mean thermal insulation and conductivity values of pig hair fibre was 0.068±0.004 m^2K/W (range 0.04 to 0.14) and 0.029±0.003 W/m/.K (range 0.026 and 0.031) respectively. Thermal conductivity values of pig hair fibre were comparable to values reported for wool, cow hair, elephant hair, horse and rabbit hair indicating that pig hair can find application in places where natural fibres are utilized for insulation. Electron microscopic analysis of the surface of pig hairs revealed presence of scales similar to those of other species.

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11.

Agricultural Human Resource Development

The Agricultural Human Resource Development continued to strive for maintaining and upgrading quality and relevance of higher agricultural education. Financial and monitoring support provided for Niche Area of Excellence (28), Experiential Learning (21 new), besides refurbishing and maintenance of educational structures, student and faculty amenities, course curricula revision/improvement, strengthening libraries with ICT and modernization of teaching with multimedia learning resources, etc. HRD programmes/ activities facilitated promotion and execution of ICAR sponsored schemes that include centralized admissions in UG/PG to reduce inbreeding, infuse merit and promote national integration; award and distribution of fellowships to attract talent and promote merit, admission of foreign students for globalization of agriculture education, capacity building of faculty through summer-winter schools and Centre of Advanced Faculty training, National Professorial Chairs and National Fellow Scheme for promotion of excellence, Emeritus Scientist Scheme as a structural method of utilizing skill bank of the outstanding superannuated professionals. Quality assurance of AUs was ensured through accreditation.

Activities for strengthening and quality assurance of State Agricultural Universities (62 SAUs) was taken up by the Agricultural Education Division of the ICAR, Deemed-to-be-Universities (5 DUs) and Central Universities (4 CUs) with Agricultural faculties under the National Agricultural Research System (NARS) to address the challenges of agricultural growth and upgrading quality of higher agricultural education. The Division, through the implementation of scheme-strengthening and Development of Higher Agricultural Education in India, assists the AUs to plan, undertake, aid, promote and coordinate agricultural education in the country. The scheme has enabled these institutions in building excellence in specific strategic areas in education and research through Niche Area of Excellence (NAE), promoting holistic higher agricultural education by blending knowledge, skill and attitude through Experiential Learning Units, RAWE, and related aspects concerning infrastructural development, gender mainstreaming and capacity building of the students with the total outlay of ₹ 358.00 crore.

Infrastructural Support

The support for minor repair/ renovation and refurbishing of structures, overall strengthening of infrastructure in AUs, maintenance of major equipments, student and faculty amenities, etc. continued during the year. With the support from the Council, the AUs initiated short courses/workshops/lectures on overall personality development, leadership programmes as well as spoken English.

Smart classrooms, supported by the Council provided comprehensive strategy for digital education, effective delivery of course curriculum enabling it to be student centric and ensuring enriched learning experience. The support for the curriculum delivery enabled common framework for curriculum management and effective implementation and preparation of the practical manuals leading to improvement in teaching as well as conducting practical classes. Teaching, learning support, guidance, mentorship, collaborative learning, feedback and assessment, personal development planning and tutoring, skills development and practice, and access to resources are encompassed in 'curriculum delivery' making it dynamic.The laboratories for UG & PG teaching and research were modernized and upgraded.

Support provided for student and faculty amenities/ tours/capacity building encouraged their participation in seminars, symposia, workshops etc. Support was also provided for student health, developing facilities for sports, organization of cultural and sporting events as Agriunifest and Agrisports. The support also helped improve amenities in the hostels and other services in the campus, including facilities for disabled. Placement cells helped students obtain placement or advice on careers. Education Technology Cells were strengthened by publication of booklets, pamphlets and exhibit model products. Substantial support from Council was provided and the universities were encouraged to develop overall personality of students by teaching them self-defence, yoga, career development talks by guest faculty, conducting workshops, counselling for exams, etc.

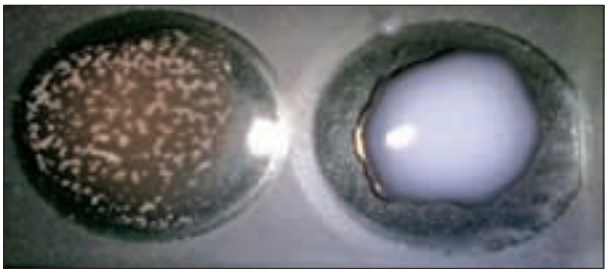
Niche Area of Excellence

For strengthening capacity building and creating excellence in specific cutting edge areas, support of ₹ 20.94 crore to 22 ongoing and five new centres of Niche Area of Excellence (NAE) on "Fish safety and quality assurance at TNFU, Thoothukudi; "Spore based sensor for monitoring pesticides residues in Milk", NDRI, Karnal; "Nutrition and Gut Health: Probiotics, Prebiotics and Phytogenics as Functional Foods to Augment Gut Health of Dogs", IVRI, Izzatnagar; "Molecular Breeding and genetic manipulation of rice and pigeonpea", ANGRAU, Hyderabad and Centre for Zoonosis", MAFSU, Nagpur, was extended during the year. Presently, ten programmes under animal science, three in fishery sciences, two in agricultural engineering, four

in plant sciences, four in natural resource management, two in plant protection and one each in horticulture and agriculture education are being supported. The IX Annual review meeting to fine tune the programmes was organized at New Delhi on May 25, 2014.

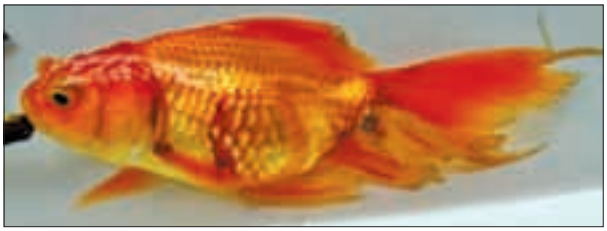
Significant achievements under the programmes were:

- Metatranscriptome sequencing runs of 48 samples for Kankarej, Gir, Jaffarabadi breeds has been done at the centre at AAU, Anand.
- A transformed canine cell line, i.e. MDCK-dSLAM ((heterozygote diploid-based synthetic lethality constitutively expressing canine SLAM molecule was developed for isolation and culture of canine distemper virus (CDV) field strains.
- Recombinant proteins of *Brucella* [P-17, OMP-25 and OMP-28] were up-scaled, purified and immobilized separately on SPR sensor surfaces.
- Label-free biosensor assays for detection of PPR virus and autoantibody signatures (biomarkers) in cases of canine mammary tumour in dogs were developed at IVRI centre.
- For monitoring pesticide residues in milk, the pesticide inhibition assay on paper strip was standardized.



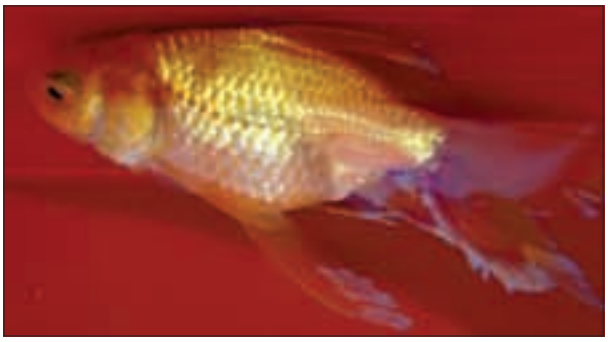
Latex agglutination test using recombinant antigen of DPV Positive serum (*left*) Negative serum (*right*)

- Bio-technological tools for diagnosis of EEHV in Asiatic elephants were validated by the wildlife and forensic health centre.
- Sensitive and specific diagnostic assay for Duck Plague Virus (DPV) was developed using recombinant antigen at TANUVAS, Chennai.
- Incidence of cyprinid herpes virus 3 and cyprinid herpes virus 2 in ornamental fish *Carassius auratus* from India was reported for the first time by the centre on "Surveillance of diseases of aqua cultured finfish and shellfish" at WBUFAS, Kolkata.



Cyprinid herpes virus 3 infected *Carassius auratus*

- Brackish water fish – *Lates calcarifer* (sea bass) reared and tested in salt affected waterlogged waste lands in Fazilka district in Punjab.



Disease free *Carassius auratus*

- Enrichment and fortification of composts and liquid manures and package of practices *w.r.t.* nutrients, insect pests and disease management for the targeted crops developed under organic farming at Palampur.
- The product based on pearl millet and semolina was developed through extrusion processing at the IARI centre.
- Designed and developed power operated single row paddy weeder and power operated planter for dry and wet field conditions for rice.

Light weight single row power weeder

- High resolution soil maps of available nitrogen, phosphorous and potassium created for Nainital district and spectral soil library of different soils series of Pantnagar region was created.
- The concept of adoption of mono and two-tier systems of rain water management in saline tract of Purna river valley on 30,000 ha area through the network of 5,500 farm ponds was promoted with the participation of 12,000 farmers.
- Low cost, innovative method for checking ravine development comprising of silvi-pastoral and crop production system helped in *in-situ* water conservation.
- Five species of pollinators were identified and nesting habitats for wild pollinators in apple

Wooden bee blocks installed in apple orchards (*Megachile* spp. isolated) 70% success rate

orchards were successfully established by the centre at SKUAST-K.

- Manuals with pictorial keys prepared for easy learning of identification methods of insects and mites. The collection of the insects in the region have been strengthened.

Hypsauchenia spp.
(New species)

Apoderus spp.
(New record in South India)

- High grain weight trait transferred from *Aegilops tauschii* to bread wheat and is being validated in the backcross progenies.
- For sustaining rice productivity, the amphiploids (PR122/*O. punctata* IRGC105137) were generated and backcrossed with the cultivars to harness and transfer the productivity traits of *O. punctata*.
- Improved root biomass and WUE efficiency traits introgressed in IR-64 background through multi parent marker assisted back-crossing.

KMP-175—A promising trait introgressed line with yield advantage (aerobic) identified

The centres organized ninety-six long (>10 days) and short (2-10 days) duration training programmes leading to capacity building of 297 faculty. About 11 awareness workshops / camps /workshops for rural agricultural extension workers, veterinary officers of State Animal Husbandry Departments/ farmers meet / demonstrations imparted knowledge and trained 300 farmers and about 75 other stakeholders for adopting the technologies generated. During the year, 58 students completed degrees and 142 students are pursuing research for MSc/MVSc/ MTech/ PhD utilizing the facilities developed under NAE programmes.The support has resulted in 113 publications in peer reviewed journals, including 51 papers in journals assigned NAAS rating of 5 and above. As a result of the workshops and awareness camps conducted under the programme some of the trainees took up entrepreneurship. Two people (entrepreneur) were engaged in fabrication of machines/tools, 108 farmers in fisheries and 5 in beekeeping and other as pollinizers for apple orchards.

Entrepreneurship Development

To instil confidence, provide hands on training and to encourage UG students to take up entrepreneurship, support was extended for experiential learning modules. These were aimed at giving experience –based and skill oriented training to the undergraduate students to promote entrepreneurship, knowledge as well as marketing skills through practical end–to-end approach in product development. Twenty new modules were established during this year and one module viz. “Mushroom production” at BHU, Varanasi was upgraded with modern equipments. New modules were supported in various profitable areas, like processing of fruits, vegetables, milk etc. for value addition, protected cultivation of high value horticultural crops, biofertilizer production, pet care units, seed production and product designing etc. in 12 AUs. Students learned marketing strategies in various programmes. The salient outcomes were:

- ELP on seed production helped students acquire experience on hybrid seed production in various crops, including sunflower.
- Value added products were produced from the horticultural products and were marketed by students under fruit and vegetable processing modules. The ELP on processing of milk and milk products trained the students in procurement and checking for adulteration in milk. Value added milk products were developed and marketed by students.
- The students under agriculture information produced four documentaries on relevant topics and conducted an exhibition related to biodiversity.
- ELP on protected cultivation of high value crops enabled the students to learn construction of polyhouses and growing vegetables with the knowledge about best package of practices. They also developed skills for plant propagation and nursery management.
- Large scale production of bio-inputs like bio-

fertilizers were mass produced, packaged and sold.

- Trainings have been imparted for effective management of insect pests and issuing plant protection advisory to the farmers.
- The ELP on custom hiring farm machinery and fabrication of need based small implements created awareness among students regarding various implements, their repair and maintenance and industrial training. The students were made aware of the advantages of setting up such an enterprise in their areas for the benefit of the community.
- In apparel production modules, skill of handling technologically advanced machines and textile designing software were acquired. Designing and preparation of facilitating materials such as charts, posters, leaflets, folders, extension bulletins etc. for dissemination of agricultural technology was undertaken in ELP on product design.

Rural Agricultural Work Experience (RAWE)

The students under RAWE were exposed to natural setting of the village situations, worked with the farm families, identified their problems and made use of various extension tools for transferring the latest agricultural technologies. The students also got opportunity to study the various on-going schemes related to agriculture and rural development and participate in their implementation. The students were given rigorous orientation and familiarization on various issues and problems expected on farmers' field and hence gain competence and confidence for solving problems related to agriculture and allied sciences. It has been implemented in adopted villages under the supervision of scientists. Activities focused on intensive observations /analysis of socio-economic and technological profile of the farm families in rural areas, participatory extension approach and acquaintance with farming situations, farm practices and interaction with progressive farmers. The students also gained first hand information on industries during attachment with identified agro based industries. Eight thousand and six hundred students benefited under RAWE through Council's support.Soil testing has become the integral part of RAWE. This is offered in the last semester of the UG programme and helps orient the agricultural graduates for participation in various rural developmental programme.

Library Strengthening

Central libraries in AUs play pivotal role in providing scientific and technical information to the students as well as faculty. The support from the Council enriched and strengthened the libraries at AUs by adding new titles to the existing collection with the financial support of ₹ 25.00 crore. The addition of latest literature in agriculture and allied subjects helped strengthen the academic programme and ensured procurement of additional need based journals not covered under CeRA. The SAUs libraries have created their own database of thesis. The academic environment and quality of teaching and research has been enhanced through the use of e-resources. Digitization and online access to the literature ensured equity and availability of learning resources in the main campus as well as off campuses colleges. Online demonstration of several instruments /machineries enhanced the conceptual information to students about the application of agricultural engineering technologies in real field situations. Book banks for the underprivileged students were established in some AUs.

Information System on Agricultural Education (NISAGENET)

The single window data retrieval system, NISAGENET portal, for universities was maintained as a regular ongoing activity of the Council at IASRI, New Delhi. All the agricultural universities provided the data as per requirements of this system. The information on infrastructural facilities, budget provisions, manpower, research and development activities of university and its constituent colleges are being collected, compiled and uploaded. The NISAGENET operational architecture which is a three tier web architecture makes it possible to directly enter/update data not only from university but also from the respective constituent/affiliated/college(s).

Five sensitization-cum-training workshops for the nodal officers of the NISAGENET were also organized during the year to sensitize and expedite data management.

Tribal Sub-Plan

Financial support of ₹ 25.00 crore was provided in ten states during the year under Tribal Sub-Plan covering 66 districts. The programmes were implemented through 15 State Agricultural Universities. The capacity building programmes on value addition and post harvest management of agri horticultural crops were initiated, improved agricultural and animal husbandry practices, apiculture, goat breeding etc. The tribal population was also trained in the areas of starch extraction from Tikhur rhizomes, cashew and apple processing production of quality planting material, backyard poultry, sustainable livestock production system etc. ensuring livelihood security and income generation for the tribals. Demonstrations and camps were held for creating awareness about recent technologies. These programmes were executed by conducting 53 training programmes and about 199 demonstrations leading to the capacity building of 8206 tribals. The support helped in installing micro-irrigation system in 13 villages and setting up of vermicomposting, biogas and packing units in 26 villages of targeted TSP districts.

Manpower Development

- **All-India Entrance Examination for Admission to UG**: The 20th Undergraduate Examination for admission to 15% seats of degree programme in agriculture and allied subjects, other than veterinary sciences, including the award of National Talent Scholarship (NTS) was conducted on April 11, 2015. The examination attracted a

record 1,22,122 applications, out of which 1,10,600 candidates appeared and 2,205 candidates were finally recommended for admission in 65 AUs through counselling. All the candidates, who joined a university outside their state of domicile, were awarded NTS of 1000/month.

- **All-India Entrance Examination for Admission to PG**: The examination was conducted on April 12, 2015 for admission to 25% seats in PG programme at 72 AUs, including award of ICAR Junior Research Fellowship (JRF). A total of 27,862 candidates appeared in the examination, out of 30,035 applicants, and 2,765 candidates were finally recommended for admissions. In all, 474 students were awarded JRF in 20 major subject groups.
- **All-India Competitive Examination for Ph.D. admission and award of Senior Research Fellowship**: The examination was held on April 12, 2015 at 17 centres across the country. A total of 4797 candidates appeared in the examination, out of 5628 applicants, and 494 candidates were finally admitted for Ph.D. admissions in 67AUs. Based on the merit, a total of 182 Senior Research Fellowships were awarded in 16 major subject groups.
- **Globalization of agricultural education:** Two hundred and three students from **29** countries like Afghanistan, Bangladesh, Belize, Bhutan, Cambodia, Egypt, Eritrea, Ethiopia, Fiji, Guyana, Ghana, Indonesia, Iraq, Iran, Kenya, Liberia, Libya, Mauritius, Madagascar, Malawi, Malaysia, Mozambique, Namibia, Nepal, Niger, Rawanda, Sudan, Sri Lanka, Syria, Seychelles, Swaziland, Tanzania, Vietnam and Uganda, exercised their preference to join various agricultural universities under different fellowships or as self-financed candidates.

Capacity Building

Summer/Winter Schools and Short Courses: Summer and Winter Schools (SWS) and Short Courses of 10 to 21 days duration (**56** SWS of 21 days and **47** Short Courses for 10 days) were organized at ICAR Institutes and State Agricultural Universities in key areas of agriculture and allied sciences like Micro-irrigation and fertigation; Concepts and techniques in development of health foods; Processing value addition and waste utilization technologies; Engineering Interventions in Conservation Agriculture; Climate Change Mitigation; Technopreneurship Opportunities; Quantitative Genetics and Statistical Genomics; Participatory Extension Research and Management; Extension Methodologies for Agricultural Development; Extension Strategy for Entrepreneurship Development; Management in Agro Processing and Value Addition; Gender Mainstreaming for Resilient Agriculture; Technical Textiles and Functional Clothing; Nutrition Security; Cross Sectoral Disaster Risk Reduction Strategies in Livestock Sector; Functional Genomic Concepts; Quality Ruminant and Poultry Production; Farmers' Empowerment and Entrepreneurial Development; Disease Diagnosis and Management; Value addition and Challenges in Quality Control; Molecular Techniques in Gene Regulation and Functional Genomics; Molecular Breeding Approaches for Genetic Enhancement; Integrated Pest and Disease Management; Biotechnological Approaches for Adaptation to Climate Change; Forecast Modelling; Agro Ecosystem; Resource Conservation; Management Practices and Bio-security; Hi-Tech Intervention; Preservation and Processing Technologies; Sustainable Production; Protected Cultivation; Biofuels-Current Innovations and Future Trends; Food Safety Management Systems; Educational Methodology and Instructional Technology, etc.

Centres of Advanced Faculty Training: The 31 Centers of Advanced Faculty Training provided training to about 1000 scientists/faculty members from the National Agricultural Research System through **46** training programs in cutting edge areas of agriculture and allied sciences. All the training programs sponsored by Agricultural Education Division were monitored through workflow based online management system. A Capacity Building Program Portal was developed to provide information on all training programmes, training proposal submission and evaluation, submission of application by a trainee, availability of e-books/lecture notes of a training and reports for all categories of users and several other features.

Promotion of Excellence and HRD

ICAR National Professor Scheme: For promoting excellence and creating a culture of basic research at national level, ten positions of National Professors have been created. Major achievements of ongoing ICAR National Professorial scheme are:

- *Designs for single factor and multi-factor experiments and their applications in agricultural systems research:* An algorithm has been developed to obtain A-optimal Balanced Treatment Incomplete Block designs for comparing several treatments with a control treatment. Methods of construction of efficient block and row-column designs for factorial experiments with baseline parameterization have been developed. A manuscript entitled "Significance of Experimental Designs in Agricultural Research" has been published with the purpose to disseminate among the stakeholders modern, appropriate and efficient designs recommended and already used by the agricultural researchers in conducting experiments along with introduction to some web resources for generation of designs and analysis of data from designed experiments. A monograph entitled "Weighting and Calibration in Sample Survey Estimation" has been published combining developments in the subject from initial times to recent times. A book chapter on "Distance Balanced Sampling Plans: An Overview" in a book "Statistical and

Mathematical Sciences and their Applications" has been written. An electronic document on "History of Statistics on Timeline" has been uploaded at Sample Survey Resources Server.

- *Assessment, prediction and enhancement of biotic carbon sequestration in agricultural soils:* Land-use and management effects on soil organic matter in central and south-western alluvial sub-regions of Punjab were enumerated through physical, chemical and biological fractionation techniques. It was found that majority of organic carbon in the two sub-regions occurred in active pool pointing towards its possible loss as a consequence of soil mismanagement. Rice-wheat and fodder-based cropping systems were characterized by relatively decomposable carbon (C) than the soils under cotton-wheat, which exhibited abundance of recalcitrant C. Different chemical fractionation methods were evaluated for enumerating soil organic matter responses to land-use and management; water soluble C emerged as the most sensitive indicator. Carbon sequestration potential of zero tillage in direct seeded rice was quantified. Zero tillage improved C sequestration by 274 kg/ha/y and the accrued C was mainly stored as particulate organic C. Carbon emissions from farm operations were estimated to identify best management practices and cropping sequence for minimizing agriculture-induced emissions of carbon dioxide.
- *Broadening the genetic base of Indian mustard (Brassica juncea) through alien introgressions and germplasm enhancement:*Released India's first Canola mustard variety RLC 3 for commercial cultivation in Punjab.Identified genetic bottlenecks in domestication related genes associated with pod shatter resistance. Cloned and sequenced the gene associated with determinacy in *B.juncea.*
- *Changing consumption pattern in India: Opportunities for diversification towards high value commodities through production and marketing linkages:* The determinants of diversification towards high value commodities (HVC) provided the empirical evidence that changing consumption pattern is distinctly driving production diversification in India. The structural changes in terms of infrastructure, technology and growing income levels have also positively influenced agricultural diversification. The share of Indian coffee exports to total global coffee exports has reached stagnation due to our inability to meet the growing consumer recognition and demand for certified and specialty coffees at the global market outlining the need to move from conventional coffee production to certified coffee production to capture high value markets.
- *Metagenomic analysis and manipulation of buffalo rumen ecosystem to improve fibre utilization and reduce methane production:* There was a significant inhibition (P=0.015) in methane emission by 20 and 24% in buffaloes fed concentrate: roughage feeds in 50:50 and 70:30 ratio, supplemented with a feed additive (0.5% garlic + 0.001% clove of dry matter intake and 15% nitrogen requirement met through nitrate feeding). There was no effect of treatment on dry matter digestibility and average daily body weight gain. The rumen microbial counts (bacteria, fungi, methanogenic archaea, ciliate protozoa, *Fibrobacter succinogenes*, *Ruminococcus flavefaciens*, *R. albus* and *Butyrivibrio fibrisolves* were not affected on 21 days of feeding, but after 120 days, all the microbes decreased significantly as compared to control animals. The feed additive appears to have a potential to explore further to mitigate methane emission by buffaloes.
- *Development of chromosome segment substitution lines (CSSL) of rice from elite × wild crosses to map QTLs/genes for yield traits:* F1s were obtained from 21 elite × wild crosses, BC1F1 from 7 crosses and BC2F1 from 5 crosses. BC1F1 from MTU1010 × *O. rufipogon* and Swarna × *O. rufipogon* were genotyped using 70 polymorphic core set SSR markers. From the previous 94 BILs from Swarna × *O.nivara*, 81848 were field evaluated during *kharif* 2014 and genotyped using 79 polymorphic SSR markers to identify a set of 50 CSSLs and 12 major QTLs for yield traits were identified. Likewise, 90 BILs from Swarna × *O. nivara* 81832 were genotyped to identify a set of 42 CSSLs, and 7 major QTLs for yield traits identified. Two high yielding stable BILs were selected after phenotypic evaluation for three seasons and intercrossed to get F1 and new F2 mapping populations.

ICAR National Fellow Scheme: With an objective to provide support and develop strong centers of research and education around outstanding scientists, 25 ICAR National Fellow positions have been provided in National Agricultural Research System. Highlights of the ongoing projects are:

- *Development of molecular platforms for point-of-care detection of major enteric viruses responsible for neonatal mortality in animals:* Molecular epidemiological investigation in an epidemic of diarrhea in piglets from north eastern state (Asom) confirmed detection of rotavirus along with concomitant existence of emerging and opportunistic picobirnavirus in 39.8% (43/108) cases. Sequence based bioinformatic analysis showed higher genomic relatedness of porcine virus isolates with humans. The work is underway on identification of immunogenic regions in rotavirus structural capsid proteins for overexpression of virus specific recombinant protein with an aim to develop rapid and economic indigenous biologicals for rotavirus detection in

animals.

- *Assessment of sustainability of treated / developed watersheds in rainfed agro-eco-sub-regions of peninsular India using GIS and remote sensing:* Based on the methodology developed for measuring agricultural sustainability through implementation of watershed program in rainfed agro-eco -sub-regions in Peninsular India, selected watersheds were monitored and evaluated based on temporal change in land use-land cover. It was seen that in Pamana watersheds in Rangareddy district, over 45% of agricultural area in a watershed of 132 ha, had achieved fairly sustainable agricultural development. On the other hand in Gollapalli watersheds in Nalgonda district with 70% land under agriculture in a watershed of 91 ha, only 4% area was assessed as fairly sustainable and 29% was measured as moderately sustainable. Awareness of watershed programme and land management practices adopted by Pamana farmers had led to sustainable agricultural development. Poor adoption of improved land management practices by farmers in Gollapalli and land conversion were the major causes for unsustainable agricultural development in the region. A DSS is being developed for monitoring and evaluation of watershed projects in an attempt to standardize the procedure.
- *Development of food biopolymer based micro and nano scale delivery systems for bioactive ingredients in functional foods:* The process for preparation of nano emulsion of fish oil and lecithin in water using high pressure homogenizer was standardized. Alginate, with either skim milk powder or whey protein concentrate powder, was explored as delivery matrix to further stabilize the nano emulsion of fish oil for incorporation in functional foods. Fish oil emulsion was oozing out in beads of alginate with skim milk powder. Alginate with whey proteins yielded beads with an encapsulation efficiency of 89% and without any oozing fish oil emulsion. These beads were coated with vanilla flavored high melting fat to fully mask the smell of fish oil.
- *Biomodulation of Marine Biopolymers for the Preparation of Biomaterials of Healthcare Importance:* Vanillic acid and coumaric acid grafted chitosan derivatives improved grafting ratio and potential application in functional food. Thiamine and pyridoxine loaded ferulic acid grafted chitosan microspheres for dietary supplementation were developed. Experimental protocols and methodologies were standardized for the extraction and purification of bioactive and biocompatible collagen from air bladder of *Pangasius hypophthalmus* and skin of *Katsuwonus pelamis* (Skipjack tuna). It is noticed that fish collagen can be used as a bio-functional wall material in different encapsulation processes.
- *Robust and Efficient Small Area Estimation Methods for Agricultural and Socio-Economic Surveys and their Application in Indo-Gangetic Plain:* Many variables of interest in agricultural, environmental and ecological surveys are semi-continuous in nature, i.e. they either take a single fixed value (typically zero) or they have a continuous, often skewed, distribution on the positive real line. Standard methods for small area estimation (SAE) based on the use of linear mixed models can be inefficient for such variables. SAE techniques were developed for semi-continuous variables under a two part random effects model that allows for the presence of excess zeros as well as the skewed nature of the non-zero values of the response variable. In particular, the excess zeros are first modelled via a generalized linear mixed model fitted to the probability of a non-zero, i.e. strictly positive, value being observed, and then model the response, given that it is strictly positive, using a linear mixed model fitted on the logarithmic scale. Empirical results show that the developed SAE method leads to efficient small area estimates for semi-continuous data.
- *Nanotechnology in aquaculture: an alternative approach for fish health management and water remediation:* Zinc oxide nanoparticles showed algicidal and anti-algal properties. These nanoparticles significantly inhibited algal growth by pore formation and disruption of plasma membrane, efflux of intracellular components, cell structure alternation and reduced the chlorophyll contents. In the laboratory study, ZnO nanoparticles were found to control unwanted algal growth in aquaculture environment. Further work is in progress. A national level training programme on “Application of nanotechnology in aquaculture and fisheries” was conducted on September 24-28, 2015 at ICAR-Central Institute of Freshwater Aquaculture, Bhubaneshwar. A total of 16 participants including researchers, entrepreneurs, farmers and students from different states took part in the programme.
- *Development of soy and multigrain based nutritionally balanced functional foods for children:* Developed nutritionally and functionally rich laddoos, nachos, eggless cake and gluten-free eggless cakes using sprouted legumes, malted millets and fruits. Eggless cakes were developed using composite flour (CF) of wheat, malted finger-millet, sprouted soy and amaranth with banana as an egg replacer. Gluten free cakes did not contain any wheat in the CF. The products had high organoleptic acceptability and were rich in protein, fibre, iron, calcium, phenolics and anti-oxidants. Patent was applied for the process of development of the gluten-free eggless cakes. Nutritional trials on school children in MP revealed that the products improved the nutritional

status of school children significantly and can be used in mid-day meal programs.

- *Precision nutrient management using GIS-based spatial variability mapping under Upper and Middle Gangetic Plain Zones of India:* In order to develop precision nutrient prescription, homogeneous fertility management zones were prepared for North Eastern Plain Zone using GIS. Spatial variability in soil organic carbon stock in Upper Gangetic Plain was assessed and relationship between agro-ecological characteristics and crop management practices was established. Calibration of Green Seeker based NDVI for real time N prescription was made in maize crop. Optimized fertilizer N, P, K prescription for targeted rice and wheat yields using reciprocal internal efficiencies for rice and wheat, contribution of indigenous nutrient supplying capacity was developed.
- *Development of Commercially Viable Process Technologies for Weaning Food based on Underutilized Crops of Uttarakhand:* Fingermillet Dehuller-cum-Pearler was designed and developed for dehulling and pearling of fingermillet grain having 8kg/h capacity and 83.68% dehulling efficiency. Process protocols standardized and optimized for underutilized crops based Probiotic weaning mix using 70:30 blend ratio (fingermillet + barnyard: black soybean), 25 h fermentation time and 2.9% *L. plantarum*.
- *Functional Genomics, Epigenetics and Gene Silencing Technology for Improving Productivity in Poultry:* BMP3 (Bone morphogenetic protein 3) gene, a negative regulator of osteogenesis was polymorphic with presence of 5 haplotypes in control broiler line where h3 was the most frequent and h2 was the least frequent haplotype in the line. This gene was also polymorphic in control layer line having 4 haplotypes of which h2 was the most predominant and h1 was the least frequent haplotype in the line. BMP4 (Bone morphogenetic protein 4) gene involved in osteogenesis was polymorphic with presence of 4 haplotypes of which h4 haplotype was predominant in both control broiler and control layer lines, and h2 and h3 were the least frequent in control broiler and control layer lines, respectively. The haplogroups of both genes had significant association with body weight at 4 and 6 weeks of age, and growth rate between 4 to 6 weeks. In second experiment, myostatin (A negative growth regulator) IgG treatment on D7 embryos showed significant effect on body weight at 4 and 6 weeks of age where 26 kDa and 52 kDa IgG had higher body weight at both 4 and 6 wks. In another experiment, whole mitochondrial genome of 6 Indian native chicken (Aseel, Ghagus, Kadaknath, Nicobari, Haringhata black and Tellichery) was found to be 16775 bp in length with 37 genes (13 proteins, 2 rRNAs and 22 tRNAs) and showed SNPs, insertion as well as deletions. All indigenous breeds except Tellichery were very close together and close to the lineage of Red Jungle fowl. A total of five shRNA molecules for myostatin gene were designed, synthesized and cloned in DEST vector of which molecule 1, 3 and 5 showed significant silencing effect on myostatin gene in myoblast primary cell culture.
- *Studies on phyto-semiochemicals involved in Insect-Plant interactions of major horticulture pests:* Symbiotic bacteria influence many aspects of an organism's evolution. The influence of endosymbionts on the evolution of sexual selection is largely unknown. It was discovered that the endosymbiont *Klebsiella oxytoca* aid females choose fit females. It was also found that *K. oxytoca* produced specific volatile compound that attract males to females. It was also found that *K. oxytoca* was involved in ovary development in females. This work is the first report about an endosymbiont influencing sexual selection in higher organisms.
- *Molecular epidemiology and surveillance of Rhabdoviral Infections in farmed exotic trout:*Work was undertaken on the development of a method for detecting the presence of any virus signal in clinical samples of fish. Interferon stimulated genes (ISG) play a vital role in controlling viral infection as Interferon mediated cell signalling leads to the expression of Mx, an indicator of viral infection. Therefore, conditions for amplification of Mx gene from Indian snow trout (*Schizothorax richardsonii*) have been standardized using PCR. Amplicons of expected size were obtained for Mx gene. This will be helpful to detect the expression of Mx upon treatment of fish cells with virus analogue poly I:C.
- *Genome data mining to unravel molecular basis of thermotolerance and adaptation to diverse environment in native cattle and buffaloes:* The transcriptome profile of buffalo PBMCs in Sahiwal (*Bos indicus*), Holstein Friesian (*Bos taurus*) and Murrah buffaloes during summer stress was generated. This study was designed to provide comparative baseline data to understand the underlying alterations in cellular tolerance towards heat stress during hot summers in dairy animals. The responsiveness of PBMCs summer stress in the present study clearly suggested unique transcriptome signature buffalo, Sahiwal and Holstein Friesian PBMCs in response to environmental heat load. The study has identified several genes from different functional classes and biological pathways associated with summer stress that could be utilized in future research.
- *Development of sensitive and specific diagnostic assays for detection of Trypanosoma evansi infection in animals using modern molecular*

tools: Monoclonal antibodies were developed against surface glycoproteins of *Trypanosoma evansi*. A monoclonal antibody based ELISA was optimised for detection of antigen bound in immune-complexes in serum of *T. evansi* experimentally infected donkeys. The serum samples from 0-192 days post infection (d.p.i.) were analysed. The assay could detect antigen successfully in serum sample 14th d.p.i. onwards obtained from experimentally infected donkeys. Validation of the assay on field samples is in progress.

- *Development of novel immuno-potentiator molecules from fish host and pathogens for broad spectrum disease control in freshwater aquaculture:* The *in-vitro* screened recombinant peptides, hepcidin and apolipoprotein A1 were tested for their efficacy in fish to protect from bacterial infections. *In vivo* trials with recombinant hepcidin and apolipoprotein A1 at 100 µg/rohu juvenile rendered 80% and 75% survival, respectively, against *Aeromonashydrophila* challenge (LD75 dose), thus opening up scope for their field applications to protect from bacterial infections. Response of three classes of immunoglobulins (IgM, IgZ and IgD) was evaluated in *Labe orohita* in response to *Argulussiamensis* infection. Parasitic infection triggers expression of all three classes of Igs during infection process. Appearance of high level of expression of IgZ and IgD in skin and mucus might pave the way for vaccine development against ectoparasite*A. siamensis*.
- *Environmentally sustainable termite control: integrative* and *inclusive approach of frontier and indigenous technologies:*A comprehensive review of farmers' ITKs across the country has been made on termites. Termite pest mapping - pest prevalence mapping was done for 4-major termite-pests viz. Odontotermes, Microtermes, Heterotermes and Coptotermes species. Identification of alates of subterranean termites by molecular characterization facilitated study of swarming. Major Indian termites' mitochondrial genes were isolated, characterized, and acquired accession numbers from NCBI. Some new records of fungi associated with termite mounds (fungal combs) are documented, acquired accession numbers as well. Soil functional diversity analysis as affected by termite infestation inside the maize stubbles was studied via viable Phospho-lipid fatty acid analysis.Push-pull-strategy for termite management in wheat-maize agro-ecosystem was demonstrated successfully to farmers. Some noteworthy mass campaign measures on Termite R&D were taken at Pusa Krishi Vigyan Mela, New Delhi and Pusa Horticulture Show & Exhibition, New Delhi, Krishi Mela, IARI Regional Station, Pusa (Bihar).

Emeritus Scientist Scheme

The ICAR continued to operate Emeritus Scientist Scheme as a structural method of utilizing Skill Bank of the outstanding superannuated professionals of NARS. Some of the major findings of the projects under this scheme are:

- The reproductive biological parameters of a high value marine finfish the Malabar trevally (*Carangoides malabaricus*) was assessed. It was observed that the species is gonochoristic, ovary maturation is asynchronous, is a batch spawner, several spawnings can be obtained in a year, the size at first maturity is around 250mm and broodstock development period is comparatively less. All the above reproductive parameters and strategies are suited for captive breeding and hence the species is recommended for broodstock development, breeding and seed production for mariculture.
- Silver nanoparticles (15-30 nm) prepared by using pea (*Pisum sativum*) peel were successful in degrading the pesticide chlorpyrifos from water at room temperature without exposure to UV. Unlike chlorpyrifos, etofenprox degraded better in toluene than in water. Zinc Oxide in toluene and edible alkali in water were found better than other reagents tested to degrade this lipophilic insecticide.
- An instruction manual in Statistical Computing with SAS/MS-Excel has been developed for the benefit of Research Scholars/Scientists working in the fields of Animal Science and Dairy Research.
- The open sea cage culture technology of lobster has been successfully demonstrated and transferred to fisherfolk of Kanyakumari coast.The trained fisherfolk of Chennamuttam, Kadiapattnam and Muttom villages are currently adopting open sea Lobster culture in cages in a profitable and sustainable level .The spread effect is also visible as fishermen of adjoining and nearby villages are also quickly adopting the same as a livelihood enterprise.

Accreditation of Agricultural Universities

The following agricultural universities have been accredited during the year on the recommendations of National Agricultural Education Board (NAEAB) in its meeting held on 16 March 2015:

- Pandit Deen Dayal Upadyaya Pashu Chikitsa Vigyan Vishwavidyalaya Evam Go-Anusandhan Sansthan, Mathura
- Dr Y.S. Parmar University of Horticulture and Forestry, Solan
- Jawaharlal Nehru Krishi Vishwa Vidhyalaya, Jabalpur
- Tamil Nadu Veterinary and Animal Sciences University, Chennai

- Bihar Agricultural University, Sabour
- ICAR-Indian Agricultural Research Institute, New Delhi

During the period, the Peer Review of six agricultural universities, namely, MPUAT, Udaipur; CIFE, Mumbai; RAU, Pusa (Samastipur); RVSKVV, Gwalior; OUAT, Bhubaneshwar and SKUAST, Srinagar has also been conducted.

Netaji Subhas-ICAR International Fellowships

With the objectives to develop competent human resource and showcasing the strengths of NARES, ICAR International Fellowships were introduced in 2009-10, for pursuing Ph.D. programme at Indian agricultural universities (AUs) and overseas universities for overseas and Indian candidates, respectively. In order to pay the tribute to the great leader of the country, the name of the scheme was modified as "Netaji Subhas-ICAR International Fellowships".

For the current year, based on the priority areas of study related to plant sciences, animal sciences, social sciences, fisheries, agricultural engineering, food processing and natural resource management, 29 candidates were selected for their Ph.D. study including 17 Indian candidates at internationally recognized foreign universities in the countries viz. USA, Germany, Belgium, Norway, Thailand and Austria and remaining 12 candidates from Nepal, Bangladesh, Sri Lanka, Nigeria, Ethiopia, Rwanda, Sierra Leone and Syria at Indian SAUs/ICAR DUs.

During this year, 27 candidates have joined their overseas laboratories for pursuing Ph.D. and the following 12 candidates including two Egyptians have completed their degree programme.

Name of the Fellow	Research Topic	Host University
Ms Kshipra Chandrashekhar	Understanding *Campylobacter jejuni* colonization and stress survival mechanism: Role of Transducer like proteins (Tlips) and Polyphosphate kinases (ppks)	Ohio State University, USA
Mr R Krishnamoorthy	Exploring the Biodiversity of Arbuscular Mycorrhizal Fungi and Associated Endobacteria to Improve Maize Growth under Salt Stress Conditions	Chungbuk National University, South Korea
Ms Archana Kumari	Molecular mechanisms that link stress and repression of cell proliferation in plants	Osaka University, Japan.
Mr N Muralidharan	Properties and applications of nano-biocomposite film based on fish gelatin	Prince of Songkla University, Thailand
Mr Sudeepta K. Panda	Establishment of mouse disease by using sequence-specific nucleases	Technical University, Munich, Germany
Mr Jagadish Hiremath	Development and Evaluation of PLGA-Nanoparticle Entrapped Influenza Virus Peptides Vaccine and Effect on Molecular Phenotype of Alveolar Macrophages with reference to DAP12 Signaling Pathway in Pigs	Ohio State University, USA.
Mr Ahmed Fawzy Abdel-Naby-Abdel-Naby El-Kot,	Marker Assisted Transfer of Novel Powdery Mildew Resistance Gene (s) from Diploid wheat *Triticum boeoricum* (Boiss) to hexploid wheat *Triticum aestivum* (L)	PAU, Ludhiana
Mr Moamen Mohamed Hamed El-Kady	Nano-science and Remote Sensing Appraisal of Pedogenic Impetus on Constituents in Desert Soils of Punjab	PAU, Ludhiana
Ms Kalavathy Rajan	Characterization of Cellulose Enzyme Inhibitors formed during the Chemical Pretreatments of Rice Straw	University of Arkansas USA
Mr Thirumala R. Talluri	Approaches for the derivation of induced pluripotent stem cells from cattle	University of Veterinary Medicine Hannover, Germany
Mr Pradeep Kumar	Grafting and application of mycorrhiza for improving tolerance to heavy Metal Stress in Tomato	University of Tuscia, Viterbo, Italy.
Ms R. Priyadharsini	Identification of Molecular role of Pelota Protein (PELO) in proliferation and differentiation of male germ stem cells (SSC) by analysis of conditional knockout mice	University of Gottingen, Germany

Netaji Subhas-ICAR International Fellowships

India-Africa Fellowship Programme

India-Africa Fellowship Programme has been implemented by Government of India. As per the programme, placements for 300 fellowships (viz. 75 per year, i.e. 50 Master's and 25 Ph.D.) are provided for students/faculty/professionals of African continent. Under the programme, a total of **195** candidates (119 Master's and 76 Ph.D.) have joined in **35** Indian Agricultural Universities. Out of which **115** candidates (78 Master's and 27 Ph.D.) have successfully completed their programmes.

India-Afghanistan Fellowship Programme

India-Afghanistan Fellowship Programme has been implemented by Government of India for providing 614 fellowships to Afghan nationals for attaining higher education in Agriculture and allied sciences in identified Indian Agricultural Universities (AUs). A total of **182** candidates (67 Bachelor's; 115 Master's) have joined in **38** Indian AUs. Out of which, **29** candidates of Master's programme have completed their programme successfully. During 2015-16, a total of **64** Afghan candidates (51 Master's and 13 Bachelor's) have been recommended for admission in Indian AUs. Eleven candidates (3 Bachelor's; Master's 8) of session 2015-16 have joined the programme, so far. To attain maximum enrolments of Afghan candidate, the tenure of programme is extended over a period of 2012-13 to 2020-2021 under the available slots of 614 fellowships for Bachelor's 50%, Master's 30% and Ph.D. 20%.

New Initiatives

Student READY

The Students READY (Rural Entrepreneurship Awareness and Development Yojana) programme was launched by the Hon'ble Prime Minister on 25 July 2015 and it will be implemented from the next academic year 2016-17. Under this programme, the fellowship of ₹ 3000 per month will be provided for a period of six months to all the under-graduate students of agricultural science. The programme aims to provide rural awareness, entrepreneurship development and practical hand-on experience in agriculture and allied sciences.

12. Social Science

Resilience of Indian agriculture to droughts

Impact of droughts on rice production was examined using district level data and the role of adaptation strategies, such as irrigation and crop varieties in mitigating the harmful effects of droughts was assessed.

On average, about one-third of the rice area was affected by drought. The effects of droughts on rice yield had weakened. The yield loss declined, in absolute as well as relative terms, under both moderate and severe drought conditions indicating rice production is becoming resilient to droughts. Econometric estimates validated these results. Improvements in irrigation systems and release of number of rice varieties for rainfed uplands and shallow lands, played important role in enhancing resilience of rice against droughts. Water is becoming increasingly a scarce resource. Improving efficiency of existing irrigation systems and conserving water through innovative measures, such as water harvesting, sprinkler irrigation, alternate wet and dry system, conservation tillage, laser land levelling, etc. need promotion. Further, greater investments in drought-tolerance research and development of extension systems capable of providing farmers timely weather forecasts and seeds of varieties differentiated by their tolerance level to droughts are the pre-requisites for tackling the drought in a holistic manner.

Trends in farm income, and agrarian distress

This study examined income status of farmers in relation to income of other sections of the society. In 1983-84, a farmer-cultivator with agriculture as primary source of income earned three-times more than the earnings of an agricultural labourer but one-third of the income of a non-agricultural worker. Over the next five years, the income of a cultivator increased but at a slower rate compared to others causing a marginal decline in the disparity between farm income and wage earnings. During 1987-88 to 2004-05 a cultivator continued to earn two-and-half times the income of a labourer. The income disparity reduced marginally in 2011-12. The disparity between a cultivator and non-agricultural worker increased from 1:3 in 1983-84 to 1:4 in 2004-05, but declined afterwards due to acceleration in agricultural growth and decline in the number of cultivators. During this period, there was also a small decline in the disparity between agricultural labourer and non-agricultural workers.

After 2004, income per cultivator grew at a rate of 7.3%. These findings indicated that low growth rate in farm income was associated with increase in farmers' distress and vice-versa.

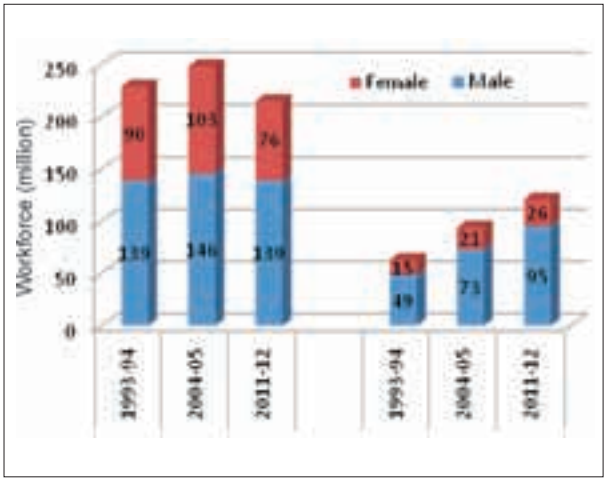
Disparities in agriculture and non-agriculture income at current prices

Year	Farm income per cultivator (₹/annum)	Wage earnings per agricultural labour (₹/annum)	Income per non-agriculture worker (₹/annum')
1983-84	4,286	1,467	12,786
1987-88	5,653	2,201	18,036
1993-94	12,365	4,784	37,763
1999-00	24,188	8,938	78,565
2004-05	26,146	10,043	10,6688
2011-12	78,264	32,311	24,6514

Emerging trends in rural employment and their implications

The rural labour market has undergone some notable changes in the past two decades. Between 1993-94 and 2004-05 rural workforce increased by 50 million, but declined by 7 million afterwards. The decline in rural workforce was primarily due to exit of female workers from the agricultural works, which could not be accompanied by a similar increase in female employment in non-farm sectors; labourers as well as cultivators left agriculture.

The changes in employment pattern are driven by a complex set of pull and push factors, such as differences in inter-sectoral growth rates and wage rates, employment guarantee programmes (e.g. MGNREGS), education levels, etc. Labour absorption capacity of agriculture has almost reached its plateau; and relatively faster growth in non-farm sectors, higher non-farm wages and



improvements in literacy level of cultivators and agricultural labourers are some important factors responsible for the recent changes in employment.

The decline in share of agriculture in workforce though is consistent with the theory of economic development, it may create imbalance in demand and supply of labour in the short-run. A significant rise in agricultural wage rate may increase cost of food production which in turn (if not compensated by improvement in agricultural productivity) may cause rise in food prices.

Crop planning for resource use efficiency and sustainability

An optimum crop plan is essential to improve resource use efficiency and sustainability of agricultural production systems. Using plot-level data from cost of cultivation scheme the net income for major crops was estimated under three situations viz. (i) at market prices, (ii) at social cost and prices (net of subsidies), and (iii) natural resource valuation (NRV) and environmental cost for Punjab.

Net income from different crops in Punjab, TE 2010-11

(₹/ha)

Crop	Market prices	Economic prices	NRV
Paddy—non-Basmati	46,198	33,191	31,353
Paddy—Basmati	53,377	41789	39,951
Wheat	36,244	25,747	25,564
Maize	13,792	5,394	5,235
Sugarcane (Planted)	98,384	85,153	81,355
Sugarcane (Ratoon)	118,676	108,077	104,279
Rapeseed and mustard	14,450	7,556	7,441
Cotton	42,187	30,530	30,479
Potato	27,138	8,209	7,974
Peas	44,549	33,354	34,646
Vegetables	36,497	26,543	26,308

Paddy, especially Basmati, remains the most rewarding crops during *kharif* under market price situation, and also even after adding subsidies to cost and internalizing environmental costs and benefits (nitrogen fixation) perhaps due to assured prices and higher yields. In *rabi* season, pea cultivation becomes more profitable than wheat.

Trend in labour productivity in agriculture

Technological change has made significant impacts on labour absorption and labour productivity in India. There has been a significant improvement in labour absorption during 1975-1995. Labour productivity also improved during this period. After mid-1990s per hectare labour use declined in general. But, there was a notable improvement in labour productivity after the mid-1990s. The net impact of this is an increase in labour earnings in crop production. Nevertheless, there are considerable disparities in labour use and labour productivity across states.

Crop wise labour use and productivity in India

Crop	Use (h/ha)			Productivity (kg/ha)		
	1973-1976	1993-1996	2007-2010	1973-1976	1993-1996	2007-2010
Paddy	861.2	959.6	859.5	2.3	3.8	5.1
Wheat	686.1	452.9	392.9	2.8	6.8	9.8
Cotton	592.5	744.6	833.5	0.8	1.4	2.3
Sugarcane	1,609.9	1,690.8	1,602.5	24.2	39.2	41.8

Harvest and post-harvest losses of major agricultural crops and allied commodities

A survey on harvest and postharvest losses of major 45 crops and livestock produce in 14 agro-climatic regions of the country revealed that in cereals, the losses ranged from 4.6% (maize) to 5.9% (sorghum) and in pulses from 6.6% (green gram) to 8.4% (chick pea). Use of improper threshers and storage practices and delayed harvesting were the main reasons of these losses in pulses. Estimated losses of oilseeds ranged from 3.1% (cottonseed) to 9.9% (soybean). The losses in fruits ranged from 6.7% (papaya) to 15.8% (guava), whereas, in vegetables from 4.5% (tapioca) to 12.4% (tomato). In plantation crops and spices, the losses ranged from 1.1% (black pepper) to 7.8% (sugarcane). The losses were 7.1% in egg and 5.2% and 10.5% in inland fish and marine fish, respectively. The loss in sheep and goat meat was 2.7% whereas the loss in poultry meat was 6.7%. The loss of milk was observed to be 0.9%. In comparison to losses during 2005-07, the losses during 2013-14 have been reduced significantly for wheat, mustard, groundnut, mango, guava, mushroom, tapioca, arecanut, black pepper and coriander, whereas, for maize, sorghum, chickpea, soybean, sunflower, citrus, sapota, cauliflower, cashew, marine fish, meat and poultry meat were significantly increased. Overall losses for food grains, oilseeds and fruits and vegetables were 4.6% to 15.8%, which were 2% lower compared to previous study in 2005-07 in spite of tremendous increase of production in last 10 years. The estimated annual value of the losses, based on average wholesale prices of 2014, was about ₹ 92,651 crore.

Fluctuations in onion prices: An analysis

Consumption of onion is growing steadily with increase in income levels, changing life-style, dietary pattern and urbanization. Post 2002-03 period witnessed exponential growth in onion production enhancing per capita availability, consumption and exports. Clustering of production and perishable nature of onion has resulted in a mismatch in demand-supply. The onion wholesale price indices (WPI) has witnessed severe volatility vis-à-vis food and non-food articles. During the last 10 years, three onion price shocks were experienced indicating the extent of onion price sensitivity to small variations in supply.

The onion prices in and arrival of the leading state, Maharashtra indicated fewer peaks in arrivals and

steeper spikes in prices. It may either due to increased storage capacity of producers enabling them to realize price advantages in lean season or increased stocks by buyers and big traders. The analysis of year 2013 onion availability revealed that traders quickly captured the signals of the impending shortage and its implications and had clear strategy to harness the situation. To encounter such a strategy, an effective mechanism is required with emphasis on the ways of stabilizing supply and prices through stock, trade, de-clustering cultivation and effective state interventions - market intelligence, crop insurance, cold chains, warehousing (particularly in Indo-Gangetic Plans and North-East), grading, sorting, processing, etc.

EMPOWERING WOMEN IN AGRICULTURE

Agriculture is the backbone of the Indian economy and women play a key role in agricultural development and have multi dimension roles in various agricultural activities which is vital for agriculture growth and food security. The Central Institute for Women in Agriculture (CIWA), Bhubaneshwar, is functioning for development methodologies, identification of gender implications in farming systems approach and to develop women specific technologies under different production systems.

Nutrition and livelihood enhancement of tribal families

Demographic profile including socio-economic status, daily routine, resource availabilities and role performance of tribal farm women were assessed. Nutritional status of children (1 to 10 age group) of tribal farm families at village Tarajodi, Mayurbhanj district, revealed that 65.12% had normal nutritional status, 9.30% moderately undernourished, and 9.30% severely undernourished. Gender difference was observed as 13.04% of girls were severely malnourished and 8.70% moderately undernourished in comparison to boys. Awareness creation-cum-skill upgradation programmes on improved methods of homestead gardening, cultivation of potato, sunflower and groundnut, scientific and hygienic storage of food grains to prevent losses during storage were conducted and interventions were made at the selected tribal villages.

Resource efficient horticultural model

A resource efficient horticulture model was developed in 2,000 m^2 area with different components like high density planting of banana, meadow orcharding of guava, high density planting of papaya, pineapple, lime, different green leafy vegetables, roots and tuber crops and other vegetables. An effort was made to standardize suitable intercrops in coconut based multi-storey cropping model with banana, papaya and guava as second storey crops. Different ground storey intercrops like cowpea, turmeric, elephant foot yam and pineapple were cultivated in the interspaces of the main crop. An income of ₹ 60,000/ year and ₹ 1,60,000/year/ha was obtained from coconut and mango as single crop at the age of six years with

Resource efficient horticultural model

average nut yield of 20 nuts/plant and fruit yield 20 kg/ plant, respectively while income of ₹ 4,76,000/year/ha was estimated from mango + turmeric cropping model.

Enhancing livelihood of rural women through livestock

Five lines of sweet potato (Keonjhar, ST-13, ST-14, Shree Kanak and Kamla Sundari) and the two highest foliage producing germplasm (Keonjhar and Kamla Sundari) were evaluated under different harvesting intensity for making available quality fodder to improve the productivity of livestock and increasing income of farm women. Three harvesting treatments were applied viz. no harvest during growth period, 100% and 50% harvest of foliage at 110 days after planting (DAP). Observations on total forage yield and tuber yield for Kamla Sundari revealed that the effect of treatment was

Clothing to combat occupational health hazards of farm workers

Functional clothing trials in cotton field

For combating occupational health hazards, protective clothing namely *kurta pyjamas*, aprons, mask, ear muff and head gear cum scarf with functional features were developed for the workers engaged in different activities in agriculture, agriculture allied sectors, and textile sectors, and assessed for its suitability and acceptability among workers through wear trials. During wear trial of *kurta pyjamas,* KP-2 with 70GSM made from non-woven fabric (cotton fabric with 126 GSM and 51 x 38 fabric count used as lining material) was found to be best (aggregate weighted mean score 2.3) with regard to suitability for plucking *ber* fruit. Similarly, for the workers engaged in okra picking, during wear trials, knitted gloves were found to be suitable, comfortable and durable with highest WMS of 4.0 than hand gloves of woven and latex coated fabric.

not significant for the tuber yield but the forage yield differed significantly among treatments. In Keonjahr germplasm, tuber yield declined significantly when foliage was completely harvested during the growth phase of the crop as compared to the control.

Aqua and poultry feed from fish and shellfish wastes

Effect of dietary inclusion of fish silage prepared from fish waste was studied in Japanese quails, poultry vanraja and rohu (*Labeo rohita*) fingerlings. In Japanese quail layers, egg production significantly increased with silage based diet. Use of fish silage with replacement of fish meal, reduced feed cost/kg egg mass up to 4.25%. The weight of vanraja birds increased significantly when the fish silage replaced fish meal and soybean meal in the diets. The feed cost/kg weight reduced by 14.03%.

Gender related indices in agriculture

Women Empowerment in Agriculture Index (WEAI) was computed as 0.66. Three new domains for indices related to gender in agriculture such as women's empowerment in agricultural activities, gender based tagging of crops/farming systems and gender friendly technologies were identified and various indicators for construction of the indices were also conceptualized.

Gender issues in IPM and suitable interventions

Data from 10 different agro-climatic zones of Odisha, collected for identification of gender issues in IPM and suitable interventions with women's perspective, revealed that women were using ITK related to pest management. Lack of access to technical information on IPM and non availability of women friendly sprayers were the constraints in every agroclimatic zones of Odisha. *Krishi Rakshaks* of two agroclimatic zones were trained for scouting and monitoring of insect pests.

AICRP on Home Science

The All India Co-ordinated Research Project (AICRP) on Home Science is in operation at 10 centres under nine State Agricultural Universities. Three new centres viz. Central Agricultural University, Tura; Tamil Nadu Agricultural University, Madurai; and Sardarkrishinagar Dantewada Agricultural University, Dantewada were included in the XII Five-Year-Plan and became operational from the financial year 2015-16. The main thrust of the project is to empower the women in agriculture for their improved nutrition and livelihood security, and drudgery reduction for better quality living.

Characterization of drudgery

To characterize drudgery of women, five operational villages were selected by each centre following the criteria of accessibility, diversification in production systems and women participation. The predominant production systems of the operational villages were selected for the survey. Six variables were selected for characterizing drudgery of women in production system viz. physical load, posture, repetitive strain, physiological load, duration/time, body pain and disorders. During the period under report, four production systems, viz. wheat, maize, vegetable (spinach, tomato) and sugarcane of the operational villages were identified to characterize drudgery. Technologies (23) were developed/refined/tested by different centres for mitigating drudgery of farm women. Eight technologies were ergonomically evaluated after field interventions, viz. hand wear for vegetables and soybean harvesting, cotton picking, cotton stalk pulling, groundnut striping, potato picking, *bhindi* picking, harvest bags (back and front model) and weeding and interculturing of strawberry production. Technologies scaled up for introduction among SHG were harvest bags (basket), seed-cum-fertilizer bag, seed placement tube, head load managers, revolving milking stool and stand, tailoring table, *gopal khore*, *trishul* weeder and cotton picking apron.

Farm activities by women

Characterization of nutritional diversity in selected cropping systems

Households (810; 90 from each centre) were selected for assessment of gaps related to food and nutritional security. Based on the socio-economic factors, families were categorized into low income group (LIG), middle income group (MIG) and high income group (HIG). In LIG category, complete immunization was recorded in Telangana (43.3%), Haryana (63.3%) and Maharashtra (46.6%) whereas in MIG category, Telangana (30%) had the lowest percentage of complete immunization. Similarly among pregnant women, food restrictions were common in Asom, Telangana and Karnataka, whereas these were not practiced in Haryana.

Empowering youth for quality living

A total of 1,350 school children from 9 centres (i.e. 100-150 children from each centre) studying in VII – X standards in the age group of 11-17 years were selected for empowering youth engaged in agriculture and allied activities with technology and life skills for quality living. In 2015, they were assessed on three aspects viz. reasons for academic backwardness, vocational interest and socio-emotional problems along with their socio-economic status and facilities available. The reasons reported for academic backwardness were academic (39.21%), health (30.56%) and familial (24.36%) reasons.

Commercialization of women-friendly technology DRWA-hand-operated maize dehusker cum sheller

The Institute has commercialized the technology 'DRWA-hand-operated maize dehusker cum sheller with Private manufacturer of agricultural implements, Cuttack on 20th Feb, 2015. The ICAR-CIWA has developed a farm machinery viz. 'DRWA- hand-operated maize dehusker cum sheller', which is a women-friendly hand operated equipment for shelling and de-husking of maize with an output of 60 kg/h. The technology has received appreciation from different stakeholders in widely tested field trials during 2012-14. Considering the necessity of the technology for large scale adoption, the technology has been commercialized for promoting localized production/manufacture to ensure the availability of this technology to the farming community, mitigate the drudgery of farm women, and promote the micro and small enterprises dealing with farm implements.

Contingency plan to tackle aberrant weather situation in Odisha

Districts viz. Mayurbhanj, Angul, Jajpur and Sambalpur of Odisha have been selected for contingency plan, based on their vulnerability to floods during monsoon season. Scientists from ICAR-CIWA are regularly visiting the villages in the districts for weather-based advisory services, and to bridge the technological gaps.

Gender in agriculture partnership (GAP)-India

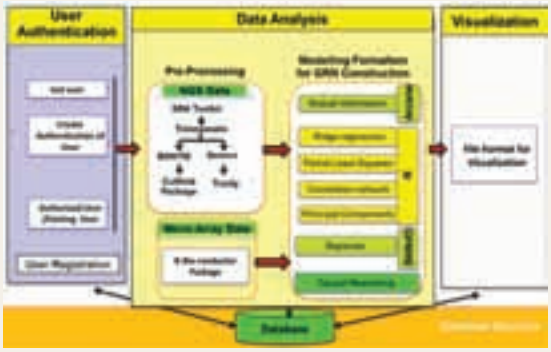
Gender in Agriculture Partnership is for transforming agriculture to empower women and deliver food, nutrition and income security. The GAP-India will work towards to catalyzing the GAP activities in South Asia and link with partners in other countries to benefit and support gender equity actions in the region.

STATISTICS

Web generation of polycross designs (webPD): Polycross nursery is a specific type of field design to ensure random mating among the genotypes and is commonly used in the breeding of wind-pollinated species. For easy accessibility and quick reference of polycross trials by the experimenters, online software was developed. This software provides freely available solution for the researchers and students working in this area and is available at http://design.iasri.res.in/webpd. The software generates five different series of polycross designs and two series of Octa Neighbour Balanced Polycross Designs balanced for eight directions. It displays the layout plans by entering the value of v (number of genotypes) and also displays the parameters of the designs. Along with the designs, the software also displays a complete description about the methods of construction along with example for all the five different series of designs. The online catalogue ($v \leq 20$) of all the five series of polycross designs was also prepared and included in the software, giving the parameters from where design can also be generated.

Web based tool for modeling gene regulatory network (GRN)

This online tool facilitates pre-processing next generation sequencing (NGS)/microarray data, constructing GRN via different modeling formalisms and visualization of network. The program computes gene expression from microarray and NGS data, which can be used further for reconstruction of regulatory networks and thereby subjected for visualization.



SBMDb: First whole genome putative microsatellite DNA marker database of sugar beet for bioenergy and industrial applications (http://webapp.cabgrid.res.in/sbmdb)

The sugar beet whole genome marker discovery and database, SBMDb was developed with 145K markers unified in a common platform. The database presents a wide source for developing and implementing new approaches for molecular breeding, which are required to accelerate industrious use of this crop, especially for sugar, health care products, medicines, and colour dye. Identified markers will help in improvement of bioenergy trait of bioethanol and biogas production along with reaping the advantage of crop efficiency in terms of low water and carbon footprint especially in the era of climate change.

Management Information System (MIS) and Financial Management System (FMS) in ICAR (http://icarerp.iasri.res.in): The system was implemented in 108 ICAR institutions. Data digitization work was carried out in all ICAR institutions; more than 20,000 users were created in the system. More than 10,000 personnel were trained on system.

Unified messaging solution (email with chat features) was implemented (https://mail.icar.gov.in)

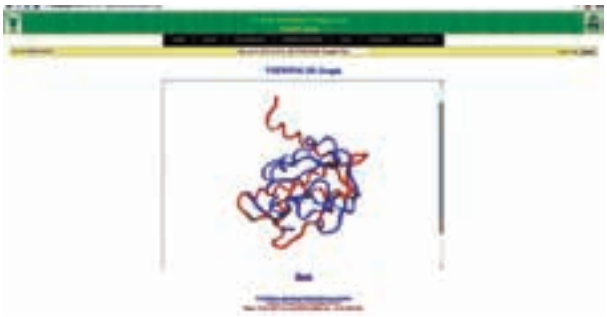
It can be accessed through webmail, outlook and mobile. Microsoft Lync provides instant messaging. E-mail ids were issued for all Directors and key

officials of ICAR-HQ. Email ids are being created for ICAR employees after verification of data from institutes. Accounts were created for more than 70 institutions. KRISHI Portal, Agroweb, NAIP and other applications running from IASRI server (HYPM, NISAGENET) were migrated into Data center environment.

Bioinformatics

Antimicrobial prediction server and algorithm/tool for protein structure comparison were developed for

cattle. Antimicrobial peptides (AMPs), the defence molecules of the host, are being natural alternative to



chemical antibiotics resistance to which is a major challenge in animal health. As cow genome sequence is already available, a computational tool was developed to predict potential peptides having properties of AMP. Ninety-nine well reported natural existing AMPs related to cattle were collected. Statistical analysis to develop model through application of artificial neuron network (ANN) and support vector machine (SVM) can predict putative genes coding for peptides having properties similar to natural existing AMP. Such predictive tool and server can be of immense use in future discovery of "organic" natural existing AMP from cattle genome without having problem of antibiotic resistance. Further, this will reduce the time and cost required in bioassay of potential AMP molecule. The species specific approach is novel and reported for the first time.

Protein structure comparison play important role in *in-silico* functional prediction of a novel proteins. This will help in understanding related coding genes and their use in development of superior varieties/ breeds /commodities in agriculture. To develop algorithm and tool for protein structure comparison, an efficient technique was developed using elastic shape analysis (ESA). The performance of the developed algorithm/tool was more efficient than the existing methods. Also, user friendly web-based application called ProtSComp was developed using above algorithm that can be accessed freely by the users.

13. Information, Communication and Publicity Services

The Directorate of Knowledge Management in Agriculture (DKMA) continued its efforts to showcase ICAR's technologies, policies and other activities through modern dissemination methods that cater various stakeholders in the field of agriculture. In partnership with Agrinnovate India Ltd, a non-profit company under Department of Agricultural Research and Education, the DKMA participated in the Global R&D Summit 2014, organized by Federation of Indian Chambers of Commerce and Industry, wherein some of the cutting edge technologies, products and solutions of ICAR Institutes were exhibited to key customers, business buyers, investors, scientific community and media at large. The DKMA signed an MoU with Project Director, The Essential Electronics Agricultural Library commonly known as TEEAL (An International Project from Cornell University, USA) for providing information on agriculture and allied sciences to the researchers across the globe, working at places where the internet is patchy especially in Africa. The DKMA participated in an International Workshop on 'Development of communication strategies for adoption of Agri-Biotechnology in Asia' held in Thailand. In the fast changing knowledge intensive era, the DKMA is committed to promote ICT-driven technology and information dissemination system for quicker and more effective out reach.

The NAIP Sub Projects 'E-Publishing and Knowledge System in Agricultural Research (EPKSAR)', 'AGRO-WEB', 'Mobilizing Media' were merged with the ICAR (Hq) under XII Five-Year Plan. As an endeavour to communicate research among scientific communities, the DKMA published peer-reviewed articles in research journals, viz. *The Indian Journal of Agricultural Sciences* and *The Indian Journal of Animal Sciences.* Besides 24 journals of professional/ academic societies are also hosted on the ICAR website (http://epubs.icar.org.in/ejournal) which provides global visibility to ICAR research in open access. The DKMA also published the *ICAR Reporter, ICAR Mail, ICAR Chiththi* (Hindi), *Agbiotech Digest, INDIA-ASEAN News on Agriculture and Forestry.* Popular form of agri-information was carried in the *Indian Farming, Indian Horticulture, Kheti, Phal Phool* along with some special issues.

Efforts were accelerated to disseminate the information and knowledge about new technologies and innovations among the stakeholders, especially farmers, by publishing various categories of popular and technical publications in Hindi, including the

development of informative literature and brochures based on the new schemes launched by the ICAR for farmers' welfare. A special issue of Hindi flagship monthly *Kheti* was published to commemorate the golden jubilee of the Green Revolution in India. The collection of precious write-ups of the veterans and stalwarts associated with the Green Revolution were included in this unique issue. Conceptualization and development of the contents for the E-books, publicity folders, posters, illustrations and video films on various important themes and programs launched by the DARE/ ICAR were also undertaken. One-day national workshop on the theme "Implementation of official language in scientific organizations –Use and promotion" was organized to promote use of Hindi in ICAR Institutes. Contents were also developed for ICAR website and social media in Hindi.

This year, DKMA published new titles, i.e. *The Onion, Mathematical Modelling of Agricultural Drainage Groundwater and Seepages*, *Sheetoshtra Phloon ki Baghbani*, a compendium of *Selected Innovative Value Chain, ICAR-Global Reach* to name a few. About 32,000 pages covering nearly 250 publications were published during the reported period. Press conferences, publicity material to press and exhibitions were also conducted by the DKMA for showcasing ICAR technologies on different occasions of national and international events across the country. Special trainings were organized to strengthen the capacity building programme in interest of the scientists. About 600 articles/features were published in the noted popular periodicals during the reported period. A professional get up was imparted to popular periodicals that included design, layout and contents. Information on various disciplines of agriculture, animal husbandry, fisheries and allied sciences was published for different

categories of stakeholders. During the year, special efforts were made for dissemination of agricultural technologies at ground level through mass media and showcasing of technologies at various national/ international expositions. The ICAR participated in more than 11 technology fairs/conferences to showcase its technological strength and information products. Capacity building activities for the ICAR scientists were organized to strengthen the agricultural communication in the country. Orientation training was provided to scientists on creative writing in agriculture at different ICAR Institutes.

A prestigious publication *Golden Jubilee of Green Revolution*, was designed and produced in a time frame manner matching international quality which was released on the occasion of Golden Jubilee of Green Revolution. Logos for different schemes of ICAR, viz. ARYA, Farmer First, *Mera Gaon Mera Gaurav*, Student Ready, Vision 2050 and *Jai Kisan Jai Vigyan* were designed in-house in DKMA, which were released by the Prime Minister of India on ICAR Foundation Day at Patna.

The DKMA extend its professional services for editing and production of publications to different institutes and related offices under ICAR system. Many publications of National Academy of Agricultural Sciences (NAAS) like *Water-State of Indian Agriculture*, *Energy-State of Indian Agriculture, Soil-State of Indian Agriculture,* and *Down the Memory Lane-25 years of NAAS* were brought out in a time frame manner during the period.

The *Vision 2050* document of all the ICAR institutes were published by DKMA while maintaining the uniform house style and printing quality. The *Vision 2050* document was released by the Prime Minister of India on the occasion of ICAR Foundation Day held at Patna.

During the reporting period 1,500 inputs were prepared and supplied to FAO electronically for merging into on-line AGRIS database of FAO in WebAgris software to enable on-line search by users all over the world. Half-yearly issues of *Indian Agricultural Sciences Abstract* and *Indian Animal Science Abstract* journals were brought out, which were hosted on ICAR website in open/on-line access in public domain. During the period ICAR website was updated daily (1,260 new pages were created), and was visited by 3,809,443 visitors (1,948,818 unique visitors from 219 countries visited the website as per Google analytics); top five countries include India, USA, UAE, United Kingdom and Kenya. ICAR Facebook page crossed 100,000 likes in 2015. Post on Black rice reached 294,061 people. Hindi blog writing and Photo/drawing contests were organized on ICAR Facebook Page. The network of KAB I, KAB II and NASC Complex was upgraded to IPv6 compliance network equipments. The wire and wireless network in KAB-I, KAB-II and NAS Complex was maintained while updating for secure password for ICAR users and guests. Work of replicating CDs/ DVDs on ICAR publications was done. KOHA Library Management software was implemented with Web-OPAC facility. Training programmes were organized on data indexing for AGRIS database of FAO using WebAGRIS software and preparation of input for AGRIS database for the participants from ICAR institutions and professional societies.

CeRA: To create awareness among scientists/faculty/ students of North-East Region along with Bihar, Jharkhand, Odisha, West Bengal and South, the DKMA-CeRA organized two Training-cum-Awareness Workshop at National Research Centre on Pig, Gauwahati and Professor Jayashankar Telangana State Agricultural University, Hyderabad, Telangana. A Training-cum-Awareness workshop was organized by the DKMA-Ce RA at Sugarcane Breeding Institute, Coimbatore, Tamil Nadu. Besides more than 23 lakh full text articles were downloaded by member institutions of CeRA and over four thousand Document Delivery requests were fulfilled. The Remote access Facility was provided to individual scientists of over 34 institutes located in remote areas. With the aim to negotiate the subscription payment to the publishers five negotiation committees meetings were held during reported period. Two meetings of National Steering Committee were held to review the performance of CeRA activity for 2014 and 2015.

During January to December 2015, the revenue to the tune of ₹ 80 lakh was generated through sale of literature and other information products.

14. Technology Assessment, Refinement and Transfer

Krishi Vigyan Kendras (KVKs) have taken up activities for assessment, refinement and demonstration of technologies/products under different agro-ecosystems developed by the National Agricultural Research System of the country. At present, 642 KVKs are functioning across the country under State/Central Agricultural Universities (435 KVKs), ICAR Institutes (55 KVKs), NGOs (99 KVKs), State Governments (35 KVKs), Public Sector Undertakings (3 KVKs) and Central/Deemed Universities and other organizations (15 KVKs). The activities of the KVKs include on-farm trials (OFTs) to identify location specific technologies in various farming systems; frontline demonstrations (FLDs); and training of farmers, farm women, rural youth and extension personnel. Besides, the KVKs also contributed for the development of contingent plans for drought and flood situations, and implementation through technical back-up to the extension system. To show potentiality of technologies in terms of technological inputs, information and knowledge, KVKs have served as the knowledge and resource centre at the district level in the country.

Technology assessment and refinement

Assessment: During the year, 2,652 technology interventions were assessed across 4,003 locations by laying out 27,008 trials on the farmers' field on various crops under different thematic areas, namely cropping systems, drudgery reduction, farm machineries, integrated crop management, integrated disease management, integrated farming systems, integrated nutrient management, integrated pest management, integrated pest and disease management, integrated weed management, processing and value-addition, resource conservation technologies, seed/planting material production, storage techniques and varietal evaluation. Major crops included paddy, wheat, maize, *bajra*, sorghum, bengalgram, blackgram, greengram, redgram, groundnut, mustard, sesame, soybean, sugarcane, cotton, onion, tomato, brinjal, cowpea, okra, amaranthus, chillies, banana, mango, apple, *amla*, papaya, turmeric, potato, capsicum, cabbage, etc.

In livestock, 439 technology interventions at 622 locations covering 4,994 trials on animals under the thematic areas, namely disease management, drudgery reduction, evaluation of breed, feed and fodder management, nutrition management, fertility improvement, processing and value-addition, and storage technologies were taken up for assessment. The major livestock species included were dairy cows, buffaloes, sheep, goat, poultry birds, pigs and fisheries.

Women specific income generation technologies (205) related to technological empowerment of rural women were assessed at 394 locations covering 2,917 trials under the thematic areas, namely drudgery reduction, farm mechanization, health and nutrition, processing and value-addition, production and management, energy conservation, small scale income generation, and storage techniques. The major enterprises included mushroom, sericulture, vermicompost production, nutritional gardens, etc.

Refinement: Refinement of 265 technological interventions was carried out at 306 locations by laying out 1,593 trials in the farmers' fields under various thematic areas, viz. drudgery reduction, farm machineries, integrated crop management, integrated disease management, integrated farming system, integrated nutrient management, integrated pest management, integrated weed management, processing and value- addition, resource conservation technologies and storage techniques. Major crops included were paddy, wheat, *bajra*, blackgram, greengram, bengalgram, mustard, soybean, groundnut, sugarcane, cotton, tomato, onion, brinjal, chillies, *bhindi*, apple, *amla*, etc.

Technological interventions (39) in 43 locations were refined through 398 trials on livestock, poultry and fisheries under the thematic areas, viz. disease management, feed and fodder management, nutrition management and production and management. Major livestock enterprises included dairy cows, buffaloes, poultry birds, sheep, goat and fisheries.

In addition, five women specific income generation technologies were refined by conducting 32 trials in five locations under the thematic areas of drudgery reduction, health and nutrition, and small scale income generation.

Frontline demonstrations

FLDs were conducted to demonstrate the production potential of the newly released improved crop varieties/ production technologies in crops/animal husbandry and other agricultural enterprises. For the benefit of farmers/ personnel involved in transfer of technologies, on-site trainings and field days were also organized at the demonstration sites

During the year, 98,624 demonstrations covering 52,326 ha were organized. Of these, 90,974 (92%) demonstrations covering 47,001 ha were on cereals, millets, oilseeds, pulses, commercial crops, fibres, spices, medicinal, plantation, fodder, horticultural crops, etc. For promoting hybrids cultivation 7,650 demonstrations covering 5,325 ha were conducted in cereals, millets,

pulses, oilseeds, etc.

Cereals: Demonstrations (27,175) covering 8,708 ha were organized in rice, wheat, maize, barley, etc. Maize recorded an increased yield of 48.44% over farmers checks followed by wheat (30.1%).

Millets: Demonstrations (2,861) covering 1,089.83 ha were organized to show the production potential of millet crops, viz. sorghum, barnyard millet, finger millet, etc. The increase of 32.8% yield was recorded over local checks.

Oilseeds: During the year, 16,485 demonstrations were conducted on oilseed crops, viz. groundnut, sesame, soybean, castor, linseed, niger, etc. covering 6,515 ha. The increase of 34% yield was observed over farmers' practices.

Pulses: Demonstrations (22,146) covering 7,439 ha were conducted for pulse crops like pigeon pea, blackgram, lentil, pea, greengram, and increase in yield was 36% over local checks.

Commercial crops: Under commercial crops, 3,149 demonstrations were organized covering 7,808 ha. Of these 2,411 (77%) covering 1,534 ha were on cotton crop and rest on sugarcane and mulberry crops. The increase in yield of cotton crop was 11% over farmers' practice.

Fodder crops: FLDs (2,119) on fodder crops like berseem, sorghum, maize, lucerne and pearl millet were conducted covering 458 ha; the increase in yield ranged from 10% in lucerne to 90% in *bajra* over farmers' practices.

Horticultural crops: A large number of demonstrations (14,406) were organized on horticultural crops. Of these, 10,891(76%) were on vegetable crops, 2,581(18%) fruit crops, 484 flower crops, 335 plantation crops, and 115 on medicinal and ornamental crops. The yield increase ranged from 27% in fruit crops to 37% in medicinal and aromatic plants over farmers' practices.

Hybrids: To demonstrate the production potential of hybrids, 7,650 demonstrations covering 5,324.66 ha were conducted for cereals, commercial crops, fodder hybrids, fruit and vegetable hybrids, millets, oilseeds such as groundnut, mustard, sesame, etc. by 428 KVKs. The yield increase ranged from 36 to 41% in cereal crops, while in cotton the increase yield of 29% was observed. In fodder crops, increase yield of hybrid Napier was 42% and of pearl millet hybrid 54% over farmers' cultivars.

An yield increase of 73% was recorded in papaya hybrid over farmers' practices. In vegetable hybrids highest yield of 124% was recorded in capsicum, and least 20% in bitter gourd crop.

Capacity development

Training programmes (52,437) were organized wherein 14.48 lakh farmers/farm women, rural youth and extension personnel participated.

Farmers and farm women: Training of 11.74 lakh farmers and farm women (41,490) was organized on various technologies to update their knowledge and skills. The courses were on productivity enhancement of field crops (21%), horticultural crops (15%), empowerment of rural women (14%), plant protection (15%), livestock production and management (11%), soil health and fertility management (9%), farm machinery tools and implements (5%), capacity building and group dynamics (4%), production of input at site (1%), fisheries (2%) and agro-forestry (3%). Out of these courses, 37% were conducted on campus (12,447) and 63% were organized off-campus (29,043). The participants included 2.54 lakh farm-women in the crop production training. Among the crop production technologies, 23.64% of the training courses were on integrated crop production technologies, followed by weed management (9.72%) and seed production (7.81%). Out of 6,430 training courses on horticulture, 3,371 were on vegetable crops, 1,871 on fruit crops, 285 on spices, 280 on ornamental, and 188 courses on medicinal and aromatic crops.

Rural youth: Skill-oriented training courses (7,112) were organized for 1.75 lakh rural youth, including 61,008 young women (35%) during the year. These courses were on integrated farming, mushroom production, value-addition, dairy farming, seed production, vermin-culture, nursery management of horticulture crops, bee-keeping, protected cultivation of vegetables, repair and maintenance of farm machinery implements, sheep and goat rearing, poultry production, production of organic inputs and small-scale processing.

Extension personnel: Capacity development programmes (3,835 courses) were conducted for 1.99 lakh extension personnel, out of which 23,636 (23.85%) were for women. These courses were organized for extension functionaries working in government and non-government organizations who were directly or indirectly related with the development of agriculture sector. Training was imparted in agricultural technologies related to productivity enhancement in field crops, integrated pest management, integrated nutrient management, group dynamics and famers' organization, management of farm animals, rejuvenation of old orchards, women and child care, livestock feed and fodder production, protected cultivation technology and ICT applications.

Sponsored training: Sponsored training courses (7,246) were conducted benefiting 2.36 lakh farmers and farm women, rural youth and in-service extension personnel. Most of the sponsored courses were related to on-site input production, economic empowerment of women, processing and value-addition, methods of protective cultivation, farm machinery tools and implements, fisheries management, household nutritional security, animal nutrition management, animal disease management, fisheries and drudgery reduction for women.

Extension programmes

For creating awareness among farmers about improved technologies and to provide timely advisory to farmers, KVKs organized different extension programmes. A total of 6.46 lakh extension programmes/ activities in the form of advisory services, diagnostic and clinic services, celebration of important days, exhibitions, exposure visits, ex-trainees *sammelan*, farm science club. Conveners' meet, farmers' seminar, farmers visits to

KVK, field days, film shows, group meetings, *kisan ghosthi*, *kisanmelas*, lectures delivered as resource persons, *mahila mandals* conveners meetings, method demonstrations, plant/animal health camps, scientists' visit to farmer's field, self help group meetings, soil health camps, soil test campaigns, workshops and others were organized which attracted the participation of 102.39 lakh participants of which 98.79 lakh were farmers and 3.60 lakh extension personnel. The KVKs also organized 0.86 lakh extension programmes through electronic and print media to have wider coverage in the districts. These included electronic media in the form of TV programmes, radio talks, CDs/DVDs, extension literature, newspaper coverage, popular articles, leaflets, folders and books/ booklets.

KVK conference

The 9th National KVK Conference was inaugurated by Hon'ble Prime Minister Shri Narendra Modi on 25 July 2015 at Patna. Prime Minister emphasized upon hastening lab-to-land process and appealed for bringing in four colour revolution, i.e. Green, Blue, White and Saffron for all round development of the country. On this occasion, four schemes namely Farmer FIRST, Attracting and Retaining Youth in Agriculture (ARYA), Mera Gaon Mera Gaurav and Student Ready were launched for enhancing farmer-scientist interface and development of skills and entrepreneurship in youths reforms.

Kharif and *Rabi Kisan Sammelan*

Pre-kharif kisan sammelans were organized by 330 KVKs with the participation of public representatives. KVKs organized film shows, provided extension literature related to agricultural technologies, displayed exhibits, posters, photographs, digital prints, display boards, sample trays, etc. for dissemination of information developed by ICAR Institutes/SAUs to the farmers and other stakeholders. During *rabi* season, it is planned to conduct the interface and exhibition by 500 KVKs.

Production of technological products: KVKs produced large quantity of technological products like seeds and planting materials of improved varieties and hybrids, bio-products and elite species of livestock, poultry and fish which benefited 31.29 lakh farmers in the country.

Seeds: During the year, 1.96 lakh q seeds of improved varieties of cereals, oilseeds, pulses, commercial crops, vegetables, flowers, fruits, spices, fodder, forest species, medicinal plants and fibre crops were produced and provided to 3.28 lakh farmers.

Planting materials: In all, 228.75 lakh quality planting materials of elite species of commercial crops, vegetables, fruits, ornamental, medicinal and aromatic crops, plantation crops, spices, tuber crops, fodder and forest species were produced and provided to 18.38 lakh farmers.

Bio-products: Bio-agents, bio-pesticides, bio-fertilizers, vermicompost, mineral mixture etc. were produced and supplied to the extent of 16,406 q benefiting 9.39 lakh farmers.

Livestock, poultry and fish fingerlings: Improved breeds of cow, sheep, goat, buffalo and breeding bull were produced and supplied to 1,341 farmers. Different strains/ breeds/eggs of poultry birds (chickens, quails, ducks and turkey) were provided to 17,630 farmers. Improved breeds of pigs were provided to 296 farmers. KVKs also enabled 19 farmers to establish rabbit rearing units by providing 99 rabbits. Fish fingerlings (116.86 lakh) were produced and supplied to 2,647 farmers.

Soil, water and plant analysis: Samples (3.35 lakh: soil, 2.59 lakh; water, 0.60 lakh; plant, 0.15 lakh, and manure, 0.003 lakh) were analyzed covering 2.72 lakh farmers belonging to 0.54 lakh villages and the revenue generated was ₹ 203 lakh.

Rainwater harvesting: A total of 355 training courses and 1,157 demonstrations were conducted and 5.01 lakh planting materials were produced. Further, 40,553 farmers and 1,871 officials visited these units and got

Pre *kharif* mela at KVK, Balaghat, Madhya Pradesh.

acquainted with the system.

Technology week: Technology week, under public-public and public-private partnership mode, was organized by KVKs benefiting 16.38 lakh farmers, farm-women, extension personnel, rural youth and members of self help groups. The events included 22,279 extension activities such as seminars, skill demonstrations, film shows, field visits, demonstrations, exhibitions and scientist-extension personnel-farmer interactive sessions.

Kisan mobile advisory

Kisan mobile advisory (KMA), an initiative by the ICAR is providing timely and need based information to farming community. KVKs provided service through various service providers. Information on weather, market, various farm operations, outbreak of pest and disease incidence and their control measures are given to farmers through Short Message Sevice (SMS). During the year, 93,949 short text messages, 14,788 voice messages and 1,180 both SMS and voice messages were sent to benefit 223.94 lakh farmers on various aspects of agriculture, horticulture and animal husbandry, weather forecast, and pest and disease control by 557 KVKs.

Technology demonstration for harnessing pulses productivity: Demonstrations (8,727) covering 4249.97 ha were laid out on mungbean (1,299 ha), urdbean (741 ha), pigeon pea (563 ha), chick pea (1,347 ha) and lentil (168 ha) showing productivity gains of 50.12, 73.69, 70.73, 55.72 and 55.77%, respectively, over local checks.

Demonstrations on climate resilient technologies: Under the sub theme-Technology Demonstrations and Dissemination for Climate Resilient Agriculture, about 1.0 lakh farmers were covered in 132 villages. Integrated packages of proven technologies were demonstrated in one village in each district for adaptation and mitigation of the crop and livestock production system to climate variability based on the available technologies. During the year, 100 KVKs carried out 12,070 demonstrations on natural resource management covering 6,968 ha, 12,070 demonstrations on crop production technologies covering 4,450 ha and 1,814 demonstrations on fodder and feed production covering 682.18 ha. About 17,315 animals/birds belonging to 3,092 farmers got benefited from the demonstrations related to livestock and fisheries. Capacity-building interventions and the extension activities like exposure visits benefited 154,024 farmers.

Technological backstopping: The Directorate of Extension (DEs) of SAUs/CAU organized 192 capacity development programmes for updating the technical knowhow of staff of Krishi Vigyan Kendras (KVKs).

Besides, the DEs also organized 169 workshops and meetings for effective implementation of programmes of KVKs. The officials of these Directorates made 1,943 visits to the KVKs during Scientific Advisory Committee meetings, Field days, Technology Weeks, Workshop/ seminar, Training programmes, etc. to review and monitor the activities of KVKs in the operational areas of respective directorates.

Likewise, the Zonal Project Directorates upgraded the knowledge and skills of 3,182 staff of KVKs by arranging 76 capacity development programmes at various SAUs and ICAR Institutes in the areas like, application of ICT, extension strategies for small farm development, etc. Awareness programme on protection of plant varieties and farmers' rights were conducted at KVKs in colaboration with PPV and FRA.

Agricultural Technology Information Centres

Agricultural Technology Information Centres (48) in the country served as single window delivery systems by providing technology information, technology services and technology inputs to the farmers. In all, 4.99 lakh farmers visited the ATICs for the technological solutions during the year. Technological information was provided to about 1.31 lakh farmers both through print and electronic media. Likewise, 2.67 lakh farmers got quality technological inputs namely, 48,550.87 q seeds, 22.99 lakh planting material, 1984 livestock, 0.27 lakh poultry birds and 1076.03 q bio-products. Besides, 7.28 lakh farmers were benefited by technological services like, soil and water testing, plant diagnostics, veterinary advisory services, soil health cards etc. were provided to farmers.

Zone 1

Mitigating the menace of bakane disease in *basmati* paddy in Delhi

Farmers started cultivating paddy variety Pusa 1121 in place of Pusa Basmati 1 in 2008, because of better yield, grain quality and price realization. However, this variety is susceptible to bakane disease. By 2010, the bakane disease incidence in Pusa 1121 variety at farmers' field was as high as 80%. FLDs, training programmes for paddy growers, method demonstrations and about 300 farm advisories through field visits, farmers' visit to KVK, and mobile advisory were synergized to tackle the bakane disease problem in paddy in Delhi. Farmers were made aware to use good quality seed from reputed producers and adopt seed, seedling and soil treatment for effective management of bakane disease. As a result of these efforts of Ujwa KVK, about 70% farmers of Delhi adopted seed/ seedling treatment of paddy with chemical/bio fungicide in 4,250 ha area. The bakane disease in paddy has reduced from 80% in 2010 to 15% in 2014 with lower intensity and paddy growers (70% farmers who have adopted seed and seedling treatment in raising paddy crop) are harvesting additional grain of 5.03 q/ha.

Activities on bakane disease management organized by KVK, Delhi.

Success stories

Empowering dairy farm women

The importance of group approach for diffusion of scientific knowledge was channelized through identified 18 SHGs each comprising farm women interested in dairy farming during the last three years in Kullu district. One of the SHGs of 25 farm women was facilitated to get loan of ` 1.00 lakh to purchase high yielding animals and construction of semi *pucca* animal sheds under the technical guidance of KVK. The performance indicators like calf mortality (decreased from 15-20% to 5-7%), age of puberty (reduced from 24.8 months to 16.42 months), age at first conception (reduced from 26.86 months to 18.28 months), milk yield per lactation (increased from 1,500-2,000 litres to 2,200-3,000 litres) and calving interval (reduced from 2.89 years to 1.23 years) showed positive trends leading to increased income of the dairy farm women. This group is currently procuring 800-1,000 litres of milk daily involving 55 other farmers of the nearby villages and is selling to the milk cooperative society. The farmers get the most reasonable rates of the milk through the society. The milk federation is also supporting by supplying quality fodder seeds, concentrate ration at subsidized rate to the women farmers. They have gained confidence that with their own management skills, they can bring economic changes in their own life.

A view of dairy farming by a SHG

Large scale adoption of TPS technology in West Tripura

KVK, West Tripura, implemented production of seedling tubers in cooperative farming mode in 17.5 ha involving 182 farmers in six clusters of villages. KVK organized an awareness programme on potato tuberlet production from TPS in the KVK campus in which 98 potato growers from the nearby villages participated. Training was provided to selected beneficiaries on different aspects of TPS cultivation including integrated pest and disease management, postharvest handling and treatment of seedling tubers etc. Besides field visits, weather based agroadvisory services through text messages were regularly provided to the farmers on plant protection measures, especially from blight.The total quantity of seedling tuber produced was 112 tonnes and the quantity of seedling tuber supplied to the Tripura Horticulture Cooperation Limited was 103 tonnes from the farmers' fields. As a result, the non-TPS areas could also be brought under TPS cultivation. Approximately 70% area of potato cultivation in the district was brought under TPS resulting in increased potato production.

Demonstration of TPS technologies

Zone II

Livelihood through integrated farming system

Shri Ajeet Kumar, a youth from Balia, Bihar having poor economic condition was motivated to adopt agriculture as mainstay of livelihood by KVK, Kishanganj. He hired 4.0 acres of land on lease for ` 1.75 lakh for integrated farming of makhana-cum-fish culture. He obtained capacity building training and technological support from the KVK and other institutions on fisheries and poultries, makhana production, jute and vegetable production beside integrated crop management. Mr Ajeet Kumar established a fish pond of 1 acre land, poultry farm with 1,200 birds, teak plantation with 400 plants and papaya nursery with Pusa dwarf varieties, backyard poultry farming with 100 Vanraja and Grampriya breeds, pigeon farming with 40 birds and goat farming with 8 Black Bengal breeds. Currently, he earns about ` 6 lakh annually through the integerated farming of makhana-cum-fish culture and other enterprises at his farm. He is also a member of Matasya Jeevi Sahyog Samiti and is continuously engaged in motivating other farmers for adopting new technologies in agriculture and allied sectors.

Zone V

Foxtail millet as climate resilient crop in South India

Yagantipalle village, Banaganapalle Panchayat, Banaganapallemandal with 70% of rainfed agriculture was selected for implementing NICRA project. *Desi* cotton and redgram were the main crops grown during *kharif* and sorghum and sunflower in *rabi*. Most of the crops get affected with late onset of monsoon followed by dry spells during critical crop growth periods, which in turn severely affect yield. The short duration millets, viz. Foxtail millet SIA 3085, Suryanandi varieties having 70-75 days duration and tolerance to drought and downy mildew were introduced in place of sorghum and *desi* cotton in 25 acres in 2011 *kharif*. Onset of monsoon was late and the crops experienced prolonged dry spells during growth period. Cotton could not be taken up and sorghum was sown but it was affected with terminal

A view of foxtail millet crop in the field.

moisture stress. These varieties of Setaria (KORRA) could escape drought due to its shorter duration. The area of foxtail millet in the village is more than 300 acres at present. With the availability of quality seed with seed banks at KVK, NICRA seed farmers and RARS, the crop was taken up in surrounding villages and mandals where there is late onset of monsoon and the area of crop increased tremendously.

Zone VI

Protected vegetable cultivation for profitability

Ms Patel Sagunaben Dipakbhai from Israma village, Petlad Taluka, Anand, obtained training of horticulture at KVK Devataj.Initially she started cultivation of capsicum (chilli) in net house of 10 guntha area, in which drip irrigation with mulching like modern technology was also used. Besides that in fellow land without cultivation she started growing seedlings in plastic tray filled with cocopit and perlife like medium in small scale. After success, she started it commercially as business to raise the seedlings of vegetables in trays for surrounding village farmers @ 40 paise/plant. She realized good income source from this business and established green house in 10 guntha and net house in 40 guntha area and started cultivation of raising seedlings, colour capsicum chilli and cucurbit like horticultural crops.

A view of vegetables grown in green house and net house.

Zone VII

Improved vegetable farming in barren land under drip irrigation

KVK, Seoni, provided technical guidance for growing nursery management, planting, fertigation schedule and insect pest management for improved hybrids of vegetables (tomato, chilli and capsicum) coupled with introduction of drip irrigation system in more than 150 ha. Identified area was linked with subsidy (70%) from Horticulture Department, Seoni. Due to KVK interventions, there was increase in area up to 4,798 ha for growing improved variety/hybrids resulting in enhanced productivity to 179 q/ha and increased income of ₹ 40,000-45,000/annum.

A view of vegetable farming in barren lands

Lac cultivation for livelihood security of tribes

Krishi Vigyan Kendra, Rajnandgaon has started project on modern methods of lac cultivation for livelihood of tribal's village Kektitola, Ambagarhchowki block, Rajnandgaon district. Farmers have been cultivating lac from many years but production was very low. KVK, Rajnandgaon implemented lac project with identification of host trees, with formation of SHGs by participatory approaches.The scientific method of lac cultivation i.e. proper pruning of lac host trees, timely tying up of brood lac, use of 60 mesh nylon *jaali*, spraying of insecticides as per requirement, and timely cutting of lac after maturity led to increased yield of lac.

Total number of palas trees were 260 and *ber* tree was nil for lac cultivation before inception of this project and after the project, there are 3,835 palas and 365 *ber* trees. In traditional farmers' technique, production was 1.25 kg/plant in palas and nil in *ber* and after the scientific intervention, it increased up to 3 kg/plant in palas and 3.5 kg/plant in *ber*. Total production of lac in village before the project was only 200 kg but after implementation of project, it increased to 11,000 kg in palas and 1,200 kg in *ber* trees. After KVK intervention the farmers of village Kektitola were capable to produce quality broodlac for their self and sale purpose.

Scientific methods of lac cultivation were adopted by by making 15 SHGs at village level comprising 10 members in each group thus benefiting 150 families of the village.

Brood lac tying

Zone VIII

Promoting entrepreneurship by adding value to finger millet

Finger millet is a major staple food crop of Chikkaballapur district. KVK, Chikkaballapure is conducting skill training on value-addition to finger millet. Smt Roopa Rajendra along with five others came forward to take up processing and value-addition to finger millet as an entrepreneurial activity. She established a small scale processing and value-addition unit in August 2013 and obtained license for sale of value-added finger

A view of ragi products production unit.

millet products under the technical guidance of KVK and the financial support of a bank. The major value-added products produced from finger millet in the unit are *malt, chakkuli, ladoo* and *hurihittu*. At present, Smt Roopa is involved in preparation and marketing of finger millet *malt* with different flavours, *hurihittu, chakkuli*, and *ladoo* and is selling them through her own selling points and mobile sales van arranged. The monthly average production of the products is around 350 kg with a net profit of ₹ 30,000-40,000.

An all-women food processing company re-writes story of women empowerment

KVK, Palakkad provided technical guidance to the group of 20 women who had established a food processing unit, known as Aiswaryasree Kudumbasree. The unit was modernized with the state-of-the-art machinery including pulveriser, roaster, blender, sealing machine etc. and all 20 women are employee-cum-shareholders of this unit. The major food products of the unit are puttu rice flour, chembaputtu rice flour, pathiri and idiyappam flour, jam, squash, and spice mixes and are marketed under the brand name "Nellara". Now the unit has an annual turnover of ₹1.5 crore. Every year the group is able to earn a dividend of ₹ 20 lakh of which ₹ 13 lakh is divided among members. Each member is able to draw ₹ 6000/month as salary and a bonus of ₹10,000 at the end of financial year. An allowance of ₹ 1,000 is given for all members during major festivals. Recently the unit has added the preparation of health food mix "Teen Plus" under the technical guidance of KVK. More than 5.00 tonnes of "Teen Plus" was supplied to different *Anganwadis* of the district. Aiswaryasree Kudumbasree participates in exhibitions and melas organized by different organizations.

A view of Aiswaryasree Kudumbasree unit.

❑

Soil Health Cards

The KVKs (609) contributed significantly in collecting and analyzing soil samples and distributing soil health cards (2.09 lakh) to farmers on the occasion of World Soil Day on 23rd November 2015. The functions were attended by Hon'ble Ministers of Central Government (16), Chief Ministers (3), Members of Parliament (95) and Members of Legislative Assemblies (143) at different locations.

Jai Kisan Jai Vigyan

To commemorate the great contributions of Former Prime Minister Chaudhary Charan Singh and Shri Atal Bihari Vajpayee in agriculture, the week (23–29, December 2015) with their birthdays was celebrated as 'Jai Kisan Jai Vigyan' week with organization of farmers-scientists interface, demonstration of technology and other related programmes of Agricultural Universities, ICAR Institutes and KVKs across the country.

15. Research for Tribal and Hill Regions

Specific technologies are required for the tribal and hill farmers of unique ecosystems of the Himalayas and Islands of Andaman and Nicobar. The research institutes located in north-west Himalayas (Vivekanand Parvatiya Krishi Anusandhan Sansthan, Almora), the north-east Himalayas (ICAR Research Complex for NEH Region, Umiam), and Andaman and Nicobar Islands and Goa (Central Island Agricultural Research Institute, Port Blair and ICAR Research Complex for Goa) are engaged in area-specific research.

NORTH-WEST HIMALAYAS

ICAR-Vivekananda Parvatiya Krishi Anusandhan Sansthan, Almora, caters to the agricultural research needs of the north-western Himalayan states of Uttarakhand, Himachal Pradesh and Jammu and Kashmir. The salient accomplishments during the period under report are discussed here.

Seed production

Breeder seed (192.36 q) of 48 released varieties/ inbreds (19 varieties and 6 inbreds of cereals, 4 of millets, 11 of pulses, 4 of oilseeds and 4 of vegetable crops) was produced. A total of 252.455 q breeder seed was supplied to different seed producing agencies to take up further multiplication. Around 18.75 q nucleus seed of 43 released varieties was also produced following standard methods to maintain genetic purity. In addition to this, 16.265 q Truthfully Labeled (TL) seed of 34 varieties (13 cereals, two of millets, 2 of pulses, 4 of oilseeds, 12 of vegetables and one each of buckwheat and amaranth) was produced to meet the demand of the institute extension activities. A total of 15.832 q TL seed was supplied.

Under farmer participatory seed production programme, 72.45 q TL seed of wheat (VL Gehun 907 and VL Gehun 892), lentil (VL Masoor 126) and garden pea (Vivek Matar 10) was produced, and 39.88 q was supplied from the seed procured.

Carbon sequestration with FYM application in mid Himalayas

An experiment was conducted for six years with different levels of FYM and recommended NPK in gardenpea-French bean cropping system. There was 133 kg more CO_2 emission through fertilizer manufacture with application of recommended NPK fertilizer than soil C sequestration. The CO_2 emission for FYM preparation was very less than sequestration. Application of 5.04 tonnes FYM/ha was able to nullify the 62 kg CO_2 emitted during FYM preparation through soil C sequestration. Hence, application of more than 5.04 tonnes FYM/ha provided net positive C sequestration. The highest net positive C sequestration (1,585 kg CO_2/ha) and the highest C sequestration (1,792 kg CO_2/ha) could be achieved by application of 16.6 and 17.1 tonnes FYM/ ha, respectively. The highest net positive C sequestering FYM application rate provided 1,443 kg CO_2/ha higher C sequestration than recommended NPK. It also provided

Vivek Maize Hybrid 45 – A stay green maize hybrid for the tribals of Jaunsar, Uttarakhand

Jaunsar tribal area in Uttarakhand comprising block Kalsi and Chakrata in the district of Dehradun is traditionally a maize growing area. Of the total 27,895 thousand hectare area under maize cultivation in Uttarakhand, the Dehradun district with a total area of 9,115 thousand hectare accounts for about 33 per cent of the total maize area in the state. Of this, about 45 per cent is located in the hill region of the district represented mainly by the tribal blocks of Kalsi and Chakrata. The contribution to maize production from the hill region, however, is only 30 per cent due to lower productivity (976 kg/ ha) compared to the plains of the district (1,879 kg/ ha). This productivity level is even below the average for the entire hill region of the State (1,187 kg/ ha).

Training and FLDs of maize hybrids were organized in this area during *kharif* 2015 to enhance the production and productivity of maize.

Vivek Maize Hybrid 45, an early maturing (85-90 days) and high yielding (5-5.5 tonnes/ha) variety tolerant to *Turcicum* and *Maydis* leaf blight, was released by Central Variety Release Committee in 2013 for cultivation in Jammu & Kashmir, Himachal Pradesh and Uttarakhand. The plant height is 200-205 cm; long cylindrical cobs with good husk cover; grains are bold (average 1,000-grain weight, 335 g) yellow and semi-flint in texture. The 'stay-green trait' makes the plant suitable for use as green fodder after harvesting of the mature cobs.

According to the farmers, the yield of Vivek Maize Hybrid 45 was about double that of their local cultivar (this is corroborated by the preliminary assessment of the scientists as well) despite less than normal rainfall during the crop season. They also reported that damage due to high speed winds was also less in this hybrid. The 'stay-green' trait of the hybrid was particularly appreciated by the farmers.

48% higher pod yield of gardenpea-French bean cropping system than recommended NPK.

EASTERN HIMALAYAS

Maize production in *jhum* condition: ICAR Research Complex for NEH Region, Umiam, Meghalaya in a participatory production technology development to identify efficient varieties and improved agronomic management practices (IAMP) for maize production in *jhum* condition, evaluated nine varieties (Hemant, Vijay Composite, DA 61A, RCM 1-1, RCM 1-3, RCM 75 and RCM 76, SaruTangring, SaruBhoi) and compared with farmers' practice at *jhum* field of Sonidan Village of Meghalaya.

Activities in *jhum* farm

Grain yield (3.22 tonnes/ha) and all other parameters were significantly higher in IAMP compared to farmer's practice (grain yield 1.96 tonnes/ha). DA 61 A (3.78 tonnes/ha) and RCM 75 (3.67 tonnes/ha) performed better over other varieties.

Maize and French bean under organic farming: Eleven varieties of maize and 10 varieties of French bean were screened under organic farming in NEH Region. In maize, green cob yield was highest in RCM 1-3 (6.40 tonnes/ha) followed by RCM 75 (6.03 tonnes/ha) and DA 61-A (5.95 tonnes/ha). On the other hand, seed yield was recorded maximum in DA 61-A (3.61 tonnes/ha) followed by RCM 75 (3.29 tonnes/ha) which was closely followed by Vijay Composite (3.26 tonnes/ha).

In French bean, highest green pod yield was recorded in Naga local (4.36 tonnes/ha) followed by RCM-FB-18 (4.11 tonnes/ha) and RCM-FB-19 (3.93 tonnes/ha). Seed yield also showed similar trend as in green pod which had recorded highest in Naga local (2.40 tonnes/ha) and lowest in Maram (0.41 tonne/ha).

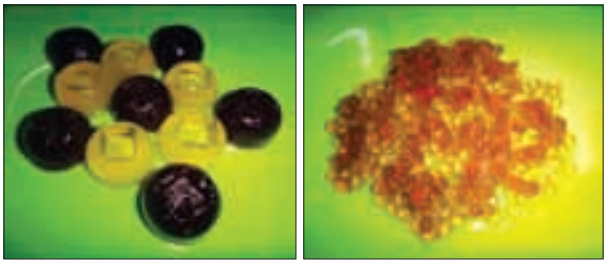
Cobs of different varieties of maize under organic farming

Seed of different varieties of French bean under organic farming

Ramie cultivation in Garo Hills: Under *Jhum* improvement programme Ramie (*Boehmeria nivea*) crop was introduced in Garo Hills. Ramie was planted in collaboration with DAO, West Garo Hills in 8 ha area benefitting 57 farmers. Three Ramie Growers Associations were formed. Seeing the growth of the plants and interest of beneficiaries, Meghalaya Government initiated 'Ramie Mission' with an outlay of ₹ 40 crore targeting 2,000 ha area.

Value-addition

Four different new generation value-added products were developed from Manipuri black cherry (*Prunus nepalensis*), passion fruit and pineapple. Passion fruit juice was converted to a semi-solid gel and shaped into small balls using silicon mould. In pineapple, the juice was converted to soft gel and the product can be used as



Value added products from passion fruit and *Prunus nepalensis*

Vatieties released and notified

Variety	Adaptation region/ agro-ecology	Yield (tonnes/ha)	Duration	Salient features
Vivek Maize Hybrid 47	Jammu and Kashmir, Himachal Pradesh, Uttarakhand, Asom, Arunachal Pradesh, Manipur, Meghalaya, Mizoram, Nagaland, Tripura and Sikkim	6.686	90-95 days in hills, 85-90 days in plains	An early duration, high yielding single cross hybrid, which is moderately resistant to *Turcicum* leaf blight, *Maydis* leaf blight and common rust, and resistant to brown stripe downy mildew and post flowering stalk rot.
Vivek Maize Hybrid 51	Rajasthan, Gujarat, Chhattisgarh and Madhya Pradesh	5.084	85-90 days in hills, 80-85 days in plains	An extra early duration, high yielding single cross maize hybrid, moderately resistant to post flowering stalk rot, Rajasthan downy mildew and *Chilo partellus*.
Vivek Maize Hybrid 53	Jammu and Kashmir, Himachal Pradesh, Uttarakhand, Uttar Pradesh, Asom, Arunachal Pradesh, Manipur, Meghalaya, Mizoram, Nagaland, Tripura and Sikkim	6.638	85-90 days in hills, 80-85 days in plains	An extra early duration, high yielding single cross hybrid, moderately resistant to *Turcicum* leaf blight, *Maydis* leaf blight and common rust, brown stripe downy mildew and post flowering stalk rot.
VL *Dhan 157*	Lower hills of Meghalaya and medium elevated hills of Uttarakhand under direct seeded, rainfed upland June sown condition	2.336 and 1.822 in lower and medium hills, respectively	100-110 days	This variety is developed from cross VR 9588/A-57. It has light yellow, short bold grain, plant height of 95-105 cm; and is resistant to leaf and neck blast.
VL *Dhan* 68	Irrigated transplanted conditions in medium hills of Uttarakhand and Meghalaya	4.947	125-130 days	VL *Dhan* 68 is derived from the cross VL 3861/ SR 1818BF-4B-1-2-1-2. It has long bold grain, 110-120 cm plant height; and is resistant to leaf and neck blast.
VL *Mandua* 352	All finger millet growing states except Tamil Nadu and Maharashtra	2.541	<100 days	It is an early duration, high yielding variety, which is moderately resistant to finger and neck blast and is suitable for those areas where monsoon gets delayed or intermittent drought occurs, hills or areas where crop growth period is limited.

Vivek Maize Hybrid 47 | *Vivek* Maize Hybrid 51 | *Vivek* Maize Hybrid 53 | VL *Dhan 157* | VL*Dhan* 68 | VL *Mandua 352*

sweet or soft candy. All the products can be served instantly, kept in a refrigerator or packed in food grade polyethylene pouch.

Nutrient and antioxidant diversity among the land races of common bean: Pole-type common bean (*Phaseolus vulgaris*) landraces (23), which were consumed locally as seeds and pods, were collected from different districts of Lushai hills in Mizoram. Seeds were multiplied and evaluated for nutrient and antioxidant diversity. A significant diversity was found for seed, N, P, K, Cu, Zn, Mn, Fe, ash content, total phenol, diphenyl-2-picrylhydrazyl (DPPH) and azinobisethylbenzo-thiazoline-6-sulphonic acid (ABTS) radical scavenging activity. Principle component analysis (PCA) resulted in patterns of variation by taking all the nutrient variables together. The first four PCs accounted for 74% of the total variation. PC1 (26%) and PC2 (21%) showed the highest variability among all the PCs. Landraces

MZFB-47, MZFB-41, MZFB-83, MZFB-116, MZFB-52, MZFB-28, MZFB-116 and MZFB-85 were the most promising ones with highest N, P, K, Cu, Zn, Mn, Fe and ash content while, total phenol, DPPH and ABTS radical scavenging activity were found maximum in MZFB-97.

Year round vegetable cultivation: The production technology of 14 high value vegetables, viz. broccoli, cauliflower, cabbage, coriander, lettuce, fenugreek, spinach, raya sag, pakchoi, garlic, pea, beet root, carrot, and radish were standardized under low cost plastic tunnels. All the 14 vegetables grew successfully year round in various cropping sequences and has shown significant increase in earliness with higher production and productivity. This combination of earliness and higher yield can significantly increase profit for the growers. The tunnels also protect plants from unfavorable abiotic and biotic stresses like high rainfall, hail, low temperature, frost, wind, insect-pests, etc. Plastic low tunnels are less expensive as compared to the plastic greenhouses, however, bed preparation, planting and harvesting need more effort under the tunnels.

Production of year round vegetable under low cost plastic tunnels

Rice–fish–pig–tuber crop based farming system: The ICAR Research Complex for NEH Region, Tripura Centre demonstrated rice-fish-pig-tuber crop based IFS on eight house hold. The whole system having an area of 0.736 ha requires a total cost of production of ₹ 45,000 during a year and provides the net income of ₹ 124,800 under rainfed situation. Therefore, this was the most suitable farming system model for marginal farmers of Tripura under rainfed ecology.

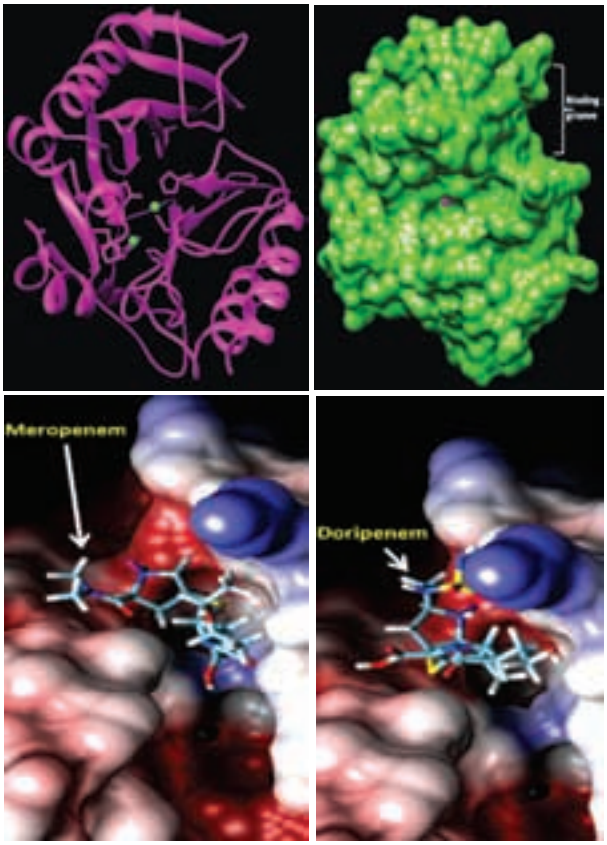
Fish seed production and distribution: During the period, 5 lakh fingerlings were produced of which 295,000 fingerlings were distributed to 285 tribal farmers of West Tripura and Khowai district under farmers income improvement programme organized by ICAR, Tripura Centre. The farmers were demonstrated with the practices of scientific fish culture such as regular feeding, fertilization, manuring, plankton checking, water and soil quality monitoring, harvesting, etc.

Establishment of hygienic meat processing unit and preparation of added products: The small scale modern hygienic meat processing unit includes raw meat area, processing area, cold storage facilities, laboratory and equipment like portioning machine, meat slicer, meat mincer, planetary mixer, sausage filling machine, deep-fridge, ice flaking machine and vacuum packaging machine. The consumer preference was highest for plastic tray packing, followed by vacuum packing. The shelf-life was better in vacuum packing as compared to others.

Various packagings for meat and value added meat products

Different value added products like pork sausage, pork nugget, pork breakfast nugget, pork pickle and chicken products like sausage and nugget blending with traditional herbs and bamboo shoots were prepared and attracted revenue to the institute. These products were exhibited in different agri-fairs for popularization.

Molecular modeling of New Delhi metallo-β lactamase-5 of bovine origin: Present study was undertaken to investigate the structural basis for increased resistance of NDM-5 with a molecular



In silico modeling and docking characteristics of NDM-5. (a) NDM-5 monomer (majenta) attached with Zinc ions (green); (b) NDM-5 surface properties; (c) Meropenem and (d) Doripenem docked to NDM-5.

modelling and docking approach. Full length of the bla_{NDM} gene was sequenced (Acc No. KC769583.2) and 3D model was computed. Results indicated 2 substitutions (Val88Leu and Met154Leu) compared to NDM-1. Modelling experiment generated a reliable model with zinc ions coordinated in trigonal bipyramid geometry. Carbapenem drugs (doripenem and meropenem) interacted within the largest cleft. Results provided possible explanation for wide range of antibiotics catalyzed by NDM-5 and likely interaction modes for 2 carbapenem drugs.

ISLAND AND COASTAL REGION

Germplasm and Crop Improvement

Twelve varieties of crops, viz. two each in rice (CIARI Dhan 8 and 9) and amaranthus (CIARI Lal Marsha and CIARI Shan), one poi (CIARI Poi Red), three mung (CIARI Mung 1,2 and 3) and four in noni (CIARI Sanjivini, CIARI Rakshak, CIARI Sampada and CIARI Samridhi) were developed and released by the Variety Release Committee of the Institute for the benefit of the farmers.

Germplasm (57), viz. French marigold (2) , African marigold (7), *Jasminum sambac* (*1*), Tania (1), sweet potato (1), alacasia (1), *Casuarina equisetifolia* seeds (11), *Calophyllum inophyllum* (1), *Calaphyllum soulattri* (1), *Aphanomixis polystachya* (1), papaya (4), banana (2), coconut (13), *Cinnamomum* (3), *Calophyllum inophyllum* (12) and one each of Korangi, Crossandra, *Casuarina equisetifolia*, *Bixa orellana*, *Sesbania grandiflora* and *Lucaena leucocephala* were collected from different parts of Andaman and Nicobar Islands.

Tomato variety Ayush gave 18 tonnes/ha followed by Arka Vikash (12 tonnes/ha), Arka Rakshak (11 tonnes/ha) and Arka Samrat (10 tonnes/ha); chilli variety 2011/CHIVAR-8 gave 8.1 tonnes/ha followed by 2012/CHIVAR-5 (7.6 tonnes/ha) and 2013/CHIVAR-4 (7.4 tonnes/ha). Brinjal variety Arka Nidhi gave 19.2 tonnes/ha followed by 2013/BRLVAR-5 (16.5 tonnes/ha) and 2013 BRLVAR-4 (15.0 tonnes/ha) and ridge gourd variety Arka Sujat gave 95.0 q/ha and Rama (90.0 q/ha) and 2012/RGVAR-3 (85.4 q/ha), respectively. All these varieties were quite promising.

Sweet potato leaf beetle pest was observed for the first time and the incidence and damage is very severe. Two species of Hadda beetles, severely damaged cucurbits and brinjal. Chrysomelid pest of cole crops, *Phyllotreta* spp. was observed for the first time. One unidentified Cerambycid pest of fruit trees was also collected. Besides, one new species of rat, *Rattus norvegicus* was observed as a pest of paddy.

Kalmegh supplementation in feed @ 3 g/bird/day reduced the serum cholesterol by 15%.

Inter-se mating and selfing was done in coconut at World Coconut Germplasm Collection, Sippighat farm and 1,811 female flowers were pollinated.

Successful captive breeding of sebae anemone fish, *Amphiprion sebae*, skunk anemone fish, *Amphiprion akallopisos*, red saddle anemone fish, *Amphiprion ephippium* was achieved for the first time in Andaman and Nicobar Islands.

Altogether, 72 species of true mangroves and mangrove associates distributed among 37 families and 68 genera were reported from the identified contiguous patches.

Nicobari pigs were successfully reared and bred under intensive system. Six piglets successfully weaned after two months without any piglet mortality.

Pemphis acidula (Lythraceae) was rediscovered after a lapse of 91 years from Andaman and Nicobar Islands. Further, *Rhizophora* (Rhizophoraceae) hybrids were reported for the first time from Hut Bay (Little Andaman).

First record of shovel nosed lobster, *Thenus unimaculatus* from Andaman and Nicobar Islands: Of the 30 species of lobsters belonging to 5 families occurring in India, 11 species belonging to three families (Palinuridae, Scyllaridae and Nephropidae) were reported from Andaman and Nicobar Islands. Shovel nosed lobsters are one of the components in multiday demersal trawlers operating in Andaman and Nicobar Islands. The only species of shovel nosed lobster belonging to family Scyllaridae reported from the islands till date is *Thenus orientalis* (Shanmughan and Kathirvel 1983). Fisheries Division of ICAR-CIARI submitted 5 nucleotide sequences of *Thenus unimaculatus* from Andaman and Nicobar Islands in NCBI GenBank, USA and accession numbers (KT362350, KT362351, KT362352, KT362353, KT362354) were provided by NCBI GenBank, USA.

Thenus unimaculatus with typical purple spots on pereiopods and carapace

Rice land race Aath Number Dhan released: Less management requirement, resilience to biotic and abiotic stresses, good source of fodder due to high plant stature and late maturity synchronizing with onset of dry season to facilitate hassle free harvesting enables C14-8 (*Aath Number Dhan*) to be quite popular in Andaman and Nicobar Islands. About 40% of the total rice area in these islands is occupied by this popular variety but it is marred

by less grain yield (2.7 tonnes/ha) and intra-varietal admixture. A pure line selection program was started leading to the purification and development of high yielding strains CIARI Dhan 8 (IET 25010) and CIARI Dhan 9 (IET 25019). Both of these varieties give about 20-25% higher yield compared to the parental population.

High yielding strains of indigenous mungbean land races: Collection, characterization, purification and evaluation of local germplasm resulted in the identification of pure and stabilized varieties of mungbean, which have also out-yielded National check varieties. Three varieties CIARI Mung 1, CIARI Mung 2 and CIARI Mung 3 were released by Institute Variety Release Committee, ICAR-CIARI.

CIARI Mung 1 (*top*), CIARI Mung 3 (*bottom*)

Captive breeding of skunk clownfish: Marine ornamental fish *Amphiprion akallopisos* (skunk clownfish) was successfully bred in the Islands. Mature brooders were collected by scuba diving from North Bay, Port Blair along with their associated anemone *Heteractis magnifica*. They were introduced into the broodstock maintenance facility after proper quarantine and were fed with squid meat and shrimp meat at morning and evening hours. The fecundity was around 550-600 number of eggs and larval survival was 40%. Attempts are being further undertaken to breed these marine ornamental fishes in low salinity waters, so as to utilize the *Tsunami* affected areas of Andaman and Nicobar Islands for developing marine ornamental fish hatchery and to transfer the technology to unemployed youth. ICAR-CIARI is also planning to ranch the seeds of *Amphiprion akallopisos* in the wild for augmenting the population of this marine ornamental fish.

One month old juveniles of *A. akallopisos*

Hepatoprotective and hypocholesteric effect of Kalmegh in Nicobari fowl: Enrichment of poultry egg with *Andrographis panniculata* (kalmegh) was studied for enhancing the immunity and lowering the cholesterol content in the Nicobari fowl. Breeding Nicobari fowls fed dried Kalmegh powder had significantly lower cholesterol. The SGOT significantly lowered in birds fed with kalmegh powder in water as well as through feed. The serum bilirubin level was significantly reduced on fifth and seventh day of supplementation in both water and feed as compared to control group. The level of iron, copper and zinc was significantly higher with supplementation of *Andrographis panniculata* extract as compared to control. *Andrographis panniculata* showed hepatoprotective and hypocholesterlemic effect in Nicobari fowl. The circulation of andrographolide in the serum after feeding of *A. panniculata* in Nicobari fowl clearly indicated that it is getting deposited in the developing yolk.

Immunomodulatory effect of noni and kalmegh on Nicobari fowl: Supplementation of 10 ml Noni + 200 mg Kalmegh significantly increased TLR 4 gene expression. The increased TLR 3, TLR 4 and TLR 5 gene expression and decreased TLR 7 gene expression in gut associated caecal tonsil in chickens fed dietary noni and kalmegh indicated that combination of herbal extracts have better immunomodulatory properties.

In conclusion, the selectively increased level of TLR 3, TLR 4 and TLR 5 and decreased TLR 7 gene expression indicated that supplementing noni and kalmegh induces antiviral and antibacterial responses in chicken.

Rural poultry farming for empowerment of women

Smt. Bichithra Biswas, a resident of Ferrargunj, South Andaman, is a landless housewife. She was one of the adopted farm women by ICAR-CIARI to empower them on improved rural poultry farming with Nicobari fowl. She did training on improved poultry technologies. ICAR-CIARI supported her to establish rural poultry farming by constructing elevated poultry shelter with 25 Nicobari fowls (20 female and 5 male). She started preparing her own poultry feed ration using locally available rice, wheat, dry fish and coconut as per the specification given by scientists of ICAR-CIARI. She devised the feeder using wooden material, bamboo and used plastic cans, bottles and waste plates for making

Success stories

Organic nutritious kitchen gardening at Car Nicobar

Per day consumption of vegetables in Car Nicobar is far short of the requirement and availability depends on other islands as the people of Car Nicobar purchase vegetables, which grow in Andaman by using imbalance chemical fertilizers and heavy pesticides. During shipment, vegetables loose nutritional quality and palatability due to lack of refrigerated transportation facilities.

KVK-CIARI, Nicobar, since 2011, has conducted 13 trainings in the field of scientific vegetables and fruits cultivation for establishment of organic nutritious kitchen gardens for nutritional food security. A total 325 farmers and rural youths including 224 males and 101 females got benefitted. In the year 2012, KVK, Nicobar adopted traditional farmer Shri. Petrik of Car Nicobar to establish organic nutritious kitchen garden. The entire programme gave emphasis on practical skill and knowledge development to start scientific vegetable cultivation with full confidence.

waterer. She vaccinated birds herself after learning the technique of vaccination in poultry. By adopting the scientific management of rural poultry instead of backyard farming, she could be able to get 910 eggs in 9 months duration from 15 numbers of hens only. She was empowered to meet out the ICMR recommendations of egg consumption of 180 eggs/year/person for her whole family. In addition, she was able to earn ₹ 3,700 by selling eggs. She is presently running the rural poultry farm successfully being motivating and inspiring factor to other women folks for being empowered to strengthen the nutritional requirement of the family through improved rural poultry farming practices with Nicobari fowl. More and more farmers are coming to CIARI to adopt the same.

Horizontal spread of HYVs of rice at North Andaman

A total of seven (7) promising rice varieties identified by CIARI in 2010, were introduced through front line demonstration by Out Reach Centre of CIARI supported by NABARD, in participatory mode to a total of 313 farmers covering 70.18 ha till 2014 (Five years).

To assess the adoption of rice varieties, PRA was conducted in December, 2014 at Diglipur, North and Middle Andaman, and it was found that a total of 2,620 farmers have adopted the HYV's varieties of rice in the total area of 1,219.64 ha spread over 32 cluster of villages at North Andaman compared to 313 farmers covering 70.18 ha. Among the total area adopted, rice variety Gayatri shared 713.53 ha of area followed by CARI Dhan 5 (146.17 ha), CSR 36(132.14 ha), CARI Dhan 4 (90.71 ha), CARI Dhan 3(60.63 ha) and Ranjit (20.68 ha), respectively. This indicates good adoption rate and horizontal spread of the varieties, which was only possible due to FLD, availability of improved varieties and quality seeds produced through seed village concept, which led to replacement of farmer varieties over the period. There is good potential for increasing the production and the productivity by adopting CIARI recommended rice varieties by the farmers in the coming years.

Pekin duck under backyard in North Andaman

Pekin duck a demand driven technology for small farmers introduced in July 2010 by ORC of CIARI to a single farmer, could spread to 63 farmers with 3-5 ducklings in the backyard totalling to 388 numbers, spread over 15 villages by 2014 . The farmer, could earn ₹ 16/egg by selling eggs, ₹ 400-450 from adults and ₹ 50-55 for ducklings, compared to desi adult duck which were sold for ₹ 200, ducklings at ₹ 10 and eggs @ ₹ 5 to 7/egg, respectively. The duck would grow to average weight of 2.637 kg with low level of mortality, compared to desi, i.e. 1.975 kg of weight with high mortality rate. Pekin duck under backyard with a unit size of 3 birds could give a net return of ₹ 4,350 against the desi birds (₹ 1,140) thus giving an additional income of ₹ 3,210. Pekin duck eggs (2013 to 14) were provided to fifteen cluster of villages by a single farmer Shri E D Menon of Keralapuram, Diglipur, North and Middle Andaman, and earn ₹ 13,215 as an additional income, which is a remarkable beginning of a credible technology of the Institute.

Pekin duck white

Shri. E.D. Menon the change agent

Production of seeds and planting material

Production of quality planting materials of coconut and arecanut (3,102), black pepper rooted cuttings (6,100), elephant foot yam (1.5 tonnes), 4.6 tonnes of truthfully labelled seeds of rice and ginger (250 kg) was achieved. Besides 29,900 fish fry of Indian major carps were produced and distributed to fish farmers of Port Blair and Hut bay. During this season 1.9 lakh spawn of Indian major carps (IMC) of rohu (*Labeo rohita*) and 1.1

lakh spawn of catla (*Catla catla*) were produced and stocked in nursery tanks for successive rearing.

Tribal Sub-Plan (TSP) Programme

Establishment of vaccine bank under TSP: In Nagaland, a vaccine bank for maintaining cold chain and supply of different vaccines for livestock and poultry, free of cost to the beneficiaries directly or through the KVKs and State Department was set up under Tribal Sub-Plan. During the reporting year 4,000 doses of swine fever, 20,000 doses of FDRD (F strain), 6,600 doses of FDRD (R_2B strain), 200 doses of goat pox vaccines were distributed to the KVKs, farmers, NGOs of Dimapur, Kohima, Wokha, Phek, Peren, Mokokchung, Zunheboto and Longleng districts of Nagaland.

Water transfer through gravity fed HDPE pipe line: In participatory mode under Tribal Sub-Plan (TSP) project of ICAR, water resource is developed through water transfer in Hattal and Sainj villages (*jaunsar* tribal region) in Dehradun, Uttarakhand where water is being transferred from surplus watershed to deficit watershed in a cost effective manner and on a sustained basis. It was done by laying gravity fed HDPE pipe lines of 6.0 km in Hattal and 5.6 km in Sainj through difficult hilly terrain to harvest and transport water from perennial springs. In both villages, farmers are organized in terms of User Groups (9 in Hattal and 6 in Sainj) and Fruit and Vegetable Grower Association.

Agri-horticulture system (12 ha) was introduced as low water requiring alternative land use system in Hattal village. Developed water resources are being properly managed by village level institution, i.e. Farmers' Associations created in these villages with effective local leadership. Presently, 670 m^3 water is available to the farmers in 24 hr in these two villages. As a result, farmers in Hattal and Sainj are now cultivating off-season vegetables in about 30 ha area.

Rainwater harvesting tanks of 21,000 liters capacity at Bernia watershed (Dungarpur)

Training programme for farmers of Lahual Spiti, Himachal Pradesh: A farmers' training programme under TSP was organized. The training emphasized on role of agroforestry in providing livelihood support and income generation in the cold desert area of Himachal Pradesh and utilization of different species of the trees and resistant clones of willow to solve the problem of willow mortality in the area.

Integrated watershed development with the help of tribal community: In Bernia watershed, Rajasthan, 100 farmers were selected for demonstration of improved *kharif* crop production practices under TSP project. Seeds (paddy-Pusa Sugandha and urd-IPU 94-1 in *kharif* and wheat-Raj 4037 and gram-RSG-888 for *rabi*), horticultural plants of mango (Mallika), DAP, urea and NPS were the inputs distributed to farmers. For capacity building of the farmers, a 3-day training course was organized. For solving the problem of drinking water in the project area, three rainwater harvesting tanks of 21,000 litres capacity were constructed at selected locations. Soil samples were collected from different locations to prepare soil health cards.

Effect of elevated temperature on soil carbon sequestration, microbial biomass and enzymatic activities: Soils from variable land use under 3 soil orders (Entisols, Inceptisols and Alfisols) were collected and samples were incubated in BOD incubator at different temperatures for one month. As compared to the samples incubated at ambient temperature, the 39ºC treated samples showed higher labile carbon, at 42ºC the same decreased again. Total organic carbon content decreased during that time and the lowest was recorded at 42ºC. This suggested that the decomposition of resistant soil organic matter is more temperature sensitive than labile organic matter. The exposure of soil samples at 42ºC showed both decrease in TOC and LC, which may be due to release of C as CO_2 at that temperature. Dehydrogenase activity increased with increasing temperature up to 39ºC. It slightly decreased at 42ºC, but the effect was at par with 39ºC. Phospho-mono esterase (acid) activity is reduced at increased temperature.

❑

Increasing apple production with pollinators in tribal district of Kinnaur

Poor fruit set on account of scant pollinating agents is a major constraint in successful production of world famous apple in Kinnaur district of Himachal Pradesh. Farmers from Village Telangi were trained under Tribal Sub Plan Programme on beekeeping. Subsequently the 40 ha area of the village was mapped by GPS to facilitate placement of honeybee boxes evenly to achieve optimum pollination activity. To augment pollination efficiency 60 beehive boxes of *Aphis mellifera*, pollination activity was monitored. Colonies were monitored and maintained ensuring proper hygiene and nutrition. The intervention resulted in enhancement of apple yield (20%) during the season. Additionally 2.1 q of pure white organic honey was extracted from the bee hives with a net return of ₹55,000.

Organised pollination in apple improved productivity as well as farmer's income due to honey production

16. Organization and Management

DARE

The Department of Agricultural Research and Education (DARE) is one of the three Departments under the Ministry of Agriculture and Farmers Welfare; the other two Departments being Department of Agriculture, Cooperation and Farmers Welfare and Department of Animal Husbandry, Dairying and Fisheries. The Department of Agricultural Research and Education (DARE) was established in December 1973. Under the Ministry of Agriculture and Farmers Welfare, this department is mandated to undertake steps towards fundamental, applied and operational research and higher education, including co-ordination and determination of standards in institutions for higher education, research and scientific/technical institutions relating to food and agriculture. The Department is also mandated to co-ordinate international co-operation in agricultural research and education, including relations with foreign and international agricultural research and educational institutions and organizations.

DARE has its administrative control over the Indian Council of Agricultural Research (ICAR), an autonomous organization, Central Agricultural University (CAU) Imphal, Rani Lakshmi Bai Central Agricultural University, Jhansi- statutory organizations and Agrinnovate India Limited, a Public Sector Undertaking. DARE was among the first few Government Departments which has been conferred the ISO 9001:2008 certification on 4 July 2013.

DARE liaises with foreign countries governments, the Consultative Group on International Agricultural Research (CGIAR) and other international agencies for cooperation in agricultural research and education. DARE also coordinates the admission of foreign students in various Indian Agricultural Universities. The Union Minister of Agriculture and Farmers Welfare assisted by the Union Minister of State for Agriculture and Farmers Welfare, is overall in-charge of the Department. Secretary, DARE & Director General, ICAR, the administrative head of the Department, is assisted by Additional Secretary, DARE & Secretary, ICAR, Additional Secretary & Financial Advisor, one Director, one Deputy Secretary, seven Under Secretaries and other staff members (Appendix II).

DARE coordinates and promotes agricultural research and education in the country and also provides the necessary governmental linkages for the ICAR, Central Agricultural University (CAU) Imphal, Rani Lakshmi Bai Central Agricultural University, Jhansi, and Agrinnovate India Ltd., New Delhi.

The Department has three Divisions viz, International Cooperation Division (IC Division), Establishment Division and Finance & Budget Division. The IC Division manages matters relating to bilateral/multilateral cooperation, cooperation with other foreign institutions/ organizations, exchange of genetic resources and other international activities as per its mandate. The Establishment Division takes care of service matters of the personnel of the Department, General Administration, RTI Matters, Redressal of Grievances etc. The Finance and Budget Division allocates budget, controls expenditure and gives financial concurrences to various proposals handled by the Department.

ICAR

The Indian Council of Agricultural Research is an autonomous organization under the Department of Agricultural Research and Education, Ministry of Agriculture and Farmers Welfare, Government of India. Formerly known as Imperial Council of Agricultural Research, it was established on 16 July 1929 as a Registered Society under the Societies Registration Act 1860, on the recommendations of the Royal Commission of Agriculture, has been reorganized twice, in 1965 and 1973. The ICAR (headquarters) is located at Krishi Bhawan, New Delhi, and its other buildings are Krishi Anusandhan Bhavan I and II, and NASC, New Delhi.

The Union Minister of Agriculture is the President of the ICAR. The Principal Executive Officer of the ICAR is the Director General, who also acts as Secretary to the Government of India in the Department of Agricultural Research and Education. The General Body of the ICAR Society is the supreme authority of the ICAR, and the Union Minister of Agriculture and Farmers Welfare, heads it. Its members are the Ministers for Agriculture, Animal Husbandry and Fisheries, and the senior officers of the various state governments, representatives of Parliament, industry, institutes, scientifics organizations and farmers (Appendix 1).

The Governing Body (Appendix 2) is the chief executive and decision-making authority of the ICAR. It is headed by the Director General, ICAR who also acts as Secretary, DARE. It consists of eminent agricultural scientists, educationists, legislators and representatives of the farmers. It is assisted by the Accreditation Board, Regional Committee, Policy and Planning Committee, several Scientific Panels, and Publications Committee. In the scientific matter, the Director General is assisted by eight Deputy Directors General, one each for, (i) Crop Science, (ii) Horticultural Science, (iii) Natural Resource Management, (iv) Animal Science, (v) Agricultural Engineering, (vi) Fisheries Science, (vii) Agricultural Education, and (viii) Agricultural Extension.

The eight Deputy Directors General are responsible for the Institutes, National Research Centers, and the fundings of Project Directorate in their respective fields.

Besides, one ADG (NASF) looks after the Secretariat of National Agricultural Science Fund (NASF) and also assists Director General, ICAR.

The ICAR recruits scientists and to such other posts and services as may be specified by the President, ICAR from time to time through competitive examination/direct recruitment by selection etc. through its independent recruitment body, Agricultural Scientists' Recruitment Board (established on 1 November 1973). The ASRB is accountable to proceeds of the ICAR Society. The ICAR receives funds from the Government of India and from the proceeds of the Agricultural Produces. The Senior Officers at the ICAR (headquarters) are listed in Appendix 3.

The Research set up of the ICAR includes 68 Institutes (Appendix 4), **6** National Bureaux (Appendix 5), **23** Project Directorates and Agricultural Technology Application Research Institutes (Appendix 6), **15** National Research Centers (Appendix 7) and **130** All-India Coordinated Research Projects (56), Network Research Projects (25) and Others (19), (Appendix 8).

The Directorate of Knowledge Management in Agriculture (DKMA) works as communication arm of the ICAR responsible for delivery of information/ knowledge generated by the network of the ICAR and its institutions. The DKMA addressed its mandate through Publications and Information, AKMU and Publication Relations Units and also CeRA.

The ICAR promotes research, education and extension education in **73** Agricultural Universities such as **62** State Agricultural Universities, **5** Deemed Universities, **2** Central Agricultural Universities, and **4** Central Universities with agricultural faculty by giving financial assistance in different forms (Appendix 9).

ADMINISTRATION

Filling up of vacant posts

During 2015-16, the following posts were filled up under the promotion quota: two Directors, one Deputy Director (OL), two Under Secretaries, four Section Officers, five Assistants, three UDCs, Fourteen Senior Administrative Officers, twenty Administrative Officers, three Senior Finance and Accounts Officers, six Finance and Accounts, Officers, four Principal Private Secretaries, and three Private Secretaries.

Financial upgradation granted under MACP Scheme

During 2015-16, eligible officers and staff of ICAR (Headquarters) and Institutes were granted the benefits of financial upgradation under the Modified Assured Career Progression Scheme in accordance with the Government of India (Department of Personnel and Trainings) instruction in this regard.

e-governance in ICAR

The following activities have been undertaken under the e-governance for better transparency and efficiency.

- The file tracking system (FTS) has been implemented in the ICAR (Hqrs.) for 800 users. All the important notices, circulars and orders have been regularly uploaded on the e-office portal of ICAR/DARE.
- Financial management system was used for processing of all the financial activities like general ledger, account payable, account receivable, cash management, fixed assets management, budget management and grants.
- Maximum procurement activity of the Council is being conducted through the online e-procurement system (introduced by GoI): this has helped in ensuring better competition and fairness.
- The Council is also on the RTI portal of the Government of India for online receipt, disposal and monitoring of the RTI applications.
- Besides Court Case Monitoring system, Vigilance Online Integrated Complaint and Enquiry and Guest House Management System are being used to maintain updated information.

Facebook page of ICAR: The ICAR has its facebook page (www.facebook.com/InAgrisearch) to connect with the people across the world, in general and youth, in particular. This facebook page provides relevant information in a crisp and interesting manner. The ICAR conducts interesting contests on its facebook page to generate the interest of the users in the activities of the Council. It has become quite popular with more than 3,08,443 visitors from 219 countries.

INTELLECTUAL PROPERTY AND TECHNOLOGY MANAGEMENT

Patents

During the period under report 49 new patent applications were filed by 25 ICAR institutes pertaining to varied sectors of agriculture as given in Table 1. Thus the cumulative figure has now risen to 980 applications from 69 ICAR institutes. Indian Patent Office published ICAR's 74 patent applications in this period, which filed in 2010 (1), 2012 (16), 2013 (47), and 2014 (10).

Further, the Indian Patent Office granted the three patents (Table 2), taking ICAR's cumulative number of granted patents to 170 from 25 institutes.

Copyrights: Thirteen copyright applications were filed by six ICAR institutes for their research outcomes including, Browse data application for relational databases; Computer software- Gypcal; Document management system; Interactive software; Online software for design of straight drop spillway-version 1.0; Pilot study on cost of production of coconut in Kerala; Pilot study to develop an alternative methodology for estimation of area and production of horticultural crops; Plant Genetic Resource (PGR); Rice resource Interactive software; Search data application for relational databases; Soil Test Based Fertilizer Recommendation Goa (STFR-GOA); Web based interactive thematic MapGen tool; and Web generation of experimental designs balanced for indirect effects of treatments. A total of 94 filed copyrights have been thus recorded from 23 ICAR institutes.

***Trademarks*:** Thirteen trademark applications were

Table 1. Important patent applications filed by ICAR Institutes in different sectors

Subject Area	Name of Innovation/Technology
Natural Resource Management	Back pressure measuring equipment; Extender for preservation of boar semen; Device and method for measurement of soil health parameters and fertilizer recommendation; Development of a microbially derived polymeric product for gel formation and microbial colonization and metals binding.
Crop Science	Process for preparing sorghum flakes from sorghum grains; Device for preparing unleavened sorghum pancakes; Process for obtaining high purity *Phycocyanin* from *Cyanobacteria*; Polynucleotide fragment for generating blast tolerant plants; Methods and uses of pathogen inducible promoter from rice; Thermo stable and pH stable laccases; Formulation of fungal entomopathogen *Metarhizum anisopliae* Tf19, *Beauveria bassiana* Tf6, *Bacillus thuringiensis* Tb160, *Bacillus thuringiensis* Tb263, and *Bacillus thuringiensis* tb261 to control rice leaf folder; Microbial consortium of nitrogen, phosphorus and potassium (NPK); Method for continuous rearing of an anthocorid predator *Blaptostethus pallescens*; Promoter from *Gossypium hirsutum* L. for enhanced expression of foreign genes in late boll developmental stages of cotton; Host-delivered siRNA-mediated, and artificial microRNA-mediated resistance against *Helicoverpa armigera*; Dynamic volatile collection system; and CICR Whitefly Adult suction trap.
Horticultural Science	Dehydration of tubers; Process for the production of low moist gelatinized dough for using in cassava papad making machine; and Bioactive multi-nutrient rock mineral fertilizer.
Agricultural Engineering	System for testing dynamically bending behaviour of semi-rigid fabrics; System for measuring electrical behaviour of textile material; Method for processing of jute fibre; Process technology for gluten free egg less cake; and Electro-spinning apparatus with friction spinning collector for production of core-sheath nano-yarns.
Animal Science	AJAS-Goat milk based natural, antiseptic and herbal beauty soaps; Kalrump Scale- A device to measure buffalo rump angularity for identification of dairy characters; Aptamers specific for cefquinome; Novel peptide sequence and polyclonal antibodies for the detection of cow and buffalo luteinizing hormone; Mold free fodder sprouts and method of producing; Monoclonal antibody based double antibody sandwich; ELISA for the detection of *Trypanosoma evansi*; Recombinant VSG and monoclonal antibody based competitive inhibition enzyme linked immunosorbent assay for detection of antibodies against *Trypansoma evans*i.
Fisheries	Portable easy to mount, flexible and graduated split beam transducer; and Process to prepare anti-diabetic concentrates from seaweeds.

Table 2. Patent numbers of Technology/Innovation by the corresponding institutes

Technology/ Innovation(Patent No.)	Institute (*Inventors*)
Development and use of rubber disc with soft rubber layers as material for self -grooving roller in roller ginning machines **(IN266213)**	CIRCOT, Mumbai and Millennium Rubber Technologies Pvt. Ltd. (*Tachaparambil Sankara Pillai; Manojkumar Lawrence Johnselva Kumar; Arude Vishnu Govind; Krishnavilas Krishnan Anand; Noby Joseph; Joji Joseph Thelly*)
Zinc chloride pre-treatment of microcrystalline cellulose for preparation of nano-cellulose by homogenization process **(IN266707)**	CIRCOT, Mumbai(*Ashok Kumar Bharimalla; Vigneshwaran Nadanathangam; Vilas Shamrao Karande*)
Method for maximum per cent recovery and detection of organochlorine and organophosphorus pesticides together from brackish water/coastal water **(IN266905)**	CIFA, Bhubaneshwar (*Kishore Kumar Krishnani; Baijnath Prasad Gupta*)

filed by four ICAR institutes for products and processes including *CIBASTIM, Eatrite bajra Eatrite barnyard, Eatrite foxtail, Eatrite jowar, Eatrite kodo, Eatrite little, Eatrite proso, Eatrite ragi, GREEN SHRIMP FEED – BT* (*GSF-BT*), *ICAR-CIBA Logo, Mridaparikshak, Swarna* (*With Logo*). Till date, a total of 70 trademark applications have been filed by 26 ICAR institutes; out of which 21 applications have been granted registration.

Plant Varieties: As the Protection of Plant Varieties and Farmers' Rights Authority notified new genera, applications for 13 varieties (9 extant and 4 new varieties) were filed at the Registry. For applications filed earlier, 167 varieties (149 extant and 18 new) were granted registration certificates during this period; raising the cumulative figure of registered varieties to 700. The cumulative total for plant variety protection applications

rose to 1,051 (912 extant; 112 new and 27 farmers' varieties).

Capacity building and outreach activities

In an endeavor to create awareness and develop expertise in the domain area of intellectual property rights and technology management, organization of various capacity building programmes at institute/zonal/national levels was emphasized. Accordingly, 20 ICAR institutes organized 76 Awareness Generation Programmes/ Interface/Product-specific Meets/Workshops/Seminars, wherein 5,834 scientists/researchers/business professionals/farmers/social workers benefited. These *inter-alia* included: Training programmes on Intellectual Property Management; IPR in Agriculture; Ice Cream, Milk and Milk Products Processing; Quality evaluation of cotton and roller ginning; Quality evaluation of cotton; Protection of plant varieties; Absorbent cotton technology; Advances in applications of nano-technology. In addition, Entrepreneurship Development Programme (EDP) were organized on Commercial dairy farming and milk and milk, products processing; Enhancing export of meat and meat products from north-eastern India; Value addition of cotton stalks; Further, Farmer-Industry-Scientist interaction meet; Horticulture-Institute Industry Interface Meet; ICAR-Industry Day; VPKAS and Industry Meet; National Meet on Modernization of Jaggery Industry in India; National Technology day; AgrIP 2014; B2B Meeting; and Workshop on Rice value chain were organized to strengthen the linkages with different stake holders and augment the outreach of Institutes and the Council.

In order to expose the scientific and technical staff to specific nuances of intellectual property and technology management issues 56 persons form 16 ICAR institutes were deputed to attend capacity building programmes organized by different national/international organizations.

Technology Transfer/Commercialization

The period also witnessed increasing engagement of the ICAR institutes with external agencies from public and private sectors, and including regional/social organizations for partnership in research and commercialization activities. The mode of partnerships largely had been through formal Memoranda of Understandings (MoUs), Licensing Agreements, Consultancies/Contract Research/Contract Service etc. Accordingly, this year, 388 such partnership agreements were firmed up with 251 public and private organizations and 32 entrepreneurs by 47 ICAR institutes in different Subject Matter Divisions. These included Agricultural Engineering (19), Animal Science (53), Crop Science (147), Fisheries (16), Horticultural Science (136) and Natural Resource Management (17). The highest number of partnerships were developed by the IARI, New Delhi (95); followed by IIHR, Bengaluru (85); NDRI, Karnal (24); and NRC Banana, Trichi (17). Out of these 388 partnerships, 106 were finalized for 43 IP protected technologies (i.e. for Design/Patents/Trademark/Copyright/Plant Variety Protection).

These agreements were signed for 113 technologies of agriculture and its allied sciences, viz. Agrilcultural Machinery (15), Animal-based Value Added Products (11), Animal Breeding (1), Animal Health (1), Animal Nutrition (3), Crop based Value Added Products (5), Crop- Variety (19), Dairy-based Value Added Products (10), Fish Production Technology (1), Fruit-based Value Added Products (9), Milk Detection Technologies (3), Plant Protection Methods and Processes (32), and Soil Health (3).

National Agriculture Innovation Fund: Based on the encouraging lessons learnt during the XI Plan Scheme, the XII Plan Scheme namely 'National Agriculture Innovation Fund' (NAIF) was proposed and approved for implementation. Thus the scope of the existing Scheme was considerably enhanced by including three specific components.

Component I: 'Innovation fund' is designed to firmly settle the best practices of IP management in the ICAR institutes by taking forward the existing institutionalized mechanisms through ten Zonal Units, that shall facilitate the IP management activities of the Institute Technology Management Units in their respective subject matter domain. In addition, this Component shall also provide institutional and financial support for value addition and up-scaling of grassroots innovation.

Component II: 'Incubation fund' is envisaged to address the critical gap observed for successful commercialization of technologies from not only ICAR institutes but also from other potential institutions doing research in agriculture and allied sectors. It addresses the much-needed requirements of business incubation for converting agriculture technologies into an attractive commercial proposition. Accordingly, 27 Agri-business Incubation (ABI) centers are being supported/established in various institutes.

Component III: 'ARYA' (Attracting and Retaining Youth in Agriculture) is to support and nurture potential youths who can develop viable business enterprises by remaining in villages. In this component, the aim is to encourage promising proven technologies from National

Success Story

Reaping the benefits of commercialization
Wheat Variety 'HD 3086'

With a mission of *"Translating Research into Prosperity"*, Zonal Technology Management Unit of IARI launched the marketing campaign of Wheat Variety HD 3086 and has successfully commercialized it to 191 seed companies in the Indo-Gangetic Plains belt comprising the states of Punjab, Haryana, Western Uttar Pradesh and Rajasthan during 2014 and 2015 within the first year of its release. The variety has semi-erect growth habit and green foliage colour; and anthocyanin pigmentation was absent on coleoptile at boot stage. HD 3086 possesses amber colour, oblong, medium size, hard grain with medium germ width. Transfer of this technology is the successful example of focused marketing strategy, effective planning and execution at filed level by ZTMU, IARI.

Agriculture Research System (NARS) as well as the potential grassroot innovations or other indigenous technologies.

As these new dimension are proposed as a top-down initiative, the overall coordination, monitoring, mentoring and facilitation of the Components I and II is being done by the IP&TM Unit at ICAR (Headquarters); while the Component III is being addressed by Agricultural Extension Division at ICAR (Headquarters) through their existing network of Agriculture Technology Application Research Institutes and Krishi Vigyan Kendras.

PROGRESSIVE USE OF HINDI

DARE

Official Language Act, 1963 stipulates provisions for the languages which may be used for the official purpose of the Union, for transaction of business in Parliament and for Central Acts etc. DARE ensures compliance of the provisions of the Official Language Act, 1963 in DARE and Autonomous Statutory Bodies and PSU coming under its purview. Efforts to make Hindi as official language in accordance with official language policy are being made on continuous and on going basis.

Targets and achievements, in brief, accomplished by Hindi Section of DARE with regard to progress of *Rajbhasha* and implementation of Official Language Policy are detailed bellow:

Policy Implementation: The Official Language Division of the Department has made continuous efforts towards implementation of the instructions issued by the Department of Official Language. In this regard, effective check points were prepared for compliance of the implementation of the Official Language Policy and circulated to all officers to ensure more and more use of Hindi while disposing of their official work. Emphasis is also given to achieve the targets of correspondence in Hindi with offices located in 'A', 'B' and 'C' Regions.

Notification of Institutions/Offices under Rule 10 (4) of the Official Rules 1976: The institutes/Offices of ICAR where 80% of staff have acquired working knowledge of Hindi, are notified under Rule 10 (4) of the Official Rules 1976. Overall 126 offices and attached stations with regional offices of ICAR have been notified till 4 October 2015.

Official Language Policy related Meetings: Quarterly Joint Meetings of Official Language Implementation Committee of DARE and ICAR were held regularly under the Chairmanship of Additional Secretary (DARE) and Secretary (ICAR) who is the nodal officer for implementation of the official language policy in DARE. Deputy Secretary/Under Secretary/Section Officer, representing various Divisions of the Ministry/ Departments, are nominated as members of these Committees, while Deputy Director (OL)/Assistant Director/Hindi Officer concerned functions as Member Secretary of the same. Four meetings were organized and follow up action were taken in compliance with the decisions taken in these meetings.

Official Language Policy related Reports: Annual Assessment Report and Quarterly Progress Reports regarding use of *Rajbhasha* in the Department are sent to the Department of Official Language regularly as per instructions on the subject.

Official Language Policy related Inspection: During reported period two Institutes of the ICAR were inspected and suggestions were given to solve practical problems being faced by the employees of these offices while working in Hindi.

Bilingual Printing of Manuals/Rules: In pursuance of Section 3 (3) of the Official Language Act 1963, all Resolutions, Notifications, Communiqués, Press release, Rules, Regulations, Administrative Reports and all Official Reports meant for laying in the Parliament are issued bilingually. Further, it was also ensured that stationary items, name plates, notice boards forms, procedural literature, rubber stamps, invitation cards etc. were prepared/issued both in English and Hindi.

Training: Apart from monitoring and implementation of the Official Language Policy and Programmes of the Government, Hindi Section arranges training of the personnel for effective use of Hindi , Hindi Typing and Hindi Stenography and translation. Officers were instructed to make use of the services of stenographers, PAs, PSs trained in Hindi Stenography for doing work in Hindi. The Stenographers not knowing Hindi Stenography are being nominated for such training.

Translation work: Hindi Section of the Department carries out translation work under Section 3 (3) of Official Language Act, 1963. Accordingly, documents like Cabinet Notes, Resolutions, Notifications, MoUs/ Agreements/CCEA Work-Plans in agriculture with other institutes were translated in Hindi within the stipulated time-frame based on their priority.

Hindi Chetana Maas: It was observed from 14 September to 13 October 2015 in the Department in association with the ICAR. On the occasion, the message of Hon'ble Union Agriculture and Farmers Welfare Minister, and Secretary, (DARE) and DG (ICAR) regarding progressive use of Hindi was circulated. Besides, various competitions were also organized at this occasion.

Use of Mechanical/Electronical equipments: All computers should be bilingual. In this regard, strict compliance of the orders issued from time to time by the Department of Official Language, is emphasized.

Incentives scheme: This scheme is operated on financial year basis and circulated every year. The Officers who participate in this scheme were asked to maintain a record of their work done in Hindi during the financial year. For considering cases of 2014-15, a circular seeking requisite material/data from all officers/ staff has been issued in September 2015.

ICAR

1. The progress of Hindi implementation was reviewed in Senior Officer's Meeting (SOC) every month by the DG, ICAR.
2. Orders were issued by the DG, ICAR to all the Officers having proficiency in Hindi to do their

maximum work in Hindi.

3. During the period under report, 7 Institutes/ Centres were notified in the Gazette under Official Language Rule 10 (4) thus raising the total number of notified institutes/offices to 128. In addition to this, five sections of ICAR (Hqrs.) have been notified under rule 8(4) to do their cent per cent administrative work in Hindi. Now total number of notified sections are 16.
4. As per the Annual Programme 4 meetings of the Joint O.L. Implementation Committee's of DARE and ICAR were held under the chairmanship of Additional Secretary (DARE) and Secretary (ICAR). During the period under report 4 Workshops were organized for various categories of staff to make them aware of the O.L. Policy of Government of India and to impart training on Unicode.
5. In most of the ICAR Institutes O.L. Implementation Committees are functioning. Proceedings of these committees are received at the ICAR (Hqrs) and appropriate suggestions and guidelines were given to the concerned institutes.
6. The quarterly progress reports were sent on-line to the Regional Implementation Office. The quarterly progress reports received from various Institutes were reviewed and suggestions given to them for effective implementation. The ICAR (Hqrs) regularly participated in TOLIC's meeting.
7. The employees are being nominated regularly for Hindi type training in every session. At ICAR (Headquarters) training in Unicode typing is also being imparted by the *Hindi Anubhag*.
8. As per orders of Department of Official Language, one day National Hindi Workshop was organized on 7 November 2015 for the Hindi Officers of ICAR Institutes in the Chairmanship of Director General, ICAR. About 90 participants from across the country participated in this workshop. This workshop gave them a platform where they discussed and interacted with each other about effective implementation in their respective institutes. The concluding session of this workshop was chaired by Additional Secretary (DARE) and Secretary (ICAR).
9. *Hindi Chetana Mass* was organized from 14 September to 13 October 2015. On this occasion an inspiring message from the Hon'ble Union Agriculture Minister was sent to all ICAR Institutes. The Director General of ICAR also appealed to make progressive use of Hindi at every level. On 19 November 2015 *Hindi Puraskar Vitran Samaroh* was organized in which prize winners of various competitions were given prizes by the Secretary (DARE) and DG (ICAR), and Additional Secretary (DARE) and Secretary (ICAR).
10. During the period under report, Cash Awards were given to 10 officials at ICAR (Headquarters) for doing their Maximum official work in Hindi under the cash award scheme of Official Language Department.
11. *Under the Rajarshri Tondon Rajbhasha Purskar Yojana*, 2013-14 following Institutes were awarded for doing their maximum work in Hindi.

1. Big Institutes	Award
1. Indian Veterinary Research Institute, Izatnagar	First
2. Indian Agricultural Research Institute, Pusa, New Delhi	Second
2. Institutes/Centre of 'A' and 'B' Region	
1. National Bureau of Soil Survey and Land First Use Planning, Nagpur	First
2. National Bureau of Plant Genetic Resources, Pusa Campus New Delhi 110012	Second
3. Institutes/Centre of 'C' Region	
1. Central Reasearch Institute for Dryland Agriculture, Santoshnagar, Hyderabad	First
2. Directorate of Oilseeds Reasearch, Rejendranagar, Hyderabad	Second

12. *Under the Ganesh Shankar Vidyarthi Hindi Patrika Purskar Yojana*, 2013-14 following magazines published from different Institutes were awarded.

Sl. No.	Name of Magazine	Name of the Institute	Award
1.	'*Pragya*'	ICAR Research Complex for Goa, Old Goa	First
2.	'*Pusa Surbhi*'	Indian Agricultural Research Institute, Pusa, New Delhi	Second
3.	'*Sukshamjeev Darshan*'	National Bureau of Agriculturally important Microorganisms, Mau	Third

13. In accordance with the instructions of Department of Official Language more than 27 Institutes were inspected during 2014-15 and suggestions were given for effective implementation of O.L.
14. *Krishika*, Hindi Research journal, is published from 2012 by ICAR (Hqrs.) and three issues have been published so far.
15. House magazine of ICAR (Hqrs.) *Rajbhasha Alok 2015* depicting the Hindi activities of different Institutes will be published shortly.
16. The Council and its institutes are organizing *Kisan Mela* and other *Gosthies* in Hindi and other Indian Languages. Training is being imparted to the farmers of different regions in their regional language and Hindi as well.
17. Cabinet Notes, Audit Accounts, Annual Plan, SDG, GB, Parliamentary Standing Committee on Agriculture, AGM of ICAR Society and Proceedings of ICAR many other meetings were prepared bilingually. The draft speeches of Union Minister

of Agriculture and Farmers Welfare and other higher officials of ICAR were prepared in Hindi.

18. His Excellency President of India, awarded scientists/officers/institute/House magazines under different award schemes of *Rajbhasha Vibhag* in Vigyan Bhawan on 14 September 2015.
    - *Rajbhasha Kirti* Official Language award 2014-15 given to CMFRI, Kochi under 'C' region bestowed third prize.
    - '*Ikshu*' Hindi magazine of IISR, Lucknow was awarded First prize in the category of magazines published in 2014-15.
    - Original writing in Hindi books for *Rajbhasha Gaurav* Official Language Award 2014 Third Prize was given to Dr Rajeshwer Prasad Uniyal, Dy. Director (OL), CIFE, Mumbai for his book, *Hindi Lok Sahitya Prabhandhan*. In addition to this Dr Kanchan Kumar Shrivastava and Dr (Prof.) Nazir Ahmed were awarded Second Prize for their book *Shitoshan Phalo ki Vaigyanic Kheti*.
    - For origional science writing in Hindi *Rajiv Gandhi Rastriya Gyan Vigyan Maulik Pustak Lekhan Puraskar 2013* was given to (*i*) *Aadhunik Phal Utpadan*, written by Dr Ram Roshan Sharma, Dr Anil Kumar Dubey and Shri Vidhyaram Sagar, IARI, Pusa, New Delhi was given First Prize, (*ii*) *Padap Karyaki Main Upyogi Vishleshnatamak Taknikiya*, written by Dr Shri Harish Chandra Joshi, Shri Maharaj Singh, Dr Jitendra Singh Chauhan, Kunwar Harendra Singh and Dr Surendra Pratap Singh of ICAR was given third Prize, (*iii*) *Samekit Krishi Pranali Ek Drishtikon*, written by Dr Rajnarayana Singh, Dr Sanjeev Kumar, Dr Sati Shankar Singh, Dr (Smt) Shivani and Dr Bhaghwati Prasad Bhatt, was given consolation prize, and (*iv*) *Samekit Nashijeev Prabhandan*, written by Dr Ram Kewal, Prof. Shri Ram Singh and Shri Aashish Kumar Singh was also given consolation Prize.
    - Under *Indira Gandhi Maulik Pustak Lekhan Puraskar 2013*, second prize was given to book '*Litchi*' written by Dr Visahl Nath, Dr Gorakh Singh and Dr Sheshdhar Pandey.
    - Under *Rajbhasha Gaurav Yojana 2014-15* for Outstanding articles, third prize was given to Shri Shyam Kishore Verma, Shri B.U. Dupare and Shri Jagadishan A.K. for their article *Khadya Avam Poshan – Suraksha Main Soyabeen Ki Bhumika, Suchana Aur Samaj*, February 2015.

FINANCE

DARE/ICAR

The Plan and Non-Plan allocation (R.E.) to DARE/ICAR for 2014-15 were ₹ 2,500.00 crore and ₹ 2,384.00 crore, respectively. An internal resources of ₹ 200.68 crore (including interest on Loans and Advances, Income from Revolving Fund Schemes and interest on Short Term Deposits) was generated for the year 2014-15. The Plan and Non-Plan allocation (B.E.) for 2015-16 are ₹ 3,691.00 crore and ₹ 2,629 crore, respectively.

AWARD CEREMONY 2015

The 87th Foundation Day and Award Ceremony of ICAR was held on 25 July 2015 at Patna. Hon'ble Prime Minister, Shri Narendra Modi as Chief Guest called upon agricultural scientists and planners to design Second Green Revolution with new vision, dimensions and objectives to address the agricultural challenges in this modern era. Prime Minister appreciated agricultural scientists and farmers for their contributions and suggested identification of commodities having high potential of income from national and global markets. He reiterated that Second Green Revolution will begin from the land of eastern India which has immense potential in terms of natural resources and willing farmers to take up experiments in fields.

Hon'ble Prime Minister, Shri Narendra Modi Ji conferred Sardar Patel Outstanding ICAR Institution Award, Jagjivan Ram *Abhinav Kisan Puruskar* (National), N.G. Ranga Farmer Award for Diversified Agriculture and Chaudhary Charan Singh Award for Excellence in Agriculture Journalism. Shri Modi also launched and released soil-testing kit developed by ICAR and distributed to farmers. Besides, this he also launched ICAR schemes 'Farmer FIRST', 'Attracting and Retention of Youth in Agriculture' (ARYA), 'Student READY' and '*Mera Gaon Mera Gaurav*'. *ICAR Vision 2050* which presents a roadmap for food, nutrition and livelihood security by 2050 was also released by him.

Hon'ble Governor, Bihar, Shri Keshri NathTripathi and Shri Nitish Kumar, (Chief Minister, Bihar), Shri Radha Mohan Singh, (Union Minister of Agriculture and Farmers Welfare), Dr Sanjeev Kumar Balyan and Shri Mohan Bhai Kundariya (Union Ministers of State for Agriculture and Farmers Welfare) were also present.

The Ministers conferred various categories of ICAR awards. Dr S. Ayyappan, (Secretary, DARE and Director General, ICAR) announced that this year a total of 82

awards were given under 18 different categories, which includes three institutions, one AICRP, nine KVKs, 55 scientists, seven farmers and six agriculture journalists. Fifteen women scientists include the list of awardees. For the first time administrative awards were also given to administrative, technical and skill supporting personnel of ICAR for their outstanding contributions (Appendix 11).

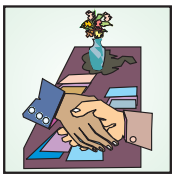
TECHNICAL COORDINATION

The Council provided the financial support to 59 scientific journals for publication, 84 societies/association/ universities for holding National Seminars/Symposia/ Conferences and 27 societies/association/universities for holding International Seminars/Symposia/Conferences. Ten queries from VIPs, 55 Parliament Questions and 18 queries under RTI Act were replied. Annual Report of DARE 2014-15 and Account Report were placed before the Parliament.

The 22ndmeetings of ICAR Regional Committee No. III comprising the state of Asom, Arunachal Pradesh, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim and Tripura was organized on 22 to 23 May 2015 under the chairmanship of the Secretary (DARE) and DG (ICAR) at Agartala, Tripura. The Presidential lecture was given by the Shri Manik Sarkar (Chief Minister, Tripura). The targets and achievements of the Universities, ICAR institutes, KVK's and AICRP's coming in the respective regions were also reviewed and action points to resolve the impediments identified. The action taken on the issues raised in the previous Regional Committee meetings was also reviewed.

Monthly report of major breakthroughs achieved in research and other related matter at various ICAR Institutes/NRCs/Project Directorates was timely submitted to Cabinet Secretariat and circulated to various Ministries and the Departments of Government of India. Action taken report on the points related to DARE was uploaded on the e-*Samiksha* portal, an online system developed for monitoring the follow up action on the decisions taken during the presentations made by the Ministries before the Prime Minister and other relevant issues.

The Conference of the Vice-Chancellors of Agricultural Universities and Directors of the ICAR Institutes was held at NASC Complex, New Delhi from 14 to 16 May 2015. The first day of the Conference i.e. 14 May 2015 was exclusively devoted to the Vice-Chancellors of the Agricultural Universities wherein all the relevant academic, administrative and financial matters pertaining to the agricultural universities were deliberated upon in details. The conference was formally inaugurated by Shri Mohan Bhai Kundariya, Hon'ble Minister of State (Agriculture and Farmers Welfare) on 15 May 2015. The Hon'ble MoS also presented the *Rajbhasha* Awards, Best Annual Report Awards and Best KVK Awards to the awardees.



17. Partnership and Linkages

The International Cooperation in DARE has been operating through the Memoranda of Understandings/ Work Plans signed with various countries/International organizations with DARE as the Nodal Department, and through participation of ICAR in the MoUs/Work Plans signed by the Department of Agriculture and Cooperation as the Nodal Department. Besides, Ministry of Science and Technology has developed Programme of Cooperation with various International Organizations in which ICAR is the participating agency in the field of agricultural research. The Joint Commissions/Working Groups constituted by the Ministry of External affairs, and the Ministry of Commerce have the component of agricultural research in which DARE participates directly or through the Department of Agriculture and Cooperation.

The DARE organizes visits of foreign nationals on request. The Department also receives proposals for customized training courses for foreign nationals.

Memoranda of Understandings

- Memorandum of Understanding between ICAR and Auburn University, USA was signed on 11 December 2014.
- Memorandum of Understanding between ICAR and the University Court of the University of Edinburgh, Scotland, United Kingdom for Cooperation in Agricultural and Veterinary Research and Education was signed on 16 February 2015.
- Memorandum of Understanding between ICAR and Eastern Africa Statistical Training Centre, Tanzania signed on 19 June 2015.
- Memorandum of Understanding between ICAR and Seychelles Agricultural Agency, Seychelles signed on 26 August 2015.

Memorandum of Agreement

Memorandum of Agreement for setting up of an 'Advance Centre for Agricultural Research and Education' at Yezin, Myanmar to assist Government of Myanmar's efforts in capacity building of Myanmar's scientific and technical staff with support of equipment, training, research and participatory knowledge management in the vital areas of New Genetics (molecular breeding), Post-Harvest Technology, Participatory Knowledge Management and Capacity Building was signed on 21 September 2015.

Work Plan

The Work Plan between ICAR and International Livestock Research Institute (ILRI), Kenya was signed. The Work Plan *inter-alia* emphasises on joint animal science research activities on selected programmes of mutual interest viz. Animal Health, Animal Breeding etc.

MAJOR EVENTS

BRICS

The Brazil, Russia, India, China and South Africa (BRICS) economies are major producers, consumers and exporters of agricultural, horticultural and meat products. 'Enhance agricultural technology cooperation and innovation' is the theme to be coordinated by India in collaboration with other four countries. During the interventions at the Seventh BRICS Summit from 8 to 9 July 2015 in Ufa, Russia, Hon'ble Prime Minister, *inter-alia* proposed setting up of BRICS Agricultural Research Centre (BARC) in India. It was also suggested to establish a system whereby BRICS countries can cooperate for production and investment in infrastructure in major agriculture/land rich nations.

The 5th Meeting of the BRICS Agricultural Cooperation Working Group (ACWG) took place in Moscow, Russian Federation from 12 to 13 August 2015 which was attended by Indian delegation led by Additional Secretary (DARE) and Secretary (ICAR). India made a presentation on the main elements of the agricultural research priorities and current state of agricultural production, prioritized challenges and climate smart agriculture. The issue of establishment of BRICS Agriculture Research Centre was raised and discussed in this meeting. The countries agreed to consider the establishment of the BARC and asked India to provide more information about the Centre.

The Department of Agricultural Research and Education prepared a Draft Framework Document for establishment of BRICS Agriculture Research Centre and circulated to all BRICS Member countries.

The Meeting of the BRICS Ministers of Agriculture and Agrarian Development was held in Moscow, Russian Federation from 7 to 9 October 2015 which was attended by the Indian Delegation led by Union Minister of State for Agriculture and Farmers Welfare, Shri Mohan Bhai Kundariya. During the meeting, it was agreed to consider the initiative to establish the BRICS Agricultural Research Centre (BARC) proposed by India and to intensify cooperation in the areas of agricultural sciences, technology, innovation and capacity building including technologies for family farming and to increase yields and farmers' incomes.

Meeting with Agriculture Counsellors of different countries

The DARE organized a meeting of Agriculture Counsellors in India on 14 September 2015 in New Delhi under the Chairmanship of Secretary (DARE) and Director General (ICAR) to showcase capability and technological strength of National Agricultural Research System (NARS).

Meeting with Ambassadors/ High Commissioners of African Countries

The DARE organized a meeting of the Ambassadors/ High Commissioners of African countries in India on 15 September 2015 in New Delhi under the Chairmanship of Secretary (DARE) and Director General (ICAR). The purpose of the meeting was to work out mechanisms to promote mutual growth and prosperity through cooperation in agriculture and allied sciences. Discussions were held on various issues, including progress made on projects being implemented by the DARE under the India-Africa Forum Summit, opportunities for African scientists to undergo training programmes in the ICAR institutes and fellowships for African students in India.

India-Africa Forum Summit

The Department of Agricultural Research and Education (DARE) has been designated the nodal department for the following programmes under the India-Africa Forum Summit:

1. India-Africa Fellowships in Agriculture (under IAFS-I and II)
2. Establishment of various laboratories/centres in Africa (under IAFS-II)
   (i) Soil, Water and Tissue Testing Laboratories
   (ii) Agricultural Seed Production-cum-Demonstration Centres
   (iii) Farm Science Centres
3. Pan African University of Life and Earth Sciences (PAULESI) at University of Ibadan, Nigeria (IAFS-II)

The India-Africa Fellowships programme envisaged a total of 200 fellowships for the M.Sc programme and 100 fellowships for Ph.D. programme in Agriculture. It has achieved major success, with 195 students joining M.Sc. and Ph.D. Programmes since its commencement, and with 106 students having successfully completed their course. With regard to the establishment of projects/ laboratories in Africa together with the Pan African University of Life and Earth Sciences (PAULESI), the department is making considerable progress, and intends to impart training (both on sites and off sites) to the African experts in tandem with the commissioning of the projects, so as to facilitate full-fledged functioning of the laboratories and their successful replication in other African countries.

Foreign Collaborative Projects with ICAR

Foreign Collaborative Projects (FCP) are undertaken by the different institutes of ICAR and same are examined in consultation with SMDs and condidered for approval.

DARE has approved following Collaborative Projects for implementation during the year:

- 'Low-Carbon Footprint Cool Storage Structure to Empower Farmers-Improving Storage and Enabling Processing of Perishable Produce'. The collaborate partners of the projects are Indian Agricultural Research Institute, New Delhi and Michigan State University (USA).
- 'Cryopreservation of embryonic stem cells and primordial germ cells for transplantation and surrogate fish production. Its partners are Central Institute of Freshwater Aquaculture, Bhubaneshwar and IIB-INTECH (CONICET-UNSAM).
- 'Improving crop and water productivity in Indira Gandhi Canal Command Area (Phase-II). The collaborate partners of the project are International Centre for Agricultural Research in the Dry Area (ICARDA) and Central Arid Zone Research Institute, Jodhpur.
- 'Developing and defining climate smart agriculture practices portfolios in South Asia'. This is sponsored by CGIAR Research Programme on 'Climate Change, Agriculture and Food Security'. The collaborating partners of this project are CIMMYT, Agricultural Universities and ICAR.

PROGRAMMES OF DARE

ASEAN-India Cooperation

Under the Medium-Term Action Plan of ASEAN-India, following Joint Collaborative Projects in different areas are under consideration:

- Agroforestry interventions for livelihood opportunities.
- Proposal for visit of ASEAN Farmers' delegation to India under ASEAN India Farmers Exchange Programme.
- Proposal for visit of Indian Farmers' delegation to Thailand under ASEAN-India Farmers Exchange Programme.
- Capacity development in managing food security and price volatility in ASEAN Countries.
- Empowerment of India: ASEAN women through Cooperatives.
- Genetic improvement of hybrid rice parental lines for enhancing yield heterosis. The approval has been received from the Indian Mission ASEAN/ MEA and the same is being examined/processed in Department of Agricultural Research and Education.
- Buffalo production using reproductive biotechnology.
- Sandwich Master Degree Programmes between India and ASEAN Member Countries.
- Exchange of scientists from agricultural research institutions in ASEAN Member States and India.

- ASEAN-India Fellowships for Higher Education in India and ASEAN Countries.
- Demonstration and Exchange of Farm Implement and Machinery.

Afghan National Agricultural Sciences and Technology University

Afghan National Agricultural Sciences and Technology University (ANASTU) at Kandahar has been established with the support of the Ministry of External Affairs, Government of India under the bilateral cooperation programme between Afghanistan and India. Various initiatives taken are as under:

- A set of books for ANASTU library has been dispatched in May 2015.
- Laboratory instruments and farm equipment for ANASTU.
- Tele Teaching on 'Principles and Practices of Weed Management' was conducted by IARI in April 2015. Subsequently, courses on 'Water Management', 'Agronomy of Oilseed Crops' and 'Pulses' were completed. Courses on 'Agronomy of Commercial Crops' and 'Basic Design of Experiments' are in progress.
- Training of ANASTU faculty (16) for six-weeks by IARI is likely to commence in five different areas.

Consultative Group on International Agricultural Research

It is an international organization that advances agricultural research for a food secure future by integrating and coordinating efforts of those who fund research and do the research. It works through various research centres located in various continents of the world. India is a donor member of CGIAR system and accordingly, provisions in Plan and Non-Plan budget have been made for the financial year 2015-16.

One of the 15 CG Research Centres, International Crops Research Institute for Semi-Arid Tropics has its Hqrs. (Office) in India. IRRI and India have been succesfully collaborating for more than 4 decades. ICAR as a nodal body for IRRIvs programmes in India endorsed GRISP on 4 September 2010 and mutually agreed to continue and strengthen collaboration.

The Indian Council of Agricultural Research as nodal body has signed MoUs/MoAs with different Institutions. These CGIAR research centres are engaged in various kinds of agricultural CG research activities in India in accordance with their subject domain through collaboration with the ICAR Institutes by aligning their activities in line with National priority in the field of agriculture.

CENTRAL AGRICULTURAL UNIVERSITIES

CAU, Imphal

The Central Agricultural University, Imphal is premier centrally funded University at Imphal. It has jurisdiction over north-eastern states except Nagaland and Asom. The University has seven campuses, and nine Undergraduate, fortyone Post-graduate courses and sixteen Ph.D. Programmes in different disciplines. During 2015-16, a total of 378, 144 and 19 students were enrolled in Undergraduate, Postgraduate and Ph.D. programmes, respectively. Altogether, 229 Undergraduate and 58 Postgraduate students completed their degrees. First Ph.D. Degree of this University was completed by one student of College of Veterinary Science and Animal Husbandry, Aizwal in the specialized area of Veterinary Microbiology during the current year.

The CAU, Imphal started classes at 4 new colleges namely B.Sc. (Agriculture) at College of Agriculture, Pasighat; B.Tech (Food Technology) at College of Food Technology, Imphal; B.Sc. (Horticultural Science) at College of Horticulture, Sikkim; and B.Sc. (Agriculture) at College of Agriculture, Barapani, Meghalaya.

RLBCAU, Jhansi

The Rani Lakshmi Bai Central Agricultural University (RLBCAU) continued its academic activities by admitting second batch of students for B. Sc. (Agriculture) programme. The Government of Uttar Pradesh has consented to make available 300 acres of land presently in use by IGFRI and Central Agroforestry Research Institute at Jhansi for the establishment and use by Rani Lakshmi Bai Central Agricultural University. Similarly, Government of Madhya Pradesh has also allotted 175 acres at Datia. The University is to establish its headquarters and constituent College of Agriculture, and College of Horticultural Science and Forestry at Jhansi and two colleges, namely College of Veterinary and Animal Science, and College of Fisheries at Datia, Madhya Pradesh. The University initiated research activities under its newly established sub-centre of AICRP on Chick pea at Jhansi.

AGRINNOVATE INDIA LIMITED

Agrinnovate India Limited (AgIn), established in 2011, is the commercial arm of the Indian Council of Agricultural Research. It identifies, protects and commercializes the intellectual property developed in ICAR. AgIn facilitates and accelerates the transfer of innovative technology from basic research to industry by working closely with industrial partners spanning the agriculture sector. Key operation areas of AgIn are Collaborative and Contract Research, Technology Management and Licensing, Strategic Collaborations and Turn Key Projects, Market Research and Marketing, Human Resource Development and Capacity Building and Business Incubation.

The Company is successfully moving towards meeting its objectives and building 'A world of Innovative Partnerships'. The Vision of the company is to stimulate, foster, enhance and catalyse innovation and capacity driven agricultural development through partnerships. AgIn coordinated various training and capacity building programmes for Biofertilizer and Biopesticides at IARI, Bioorganic Fertilization at IARI, Insect Biological Control (Mass rearing) of Agriculture Pests at NBAII,

Bengaluru, Training for 3 agricultural engineers of Seed Technology Centre-Iraq for 8 days at IARI, New Delhi, and training on Pesticide testing under FAO at IARI, New Delhi for two technical persons from Mongolian Government.

AgIn in partnership with Directorate of Knowledge Management in Agriculture, participated in the Global R&D Summit 2014 organized by Federation of Indian Chambers of Commerce and Industry (FICCI) wherein some of the cutting edge technologies, products and solutions of ICAR Institutes were exhibited to key customers, business buyers, investors, scientific community and media at large. AgIn has also licensed designs of 31 Agricultural Engineering Machineries from Indian Institute of Horticultural Research, Bengaluru to private sector on 19 January 2015.

Agrinnovate India Limited has also facilitated in organizing training programmes for West Africa Agricultural Productivity Programme for Nigerian candidates in Fish Breeding Technology at CIFA, Bhubaneshwar course on Food Science Technology at Central Institute of Agricultural Engineering, Bhopal; and also a programme on Seed Technology at Directorate of Seed Research, Mau, for Nigerian candidates.

CONSULTANCIES

Consultancy proposals as and when received from different ICAR institutes are examined in consultation with SMDs and considered for approval. The following consultancy proposals were approved during the reported year.

- Principal Scientist and Incharge, ZTM & BPD, Indian Agricultural Research Institute (IARI) has undertaken International Consultancy for technical advice to NSB/NARC for Intellectual Property Right (IPR) and Business Models for seed varieties and planning material to IFPRI, Washington, USA in Cunsultation with SMPS.
- National Fellow, IASRI, New Delhi provided consultancy for implementation of the Global Strategy to Improve Agricultural and Rural Statistics in Sri Lanka with home-based work as a sampling expert to assist with development of improved sampling design/methodology for crop yield estimation in the country at national and sub-national levels for 45 days in mission during 2015 and 2016 under the FAO Project.
- Consultancy proposal of IVRI, Izatnagar in the area of 'Videos for Farmers'.

INTERNATIONAL WORKSHOPS/ CONFERENCES/SYMPOSIA

The Department of Agricultural Research and Education is the nodal Department for granting permission for organizing workshops/conferences/symposia in agricultural research and education. Following International Conferences, Seminars, Symposia have been approved during the reported period.

- XII Agricultural Science Congress (ASC 2015) on Sustainable Livelihood Security for Small Holder Farmers was held from 3 to 6 February 2015 at National Dairy Research Institute, Karnal.
- World Health Organization sponsored International Workshop on 'Third Pilot Session of the Five Keys to Safer Aquaculture Products to Protect Public Health' at Central Institute of Freshwater Aquaculture, Bhubaneshwar (Odisha) from 2 to 4 February 2015.
- Joint International Workshop between Indian Council of Agricultural Research, India and University of Edinburgh, United Kingdom on 'Production, Animal Health and Welfare Research: Impact and Opportunities' was held from 16 to 17 February 2015 in New Delhi.
- Indo-French Workshop on 'Scientific Cooperation for Agricultural Research' was held from 9 to 11 March 2015 in New Delhi.
- Second International Symposium on 'Marine Ecosystems – Challenges and Opportunities (MECOS2)' was held from 2 to 5 December 2014 at Kochi, Kerala.
- Food and Agriculture Organization sponsored 'Expert Workshop on Food loss from Gillnet and Trammel Net Fishing' at Central Institute of Fisheries Technology, Cochin from 8 to 10 April 2015.
- International Conference on 'Plant Pathogens and People' with the mission 'Challenges in Plant Pathology to benefit humankind' from 23 to 27 February 2016, New Delhi.
- Asian Seed Congress, 2015 was held from 16 to 20 November 2015 in Goa.
- The 25 Asian-Pacific Weed Science Society Conference on 'Weed Science for Sustainable Agriculture, Environment and Biodiversity' was held in Hyderabad from 13 to 16 October 2015.
- International Conference on 'Pulses for Nutritional Security and Agricultural Sustainability (PulsCon 2016)' was held from 12 to 14 November 2015 in New Delhi.
- International Conference on 'Agroforestry in South Asia: The way Forward' was held from 8 to 10 October 2015 New Delhi.
- V International Symposium on 'Cage Aquaculture in Asia (CAA5)' was held from 25 to 28 November 2015 in Cochin (Kerala).

PROTOCOL ACTIVITIES

VIP Delegations

- Minister for Agriculture, Fiji's Mr Inia Batikoto Seruiratutour, led 15- member delegation from Rural and Maritime Development and National Disaster Management, Fiji visited Central Inland Fisheries Technology and Central Marine Fisheries Research Institute, Cochin from 25 January to 5 February 2015.
- Mr Akram Chehayeb, Lebanese Agriculture

Minister led a 15-member delegation and visited Indian Agricultural Research Institute on 6 February 2015.

- Minister for Food, Agriculture and Forestry, State of Bavaria, Germany, Mr Helmut Brunner led a 20-member high level business delegation and visited University of Agricultural Sciences, Bengaluru between 27 March and 2 April 2015.
- A six member Nepalese delegation visited India from 24 to 30 March 2015 under Indo-Nepal Joint Agricultural Working Group. The delegation visited NDRI, Karnal; IVRI, Izatnagar; and IARI, New Delhi.
- A Chilean delegation along with some diplomats from the Embassy of Chile, New Delhi visited Indian Agricultural Research Institute, New Delhi on 14 April 2015.
- State Minister of Agriculture from Zhejiang State, China led agriculture delegation to India in April 2015.
- Mrs Katia Abreu, Minister of Agriculture, Livestock and Food supply, Brazil and Mr Mericino Antonio Lopes President, Agriculture Research of the Cooperation (EMBRAPA) from Embassy of the Federative Republic of Brazil, visited IARI, New Delhi on 13 November 2015. ❑

18.

National Agricultural Science Fund

The 'National Agricultural Science Fund' with an outlay of ₹ 500 crore during the XII Plan, supports basic and strategic research in agriculture. The main objective of the scheme has been to build capacity for basic, strategic and cutting edge application research in agriculture and address issues which can be solved by intensive, basic and strategic research jointly by team of organizations/ institutions. Underlying this objective are the following aims: (i) Foster research and a research culture that will use and advance the frontiers of scientific knowledge to effectively meet the present, anticipated and unanticipated problems of agriculture through various modes and critical investments in research projects; (ii) build the capability of the National Agricultural Research System through development of wide partnerships in science through projects; (iii) build a storehouse of advancement of knowledge in science related to agriculture and awareness of the national importance of basic and strategic research in agriculture; (iv) to provide policy support to the decision makers for use of basic and strategic research in agriculture, and; (v) organization of workshops, seminars, conferences etc. to create awareness, prioritization, scientific popularization and related issues. The scheme has already funded 111 projects, mostly in consortium mode out of which 79 are on-going projects and 65 are multi-institutional in nature.

Besides supporting, reviewing, monitoring and evaluation of the ongoing projects during the year 2015-16, NASF initiated for funding of new projects which were in the process of evaluation. From the last advertisement made, a total of 50 'Concept Notes' (CNs) were selected. The full proposals submitted by the PIs were evaluated by the Expert Committees and the Empowered Committee. A total of 13 projects were approved and sanctioned during 2015-16. Another eight projects were observed to be revised and resubmitted for further consideration.

Advertisement for new call (Call VI) were made in September 2015 to invite fresh proposals. A total of 996 CNs were received. They are in the process of being evaluated by respective DDGs and Expert Committees of ICAR. NASF was also engaged in creating awareness for the need and nature of the basic research for agriculture among institutions within and outside the traditional NARS, inviting new project proposals.

Monitoring of ongoing projects: The ongoing projects are being monitored at three levels. Each project has an 'Advisory Committee' which intensively reviews and monitors the projects. Besides, the projects are being reviewed by the 'Expert Committees' and the 'Empowered Committee'. More than 25 advisory committee meetings were held in 2015-16 to mentor, monitor and evaluate the projects. Similarly, seven Annual Review meetings were held in the month of February 2015 to review the ongoing projects by the Expert Committees. Two mega projects of national importance, viz. 'Phenomics of moisture deficit and low temperature stress tolerance in rice' and 'Stock characterization, captive breeding, seeds production and culture of hilsa (*Tenualosa ilisha*)' were monitored by the Empowered Committee on April 20, 2015 separately. Besides, the 4th Annual Workshop of NASF was held on 28-29, May 2015. The workshop was attended by the Chairman and members of Empowered Committee, Director General, ICAR, Deputy Director Generals, ICAR, members of Expert Committees, Chairmen, Advisory Committees, CPIs and CCPIs of the projects. A total of 19 projects were presented and reviewed. Besides, all the policy issues were deliberated in details and decisions were taken for the smooth functioning of NASF.

The projects under the NASF on the whole have started giving desired results. In addition to the results in terms of high impact publications, patents and technologies, a strong and sustainable platform for developing scientific capacity and culture that encompasses the extended NARS is being established. This will ensure continuous flow of knowledge, ideas and working together among different stakeholders in the basic, strategic and frontier areas for solving problems in agriculture and also forming science policy in agriculture.

SALIENT ACHIEVEMENTS

During 2015-16, besides having 109 publications in reputed journal, NASF had five patents and 38 technologies. The research highlights of some selected projects are as follows:

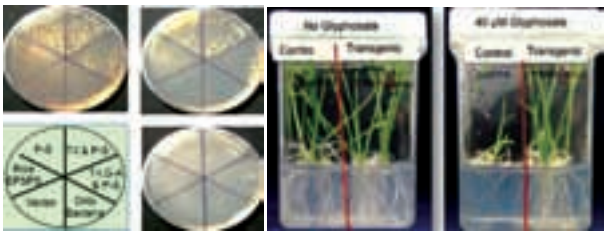
Phenomics of moisture deficit and low temperature in rice

Hyperspectral reflectance based models which can predict relative water content with high accuracy were developed for high throughput non-destructive phenotyping drought tolerance of rice. Further, to differentiate rice genotypes, hyperspectral method based separability index was developed. Twenty-five candidate genes from rice have been cloned and functional validation is in progress. Analysis rice F-box protein genes *OsFBX257* and *OsFBK10* and homeodomain

protein gene *OsHOX22* in *Arabidopsis* showed that these genes are negative regulators of stress tolerance. Transgenic analysis showed that ABA receptor (*OsABAR6*) gene confers enhanced drought tolerance to rice.

Double herbicide tolerant transgenic rice for weed management

The rice EPSP synthase (P173S) and acetolactate synthase (P171S) were mutated by site directed mutagenesis to confer tolerance to herbicide glyphosate and sulfonylurea, respectively. The mutated EPSP synthase (P173S) and ALS (P171S) genes were transformed simultaneously and stable rice transgenic rice lines with moderate tolerance to glyphosate and sulfonylurea were developed without any fitness cost.



Validation of EPSPS mutants for conferring tolerance to glyphosate

Selective multisite-compensating mutations in rice EPSPS by molecular docking were generated. The double (P173S and T169I) and the triple (P173S, T169I and G168A) compensating rice EPSPS mutant encoding genes were cloned and expressed in *E. coli*. Both the double and triple mutants produced functionally active EPSP synthase in *E. coli* and confer higher tolerance to glyphosate compared to wild type or single amino acid substitution (P173S) rice EPSPS mutant. Glyphosate-metabolizing strategy in transgenic lines by constitutively overexpressing codon optimised IgrA gene from *Pseudomonas* to degrade glyphosate into glycine and phosphate in transgenic rice plants to enhance glyphosate tolerance and minimize crop injury was utilized.

Development of transgenic pigeon pea and chickpea

Emphasis was given on generating large number of transgenic chickpea lines using the following constructs; 35S promoter regulated *Cry2Aa*; AraSSU promoter regulated *Cry2Aa*; and 35S regulated *Cry1Ac-full* genes. The idea of using different versions of *Bt* constructs was to obtain lines with optimum level (30 – 80 ng/mg of protein) of *Bt* toxin having complete protection against pod borers. In all, 20 independent events were obtained with 35S-cry2Aa gene and 13 independent events with AraSSU-Cry2Aa gene. A total of 45 putative independent events were generated using the chimeric 35S-cry1Ac-full length gene. Out of these 45 lines, only four lines were found to have high expressing for Cry1Ac toxin. T_1 plants of the high expressing line are currently being grown for segregation analysis.

Transgenics in pigeon pea were developed with two *Bt* ICPs, *cry1AcF* and *cry2Aa*. The progeny of 28 T_1 plants of *cry1AcF* events and progeny of 54 T_1 plants of *cry2Aa* were advanced into T_2 generation. Based on the PCR analysis using various primers, 74 plants with *cry2Aa* gene and 45 plants with *cry1AcF* gene were tested positive. Complete characterization of transgenic events generated in the first phase was achieved. Besides, emphasis was also given for the generation of large number of transgenic lines using the constructs; 35S promoter regulated *cry1Ac* and 35S regulated *cry2Aa*. Three hundred and thirty eight primary transformants carrying *cry*1Ac and 283 primary transformants carrying *cry*2Aa gene have been established in pigeon pea and seeds have been harvested from 190 primary transformants carrying *cry*1Ac and 216 primary transformants carrying *cry2Aa*. Twenty seeds each from these primary transformants have been sown in pots and screening for the presence of transgene is in progress.

Mechanisms of non-host resistance against rust and blast in rice and wheat

Techniques for plant infection and multiplication of uredospores under controlled conditions and their visualization on/in plant surface were standardized. Uredospores were found germinating on host (wheat) and non-host (rice) surfaces alike as revealed in fluorescence and scanning electron microscopic analysis. Surface hydrophobicity and medium influenced uredospore germination. Predominant *Magnaporthe oryzae* causing rice blast was identified as O_2 type, using MLST based genotyping; rice infecting O_2 type and a non-O_2 type was found infecting wheat also at conducive environmental conditions. One each of O_2 and O type was genetically transformed for green fluorescence protein expression that was used for deciphering their interaction with plants. qPCR based absolute quantitation of *M. oryzae* was optimized. A genomics-guided approach was developed to identify NHR genes in wheat and to map their homologs in rice. Thirty full-length candidate NHR genes and 60 phytohormone signaling genes were identified in wheat and further mapped to rice genome by combining homology search, EST assembly and mapping to the draft genomes. EDS1 and NPR1 were identified as two strong NHR candidates in wheat-blast-rice-rust system. Homologs of these genes had not been previously identified in wheat. qPCR based assays have been developed for evaluating gene expression in wheat and are being translated to rice.

Dominant nuclear male sterility system in rice for hybrid seed production

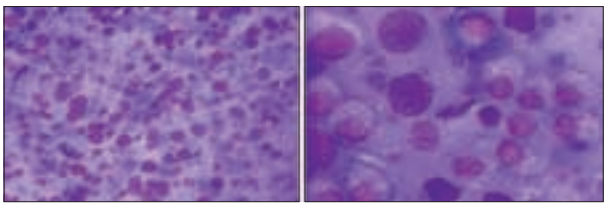
Efforts were made to develop a dominant nuclear male sterility (NMS) system using *Syn orfB* gene in different genetic backgrounds and evaluation of fertility restoration system using *Cre-lox* mediated excision, RNAi-mediated down regulation of the male sterility inducing *Syn orfB* gene. Tapetum specific RTS2 promoter was cloned from IR64 and characterized in transgenic tobacco. The Real-time PCR and histochemical study confirmed higher expression of *Gus* gene in anther as compared to leaf and root. The transformed plantlets having *Cre* gene

Transgenic IR 64 with *orf* B

construct were regenerated. Based on standard heterosis, the best heterotic combinations identified are Reeta/ CR3854, CR3813-2-2-5-1-1/R261 and Improved Tapaswini/MTU1010.

Infertility in crossbred bulls and early prediction of fertility

Safe extraction of spermatogenic and sertoli cells from the testis of live bulls using percutaneous needle aspiration biopsy (PNAB) method was standardized. Methodology for *in vitro* culture of spermatogenic cells and sertoli cells was standardized. Among the several proteins that were differentially expressed between the high and low fertile bulls, MDH2, ENO1, RIBC1, CAPN7, ATP5D, GLB1L2, NCAPD3, DECR1, GCNT2, GDI2, TOP, and USP12 were found over expressed in high fertile spermatozoa, whereas DST, TMEM43 and BSP1 were over expressed in low fertile spermatozoa.


Testicular cells isolated from live bulls using PNAB method

Transgenic goat for production of human lactoferrin

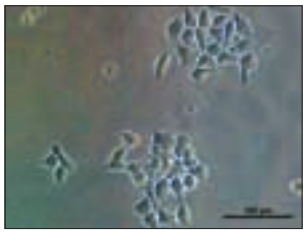
The human lactoferrin gene construct was developed with highest promoter activity under 6.5 kb fragment of beta-casein. Simultaneously, goat mammary epithelial cell line was established and characterized. Subsequently, the construct prepared was transfected into goat mammary epithelial cell line by nucleofection. The cells were observed for the expression of GFP as the expression vector contains GFP as the reporter marker. Lactoferrin expression in the transgenic cell line was also confirmed by western blotting. The embryos were transferred in the uterine lumen by means of a long micropipette (conditioned in 10-20 µl PBS medium).

Parthenogenetic goat from embryonic stem cells

The overall cleavage rate and blastocyst production in TRIS + Heparin (37.67% and 13.8%) were comparatively higher as compared to sperm capacitated in TALP + Heparin (35.07% and 10.07%). The overall cleavage rate, morula and blastocyst production in mCR_2aa and mCR_2aa+cysteamine were 36.39, 21.62 and 4.95% and 31.72, 30.89 and 8.98%, respectively. The mechanical activation failed to induce cleavage in *in vitro* matured goat oocytes whereas chemical activation of intracytoplasmic sperm injected *in vitro* matured goat oocytes (29.66%) showed significantly higher ($p<0.05$) cleavage rate as compared to non-activated oocytes (8.14%). The blastocyst production was significantly higher following activation of *in vitro* matured oocytes by 5 µM calcium ionophore and 6-DMAP as compared to ethanol activation. IVF derived embryos were selected at the 2-cell stage between 32 and 48 h post-insemination. Altogether electro-fusion of two cell stage IVF derived embryos at 1.25kV/cm for 99 µsec tend to show more developmental competence than other fusion parameters as it reached up to 8 cell stage.


Transgenic goat embryo at morula stage expressing hLF-GFP protein

Regulation of fatty acid synthesis by RNAi in pig


Porcine induced pluripotent stem (iPS) cell colonies

The project aims to produce designer pork with reduced fat using transgenic induced pluripotent stem (iPS) cells. The siRNA against SCD1 gene in porcine mesenchymal stem cells were screened. Of the three siRNA sets, one is shown to down-regulate expression of SCD1 in a dose dependent manner. From mesenchymal stem cells, induced pluripotent stem (iPS) cells were produced for transgenesis. Mesenchymal stem cells (MSC) were transfected three sets of siRNAs designed against porcine SCD1. One of these sets was found to down-regulate the SCD1 gene in a dose dependent manner.

Genetically engineered vaccines against poultry viral diseases

The IBDV VP2 gene cassette inserted into the final cDNA clone of the NDV virus generated at sites, SacII (position 2354) and AvrII (position 5251). The final clone had an expected size of 21,344 bp. Transfection was done using the full length clone of the virus along with the support plasmids and recombinant virus was rescued. The

demonstration of recombinant virus was done by RT-PCR using gene specific primers for both NDV and IBD VP2. The rescued virus was pelleted, run on SDS-PAGE and reacted with NDV and IBDV specific antisera on a western blot. Specific bands in relation to VP2 protein (44 kDa) and NDV proteins were observed in the blot.

Adaptive mechanisms and captive breeding in hilsa

Hilsa grown in freshwater pond (161 g)

Assessment of the population characters of hilsa from Hooghly estuary and near shore areas showed over exploitation of the stock, as current exploitation level exceeded maximum sustainable yield levels; exploitation of spawning stock biomass is 40% more than the level of sustainability. Major habitat parameters and their favorable range in nature for the fish has been identified for juveniles and adults. Size-wise natural food items, feeding habits, reproductive biology, sex ratio, breeding seasons and location of availability of brooders were established. Genetic analysis showed definite differentiation between east and west coast samples (F_{st} value 0.51225 to 0.94259 $p<0.05$). Hilsa of Hooghly was found genetically distinct from that of Padma and Brahmaputra rivers. Juvenile hilsa showed higher branchial NKA activity prior to seaward migration indicating physiological preadaptation to face salt water. Plasma estradiol and 17α 20α-dihydroxy progesterone (DHP) in the fish showed biannual surge, linked with growth and maturation of oocytes. Attempts on artificial breeding resulted in 30 to 95% fertilization of eggs and 38-98% hatching. Management of live feed and water quality management could improve hatchery-stage larval survival up to 40% and nursery- stage up to 30%. Culture trials in freshwater ponds resulted in average weight gain of 160g/252 mm in 13 months with 20% survival; in brackish water ponds, hilsa attained average weight gain of 250 g in 13 months with 30% survival. Freshwater pond reared specimens showed ovary growth up to stage IV.

Green fishing systems for tropical seas

Designs of 79 trawl nets, 31 gillnets, 11 purse seines, 4 ring seines, 14 hook and lines, and 2 dolnets were collected and documented. Measures to reduce drag of trawl nets were identified. Two new trawl nets, one fish trawl and one shrimp trawl each were fabricated incorporating drag reduction measures such as increased mesh size and reduced twine size. A modified method (mathematical formula) for calculating the sinking speed of seine nets has been derived. The *in situ* validation of the derived formula has been conducted at Lakshadweep by trained project staff with assistance from Scuba divers. A design for an optimized gillnet with new generation materials, Sapphire (7x3) and STAR (No.8) with mesh size 150 mm for targeting large pelagic species was developed.

Defense genes of tiger shrimp against bacteria and white spot syndrome virus

2-D gel analysis was carried out with respect to different time point intervals of WSSV infection. Different spots were observed in white spot syndrome virus (WSSV) infected shrimps. The spots were excised and MALDI-TOF analysis revealed differentially expressed proteins. At 72 h post-infection, two of the proteins, viz. Tropomyosin and Arginine Kinase were overexpressed in WSSV infected tissues indicating specific role of these host proteins. Both conventional RT-PCR and real time analysis for differentially expressed genes with respect to WSSV infection were carried out. Expression analysis was carried out for about 22 defense genes. While it was difficult to differentiate the expression pattern by conventional RT-PCR, real time PCR could differentiate clearly the differences at different time point intervals. Immune genes involved in the Toll pathway of shrimp, such as Spatzle (extracellular ligand of Toll), myeloid differentiation factor 88 (MyD88), tumor necrosis factor receptor-associated factor 6 (TRAF6), cactus (mammalian IkB homologue) and dorsal (mammalian NF-kB homologue) were characterized. Full gene sequencing of myeloid differentiation factor 88 (MyD88), tumor necrosis factor receptor-associated factor 6 (TRAF6) and spatzle, and partial gene sequencing of cactus (mammalian IkB homologue) and dorsal (mammalian NF-kB homologue) was done. The akirin gene that showed maximum upregulation during infection was amplified, cloned and expressed. Recombinant clones of akirin (AKN) were sequenced.

Diversity and synthesis of immunoglobulins in the Indian major carps

Immunoglobulin (Ig) Z and IgM expression has been analyzed in rohu and catla following argulus infection and the qRT-PCR data revealed significant induction of IgM in skin, muscle, gill and kidney of rohu. In catla, IgZ gene expression was enhanced in blood and gill followed by intestine and spleen. These data suggests important role of IgM and IgZ in parasite infection in fish. The B cell activating factor (BAFF) has been cloned and sequenced in rohu. Full-length BAFF–cDNA has been amplified through RACE, and its structural domains has been characterized.

Microalgal triacylglycerols (TAGs) as source of biodiesel

A locally isolated microalga *Scenedesmus obliquus* (Turpin) Kützing (GA 45) was grown successfully using the low-cost farm-fertilizer (UZn) medium in closed raceway pond system. The maximum biomass and lipid yield were recorded as 1.10 g/L and 115 mg/L, respectively, for 30 cm culture depth. The maximum areal biomass productivity was recorded as 11 g/m^2/day with lipid productivity of 1.15 g/m^2/day. Under biphasic N-starved condition, lipid productivity was doubled up to 2.28 g/m^2/day. Harvesting techniques involving pH-

Closed raceway pond system for cultivation of microalgae

induced flocculation and dissolved air floatation (DAF) with alum were found to be suitable for large scale testing of microalgal harvesting. Oven, tray and solar drying protocols were fully standardized for the microalgae.

Decision support system for enhancing productivity of grapes

A dynamic simulation model for growth, development, biomass and yield of grape vines was designed to run at daily step (for 20 years cycle) and to provide outputs on phenology, growth and yield parameters taking into account the effects of water and nutrient (nitrogen) stresses. This DSS is available to farmers for use and validation. A total of 40 growers were registered and trained on DSS software usage.

Polymeric nano-materials for microencapsulation of nutraceuticals

Shelf life of guava dices stored in the egg shell could be extended up to 14th day compared to only 6 days in the macro-perforated package. The same for papaya was up to 20th day in the egg shell compared to only 4 days under macro-perforated package. Different modifications of native starch and incorporation of plasticizers and functional compounds were tried to arrive at a suitable biodegradable film for subsequent use. Hydrophilic OH-MMT was prepared by simple ion exchange reaction method between THAC and Na^+-MMT. The good degree of exfoliation achieved can be attributed with the strong interactions between the modified silicate layers and polymer matrix through efficient hydrogen bonding.

Biodegradable electrospun fibre mat for packaging of fresh perishable agricultural material

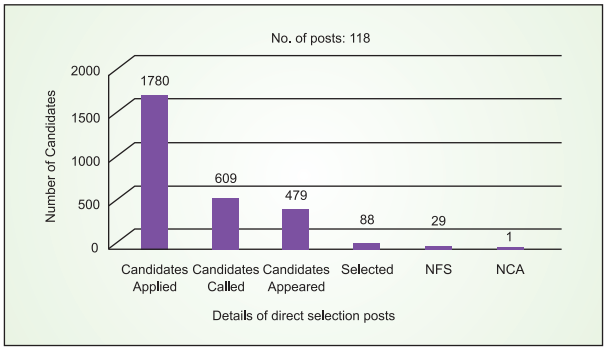
Multi-phase electrospinning setup was fabricated for production of electrospun nano fibre mat. The machine has multi-axial arrangements with adjustable nozzle geometry that can orient the needle to desired angle; automated linear motion and multiple parallel needles. The machine has the advantage of forming multi-layer fibre and produce mat with even surface. The parameters for electrospining process, viz. voltage, distance, flow rate and duration were optimized. The optimized parameters were 25 kV voltage, 15 cm distance, 0.04 ml/min flow rate and 15 min duration. Volatile gas profile of the Alphonso mango during the ripening stage was mapped by non-destructive method. Analysis revealed major gases that are coming from the mango fruit during ripening were 3-methyl furan, α-pinene, α-ocimene, P-mentha-1,4-diene, tetramethyl cyclohexadiene, dimethyl octatriene, ethyl octanoate, ethyl-trans-4-decenoate, ethyl decanoate and caryophyllene.

Colorimetric sensor for mango ripening

19. Science Resource Management

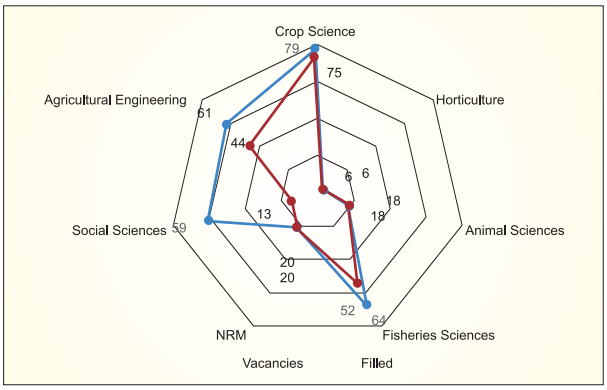
Direct recruitment/lateral entry

During 2015-16, the ASRB completed recruitment process for 118 posts. Out of these, 22.03% posts were Research Management Positions (RMPs) and remaining 78% posts were of Head of Divisions, Project Coordinators, Principal Scientists, Senior Scientists and Programme Coordinators. Against these 118 positions, Board recommended candidates for 88 posts. Whereas, no candidate was found suitable (NFS) for 29 posts and none appeared for the remaining one.

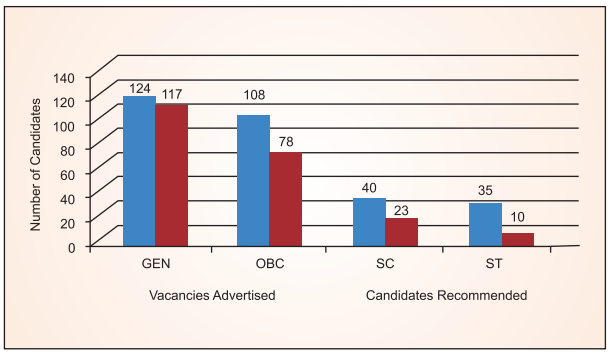


Recruitment of entry level scientists (ARS-2014)

The Agricultural Research Service 2014 (Main) Examination was held on 28 December 2014 at 12 centers across the country for recruitment of 307 vacancies in 37 different disciplines. A total of 2,065 candidates qualified for the main examination and out of these 1,835 candidates actually appeared for the examination. The viva voce were conducted from 09 March to 10 April, 2015 for 706 qualified candidates. Based on performance of candidates in the main written examination and viva voce, a total of 228 candidates were recommended for the appointment.



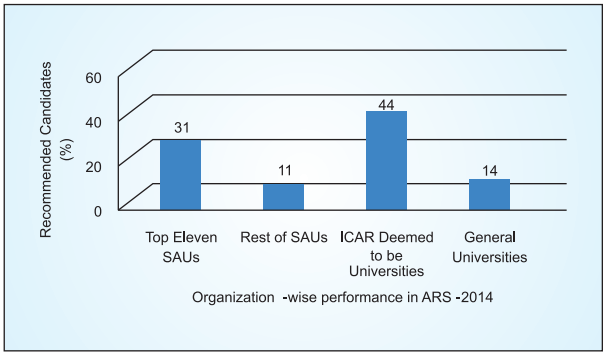
Major discipline-wise candidates recommended against vacancies advertized in ARS 2014.



Category-wise candidates recommended in ARS 2014

Organization-wise contribution

Out of 228 recommended candidates, 31% were from 11 State Agricultural Universities SAUs (UAS, Bengaluru; TNAU, Coimbatore; GBPUA&T, Pantnagar; WBUA&FS, Kolkata; UAS, Dharwad; SKRAU, Bikaner; CCSHAU, Hisar; AAU, Anand; KVAFSU, Bidar; OUA&T, Bhubaneshwar; PAU, Ludhiana) and 44% from Deemed-to-be Universities (IARI, New Delhi; CIFE, Mumbai; IVRI, Izatnagar and NDRI, Karnal) and the remaining 11% were from rest of SAUs and 14% were from general universities.



State-wise distribution

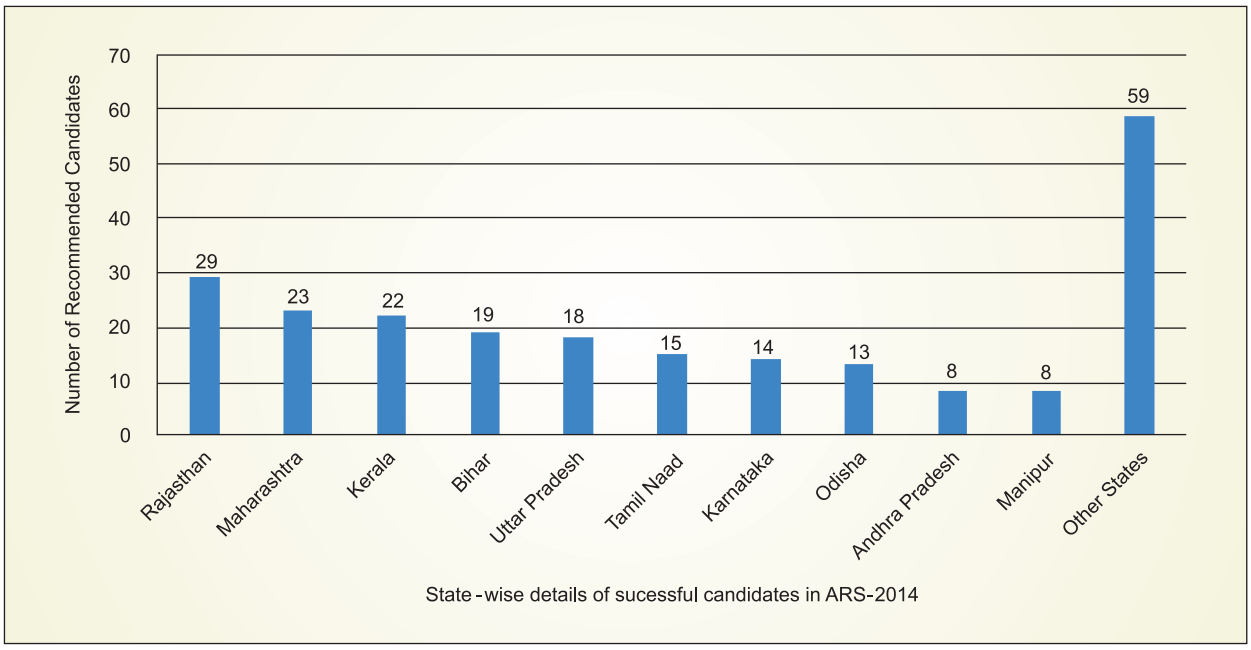
State-wise distribution of data showed that about 58% of successful candidates came from just 10 states (Rajasthan, Maharashtra, Kerala, Bihar, Uttar Pradesh, Tamil Nadu, Karnataka, Odisha, Andhra Pradesh and Manipur). States like Arunachal Pradesh, Asom, Chhattisgarh, Mizoram and Sikkim have very little representation in the list of successful candidates.

Gender-wise distribution

Among 228 selected candidates 75 (33%) were women and 153 (67%) males in ARS 2014.

ARS (Preliminary) and NET 2015

Combined ARS (preliminary) and National Eligibility Test (NET) 2015 examination was conducted from 4 to 10 December 2015 in online mode on 22 centres across



India. However, at Chennai centre examination could not be conducted due to heavy rainfall.

Recruitment of Administrative Officers and Finance & Accounts Officers

An all India open competitive examination was conducted for recruitment of 28 Administrative Officer and Finance and Account Officer posts on 23 November, 2014. Further recruitment action is under progress.

Recruitment of assistants

An all India online open competitive examination for recruitment of 270 Assistants was conducted from 5th January to 2nd February 2015. Out of 24,468 candidates, 8,302 candidates qualified for main examination. Main examination was successfully conducted on 18 October 2015.

Recruitment of Assistant Chief Technical Officer

To fill up one post of Assistant Chief Technical Officer-Agriculture Engineer (T-7-8) located at CIAE, Bhopal, a written test was conducted on 5th July 2015. Out of 113 candidates who applied for this post, only 55 candidates appeared for test. Further selection process is in progress.

Recruitment of Assistant Directors (Official Language)

An all India open competitive examination was conducted for recruitment of 11 Assistant Directors (Official Language) posts at four centers across India. 534 candidates applied for the posts and among them 172 candidates appeared in the examination which was held on 22nd November 2014. All posts have been filled.

Limited Departmental Competitive Examinations

During the period three examinations for the posts of Section Officers and Private Secretaries, Assistants and Upper Division Clerks were conducted. Details are as follows:

Category	Vacancies	Filled
Section officers and private secretaries	16	13
Assistants	8	5
Upper division clerks	3	3

Career Advancement Scheme

About 250 proposals were received from different ICAR Institutes for the promotion from Senior Scientist to the grade of Principal Scientist under Career Advancement Scheme (CAS). Interview process has been completed successfully.

REFORMS

Score card for direct recruitment

The revised proposed score card and guidelines proposed by an expert committee for direct selection for RMP and non RMP positions has been approved by the Council. ❑

(A) DEPARTMENT OF AGRICULTURAL RESEARCH AND EDUACATION

APPENDIX I

SUBJECTS ALLOCATED TO DEPARTMENT OF AGRICULTURAL RESEARCH AND EDUCATION (*KRISHI ANUSANDHAN AUR SHIKSHA VIBHAG*)

Part I

The following subjects which fall within List I of the Seventh Schedule to the Constitution of India:

1. International cooperation and assistance in the field of agricultural research and education including relations with foreign and international agricultural research and educational institutions and organizations.
2. Fundamental, applied and operational research and higher education including coordination of such research and higher education in agriculture, agro-forestry, animal husbandry, dairying, fisheries, agricultural engineering and horticulture including agricultural statistics, economics and marketing.
3. Coordination and determination of standards in institutions for higher education or research and scientific and technical institutions in so far as they relate to food and agriculture including animal husbandry, dairying and fisheries. Development of Human Resources in Agricultural Research/Extensions and Education.
4. Cess for financing to the Indian Council of Agricultural Research and the Commodity Research Programmes other than those relating to tea, coffee and rubber.
5. Sugarcane research.

Part II

For Union Territories the subjects mentioned in Part I above, so far as they exist in regard to these Territories and in addition the following subject which falls within List II of the Seventh Schedule to the Constitution of India:

6. Agricultural Education and Research.

Part III

General and Consequential:

7. Plant, animal and fish introduction and exploration.
8. All India Soil and Land Use Survey relating to research training, correlation, classification, soil mapping and interpretation.
9. Financial assistance to State Governments and Agricultural Universities in respect of agricultural research and educational schemes and programmes.
10. National Demonstrations.
11. Indian Council of Agricultural Research and its constituent Institutes, National Research Centres, Project Directorates, Bureaux and All India Coordinated Research Projects.
12. Research and Development on production and improvement of bio-fuels plants

APPENDIX II

TOTAL NUMBER OF POSTS AND NAMES OF IMPORTANT FUNCTIONARIES

Group	Designation	Sanctioned strength
A	Secretary (DARE) and DG (ICAR)	1
A	Additional Secretary (DARE) and Secretary (ICAR)	1
A	Additional Secretary and Financial Advisor	1
A	Director	1
A	Deputy Secretary	1
A	Senior Principal Private Secretary/Principal Staff Officer	1
A	Joint Director	1
A	Under Secretary	7
A	Principal Private Secretary	3
B	Assistant Director (OL)	1
B	Private Secretary	3
B	Section Officer	4
B	Assistant	5
B	Personal Assistant/Steno Grade 'C'	3
B	Junior Hindi Translator	1
C	UDC-cum-Cashier	1
C	UDC	1
C	Stenographer Grade 'D'	3
C	UDC-Hindi Typist	1
C	Staff Car Driver	2
C	LDC	1
D	Daftry	1
D	Peon	5
	Total	49

NAMES OF THE IMPORTANT FUNCTIONARIES

Sl.No.	Name	Designations
1.	Dr S. Ayyappan	Secretary (DARE) and DG (ICAR)
2.	Shri Sunil Kumar Singh	Additional Secretary and Financial Advisor
3.	Shri Chhabilendra Roul	Additional Secretary (DARE) and Secretary (ICAR)
4.	Shri Ravinesh Kumar	Director
5.	Smt Niranjan Kaur	Deputy Secretary
6.	Shri Mohinder Kumar	Senior Principal Private Secretary
7.	Shri T. Khaling	Under Secretary
8.	Smt Alka Ahuja	Under Secretary
9.	Smt Madhu Bala	Under Secretary
10.	Shri Vijay Singh	Under Secretary
11.	Shri Jitendra Misra	Under Secretary
12.	Shri P.P. Maurya	Under Secretary
13.	Shri T. B. Bhaviskar	Under Secretary
14.	Shri V. Kurien John	Principal Private Secretary
15.	Shri Sanjeev Kumar Sharma	Principal Private Secretary
16.	Dr Puran Singh	Assistant Director (OL)

APPENDIX III

ACTIVITY PROGRAMME CLASSIFICATION

The Budget Estimates (BE) of DARE (Plan, Non-Plan) for 2014–15 is ₹19,000.00 Lakh and ₹ 1,124.00 Lakh and Revised Estimates (RE) of DARE (Plan, Non-Plan) for 2014–15 is ₹ 15,401.00 Lakh and ₹ 1,039.26 respectively. The BE for 2015–16 (Pan, and Non-Plan) is ₹ 19,800.00 Lakh and ₹ 1,179.35 Lakh. The detailed break-up of these financial figures are given below in Tables 1, 2.

Table 1. Budget estimates and revised estimates of DARE/ICAR

(Rupees in lakh)

Budget head	Item	Budget Estimates 2014–2015		Revised Estimates 2014–2015		Budget Estimates 2015–2016	
		Plan	Non-Plan	Plan	Non-Plan	Plan	Non-Plan
Major Head '3451'							
090	Secretariat	–	581.00	–	478.00	–	611.00
Major Head '2415'							
80	-General						
	International Co-operation						
(80.120)	Assistance to other institutions						
02	Grant-in-Aid Central Agricultural University Bundelkhand						
(020031)	-Grants-in-Aid-General	100.00	–	5.00	–	150.00	–
(020035)	-Grants for creation of Capital assets	800.00	–	1.00	–	700.00	–
(020036)	-Grants-in-Aid-Salaries	100.00	–	50.00	–	150.00	–
(03)	-Grants-in-Aids to Central Agricultural University, Bihar						
(030031)	-Grants-in-Aids-General	100.00	–	0.34	–	200.00	–
(030035)	-Grants for creation of Capital Assets	200.00	–	0.33	–	150.00	–
(030036)	-Grants-in-Aid-Salaries	700.00		0.33	–	650.00	–
(05)	Grant in Aid to Natiional Academy of Agricultura Sciences and Indian Agricultural Universities Association						
(050031)	-Grants in Aid Genaral			156.50		250.00	
(050035	-Grants for creatio of Capital Assets					250.00	
(050036)	-Grants in Aid Salaries			43.50		100.00	
(80.798)	International Co-operation						
(010032)	India's membership contribution to Commonwealth Agricultural Bureau International (CABI)		22.95		22.95		25.00
(020032)	India's membership contribution to Consultative Group on International Aricultural Research		470.00		487.50		487.50
(040032)	India's contribution to Asia Pacific Association of Agricultural Research Institutions (APAARI)		6.30		6.11		7.30
(050032)	India's contribution to NACA		40.00		40.00		44.00
(070032)	India's contribution to Seed Testing Associations		3.50		4.25		4.25
(080032)	ISHS Belgium		0.25		0.45		0.30
Major head '2415'							
Major Head '2552' North Eastern Areas							
259	General (Agri. Res. & Edn. Schemes)						
(01)	-Grants-in-Aids to Central Agricultural University, Imphal						
010031	-Grants-in-Aids-General	1,619.00	–	1,882.55	–	2,000.00	–
010035	-Grants for creation of Capital Assets	2,930.80	–	6,347.91	–	7,600.00	–
010036	Grants-in-Aids-Salaries	7,351.30	–	6,669.54	–	7,000.00	–
02	Grant-in-Aids Central Agricultural University, Barapani						
020031	Grants in Aids General	20.00	–	34.00	–	50.00	–
020035	Grant for creation of Capital Assets	20.00	–	33.00	–	500.00	–
020036	Grants-in-Aids-Salaries	60.00	–	33.00	–	50.00	–
	Total	**19,000.00**	**1,124.00**	**15,401.00**	**1,039.26**	**19,800.00**	**1,179.35**

Table 2. Details of financial outlay
Department of Agricultural Research and Education

The gross provision for Demand No. 2 - DARE, excluding *(Rupees In crore)*

Particulars	Actuals 2013-14			Budget 2014-2015			Revised 2014-2015			Budget 2015-2016		
	Plan	Non-Plan	Total	Plan	Non-Plan	Total	Plan	Non-Plan	Total	Plan	Non-Plan	Total
Revenue	2599.97	2279.96	**4879.93**	3715.00	2429.39	**6144.39**	2500.00	2384.00	**4884.00**	3691.00	2629.00	**6320.00**
Capital	*0.00*	*0.00*	***0.00***	0.00	0.00	**0.00**	0.00	0.00	**0.00**	0.00	0.00	**0.00**
Total	**2599.97**	**2279.96**	4879.93	**3715.00**	**2429.39**	6144.39	**2500.00**	**2384.00**	4884.00	**3691.00**	**2629.00**	6320.00

A. The Budget allocations, net of recoveries and receipts, are given below: *(In crores of Rupees)*

Sl. No.	Group/Sub Group/Sub Sub Group/Scheme/Sub Scheme/ Programme/Sub Programme		Actuals 2013-2014			Budget 2014-2015			Revised 2014-2015			Budget 2015-2016		
			Plan	Non-Plan	Total	Plan	Non-Plan	Total	Plan	Non-Plan	Total	Plan	Non-Plan	Total
	Revenue		2450.80	2279.96	**4730.76**	3715.00	2429.39	**6144.39**	2500.00	2384.00	**4884.00**	3691.00	2629.00	**6320.00**
	Capital		*0.00*	*0.00*	***0.00***	0.00	0.00	**0.00**	0.00	0.00	**0.00**	0.00	0.00	**0.00**
	Total		**2461.44**	**2048.31**	**4509.75**	**3415.00**	**2314.17**	**5729.17**	**2600.00**	**2281.08**	**4881.08**	**3715.00**	**2429.39**	**6144.39**
1.	Secretariat - Economic Service	**3451**	**0.00**	**4.49**	**4.49**	**0.00**	**5.81**	**5.81**	**0.00**	**4.78**	**4.78**	**0.00**	**6.11**	**6.11**
	Agricultural Research and Education Payments to Indian Council of Agricultural Research (ICAR)													
2.	*Crop Husbandry*													
2.01	Payments of net proceeds of cess under Agricultural Produce Cess Act, 1940	2415	0.00	0.25	0.25	0.00	0.50	0.50	0.00	0.25	0.25	0.00	0.25	0.25
2.02	Other Programmes of Crop Husbandry													
2.02.01	Crop Science	2415	375.00	682.93	1057.93	458.00	737.04	1195.04	369.35	712.11	1081.46	556.00	778.59	1334.59
2.02.02	Horticulture	2415	149.00	269.40	418.40	200.00	290.96	490.96	139.35	287.48	426.83	214.00	324.80	538.80
2.02.03	Agricultural Extension	2415	540.00	3.53	543.53	522.00	3.75	525.75	459.00	3.76	462.76	570.00	3.91	573.91
2.02.04	Agricultural Education	2415	405.00	46.53	451.53	530.00	54.12	584.12	390.00	48.39	438.39	557.00	50.81	607.81
2.02.05	Economic Statistics and Management	2415	6.00	33.10	39.10	30.00	37.28	67.28	15.50	35.03	50.53	20.00	37.68	57.68
2.02.06	Agricultural Engineering	2415	55.00	91.11	146.11	82.00	96.01	178.01	62.50	95.36	157.86	87.00	109.57	196.57
2.02.07	ICAR Headquarter Administration	2415	100.00	125.02	225.02	400.00	130.30	530.30	161.00	123.11	284.11	308.00	144.27	452.27
2.02.08	National Fund for Basic, Strategic and Frontier Application Research in Agriculture	2415	110.00	0.00	110.00	121.00	0.00	121.00	58.90	0.00	58.90	130.00	0.00	130.00
2.02.09	National Agricultural Innovation Project/Externally Aided Project	2415	235.00	0.00	235.00	99.00	0.00	99.00	84.65	0.00	84.65	0.00	0.00	0.00
2.02.10	Agriculture University, Andhra Pradesh	2415	0.00	0.00	0.00	100.00	0.00	100.00	10.00	0.00	10.00	75.00	0.00	75.00
2.02.11	Horticulture University, Telengana	2415	0.00	0.00	0.00	100.00	0.00	100.00	10.00	0.00	10.00	75.00	0.00	75.00

(Table 2 continued)

(Rupees In crore)

Sl. No.	Group/Sub Group/Sub Sub Group/Scheme/Sub Scheme/ Programme/Sub Programme		Actuals 2013-2014			Budget 2014-2015			Revised 2014-2015			Budget 2015-2016		
			Plan	Non-Plan	Total	Plan	Non-Plan	Total	Plan	Non-Plan	Total	Plan	Non-Plan	Total
2.02.12	Agriculture University, Rajasthan	2415	0.00	0.00	0.00	0.00	0.00	0.00	5.00	0.00	5.00	25.00	0.00	25.00
2.02.13	Horticulture University, Haryana	2415	0.00	0.00	0.00	0.00	0.00	0.00	5.00	0.00	5.00	25.00	0.00	25.00
2.02.14	IARI type Deemed University, Asom	2415	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.00	0.10	0.00	0.00	0.00
2.02.15	IARI type Deemed University, Jharkhand	2415	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.00	0.10	0.00	0.00	0.00
Total-Other Programmes of Crop Husbandry			***1975.00***	***1251.62***	***3226.62***	***2642.00***	***1349.46***	***3991.46***	***1770.45***	***1305.24***	***3075.69***	***2642.00***	***1449.63***	***4091.63***
Total-Crop Husbandry			**1975.00**	**1251.87**	**3226.87**	**2642.00**	**1349.96**	**3991.96**	**1770.45**	**1305.49**	**3075.94**	**2642.00**	**1449.88**	**4091.88**
3.	Soil and Water Conservation													
3.01	Natural Resource Management Institutes including Agro-Forestry Research	2415	175.00	320.42	495.42	200.00	347.64	547.64	157.50	346.57	504.07	220.00	383.83	603.83
3.02	Climate Resilient Agriculture Initiative	2415	70.00	0.00	70.00	95.00	0.00	95.00	62.50	0.00	62.50	103.00	0.00	103.00
3.03	National Adaptation Fund	2415	0.00	0.00	0.00	90.00	0.00	90.00	0.19	0.00	0.19	0.00	0.00	0.00
Total-Soil and Water Conservation			***245.00***	***320.42***	***565.42***	***385.00***	***347.64***	***732.64***	***220.19***	***346.57***	***566.76***	***323.00***	***383.83***	***706.83***
4.	Animal Husbandry	2415	189.98	465.50	655.48	215.00	477.73	692.73	152.50	482.41	634.91	233.00	515.50	748.50
5.	Fisheries	2415	70.00	232.46	302.46	92.00	242.82	334.82	63.50	239.14	302.64	97.00	268.00	365.00
Total-Payments to Indian Council of Agricultural Research (ICAR)			***2479.98***	***2270.25***	***4750.23***	***3334.00***	***2418.15***	***5752.15***	***2206.64***	***2373.61***	***4580.25***	***3295.00***	***2617.21***	***5912.21***
6.	Grant in Aid to National Academy of Agricultural Sciences and Indian Agricultural Universities Association	2415	0.00	0.00	0.00	0.00	0.00	0.00	2.00	0.00	2.00	6.00	0.00	6.00
7.	Contributions to Commonwealth Agricultural Bureau, Consultative Group on International Agricultural Research and Association of Asia Pacific Agricultural Research Institute	2415	119.99	5.22	125.21	0.00	5.43	5.43	0.00	5.61	5.61	0.00	5.68	5.68
8.	Central Agricultural University, Bundelkhand	2415	0.00	0.00	0.00	10.00	0.00	10.00	2.00	0.00	2.00	10.00	0.00	10.00
9.	Central Agricultural University, Bihar	2415	0.00	0.00	0.00	10.00	0.00	10.00	0.01	0.00	0.01	10.00	0.00	10.00
10.	Lumpsum provision for projects/ schemes for the benefit of North Eastern Region and Sikkim	2552	0.00	0.00	0.00	361.00	0.00	361.00	289.35	0.00	289.35	370.00	0.00	370.00
Total-Agricultural Research and Education			***2599.97***	***2275.47***	***4875.44***	***3715.00***	***2423.58***	***6138.58***	***2500.00***	***2379.22***	***4879.22***	***3691.00***	***2622.89***	***6313.89***
11.	Actual Recoveries	2415	-149.17	0.00	-149.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Grand Total			***2450.80***	***2279.96***	***4730.76***	***3715.00***	***2429.39***	***6144.39***	***2500.00***	***2384.00***	***4884.00***	***3691.00***	***2629.00***	***6320.00***

Starting - Part D (Major Head-wise Totals)		Actuals 2013-2014			Budget 2014-2015			Revised 2014-2015			Budget 2015-2016		
		Plan	Non-Plan	Total	Plan	Non-Plan	Total	Plan	Non-Plan	Total	Plan	Non-Plan	Total
	2415	2450.80	2275.47	4726.27	3354.00	2423.58	5777.58	2210.65	2379.22	4589.87	3321.00	2622.89	5943.89
	2552	0.00	0.00	0.00	361.00	0.00	361.00	289.35	0.00	289.35	370.00	0.00	370.00
	3451	0.00	4.49	4.49	0.00	5.81	5.81	0.00	4.78	4.78	0.00	6.11	6.11
Total		**2450.80**	**2279.96**	**4730.76**	**3715.00**	**2429.39**	**6144.39**	**2500.00**	**2384.00**	**4884.00**	**3691.00**	**2629.00**	**6320.00**

(B) INDIAN COUNCIL OF AGRICULTURAL RESEARCH

APPENDIX 1

INDIAN COUNCIL OF AGRICULTURAL RESEARCH SOCIETY

i) *Minister-in-charge of the portfolio of Agriculture in the Union Cabinet- President of the Society.*

1. Shri Radha Mohan Singh — *Ex-Officio*
   Minister for Agriculture and Farmers Welfare, Government of India
   Krishi Bhavan, New Delhi-110 001

ii) *Minister of State in the Union Ministry of Agriculture dealing with the ICAR- Vice-President.*

2. Dr Sanjeev Kumar Balyan — *Ex-Officio*
   Minister of State for Agriculture and Farmers Welfare, Government of India
   Krishi Bhavan, New Delhi-110 001

iii) *Union Ministers holding charge of Finance, Planning, Science & Technology, Education and Commerce (in case the Prime Minister is holding any of these portfolios, the Minister of State in the Ministry/Department concerned)*

3. Shri Arun Jaitley — *Ex-Officio*
   Minister of Finance
   Government of India,North Block
   New Delhi-110 001
4. Shri Inderjit Singh Rao — *Ex-Officio*
   Minister of State for Planning
   Government of India,Yojna Bhawan
   New Delhi-110 001
5. Dr Harsh Vardhan — *Ex-Officio*
   Minister of Science and Technology & Earth Science, Government of India
   CSIR Building, 2 Rafi Marg
   New Delhi-110 001
6. Smt. Smriti Zubin Irani — *Ex-Officio*
   Minister of Human Resource Development
   Government of India
   Shastri Bhavan, New Delhi-110 001
7. Smt. Nirmala Sitharaman — *Ex-Officio*
   Minister of State for Commerce & Industry
   Government of India,Udyog Bhavan
   New Delhi-110 001
8. Shri Mohanbhai Kalyanjibhai Kundariya — *Ex-Officio*
   Minister of State for Agriculture and Farmers Welfare, Government of India
   Krishi Bhavan, New Delhi-110 001

iv)

ANDHRA PRADESH

9. Shri Prathipati Pulla Rao — *Ex-officio*
   Minister for Agriculture & Animal Husbandry & Fisheries,
   Government of Andhra Pradesh
   A.P. Secretariat
   Hyderabad, Andhra Pradesh-500 022

ARUNACHAL PRADESH

10. Shri Phurpa Tsering — *Ex-officio*
    Minister
    for Animal Husbandry
    Government of Arunachal Pradesh
    CM Secretariat
    Itanagar, Arunachal Pradesh-791 111.
11. Shri Tanga Byaling — *Ex-officio*
    Minister for Horticulture
    Government of Arunachal Pradesh
    CM Secretariat
    Itanagar, Arunachal Pradesh-791 111

ASOM

12. Shri Rockybul Hussain — *Ex-officio*
    Minister for Agriculture and Horticulture
    Government of Assam
    Janta Bhavan, Dispur
    Guwahati, Asom-781 006
13. Shri Khor Sing Engti — *Ex-officio*
    Minister for Animal Husbandry
    Government of Assam
    Janta Bhavan, Dispur
    Guwahati, Asom-781 0066.
14. Shri Basanta Das — *Ex-officio*
    Minister of Fisheries
    Government of Assam
    Janta Bhavan, Dispur
    Guwahati, Asom-781 006

BIHAR

15. Shri Awdhesh Kumar Singh — *Ex-officio*
    Minister for Animal Husbandry and Fisheries Resources
    Government of Bihar
    Vikas Bhavan, New Secretariat
    Bailey Road, Patna, Bihar- 800 015
16. Shri Ramvichar Rai — *Ex-officio*
    Minister for Agriculture
    Government of Bihar
    Vikas Bhavan, New Secretariat
    Bailey Road, Patna, Bihar 800 015

CHHATTISGARH

17. Shri Brijmohan Agarwal — *Ex-officio*
    Minister of Agriculture
    Animal Husbadry and Fisheries
    Government of Chhattisgarh
    Sachivalaya, Raipur (Chhattisgarh)

DELHI

18. Shri Gopal Rai — *Ex-officio*
    Minister for Development
    Delhi Secretariat, I.P. Estate
    New Delhi-110 002

GOA

19. Shri Ramesh Tawadkar — *Ex-officio*
    Minister of Agriculture, Animal Husbandry Government of Goa, Secretariat,
    Panaji, Goa-403 001
20. Shri Avertano Furtado — *Ex-officio*
    Minister for Fisheries
    Government of Goa, Secretariat,
    Panaji, Goa 403 001

GUJARAT

21. Shri Babubhai Bokhiria — *Ex-officio*
    Minister for Agriculture, Fisheries & AH
    Government of Gujarat, Ist Floor, Swarnim Sankul-I
    New Sachivalaya,
    Gandhinagar, Gujarat 382 010

HARYANA

22. Shri Om Prakash Dhankar — *Ex-officio*
    Minister for Agriculture, Fisheries & AH
    Government of Haryana,

Haryana Civil Secretariat,
Chandigarh, Haryana

HIMACHAL PRADESH

23. Shri Anil Kumar — *Ex-officio*
Minister of Animal Husbandry
Government of Himachal Pradesh
H.P. Secretariat
Shimla, Himachal Pradesh 171 002

24. Shri Rohit Thakur — *Ex-officio*
Minister for Agriculture
Government of Himachal Pradesh
H.P. Secretariat
Shimla, Himachal Pradesh 171 002

25. Smt. Vidya Stokes — *Ex-officio*
Minister for Horticulture
Government of Himachal Pradesh
H.P. Secretariat
Shimla, Himachal Pradesh 171 002

26. Shri Thakur Singh Bharmouri
Minister for Fisheries
Government of Himachal Pradesh
H.P. Secretariat
Shimla,Himachal Pradesh 171 002

JAMMU & KASHMIR

27. Mr Ghulam Nabi Lone — *Ex-officio*
Minister for Agriculture Production
Government of Jammu & Kashmir
Civil Secretariat,Jammu
Jammu & Kashmir-180 001

28. Mr Abdul Rehman Bhat (Veeri) — *Ex-officio*
Minister for Horticulture
Government of Jammu & Kashmir
Civil Secretariat,Jammu
Jammu & Kashmir-180 001

29. Mr Sajad Gani Lone — *Ex-officio*
Minister for Animal Husbandry
Government of Jammu & Kashmir
Civil Secretariat,Jammu
Jammu & Kashmir-180 001

JHARKHAND

30. Shri Randhir Singh — *Ex-officio*
Minister of Agriculture, Animal Husbandry
& Fisheries, Government of Jharkhand
Project Building HEC, Dhurva
Ranchi, Jharkhand-834 002

KARNATAKA

31. Shri Shamanoor Shivashankarappa — *Ex-officio*
Minister of Agriculture & Horticulture
Government of Karnataka
Vidhan Soudha, Bengaluru
Karnataka-560 001

32. Shri K. Abhayachandra Jain — *Ex-officio*
Minister of Fisheries
Government of Karnataka
Vidhan Soudha, Bengaluru
Karnataka-560 001

33. Shri T.B. Jayachandra
Minister of Animal Husbandry
Government of Karnataka
Vidhan Soudha, Bengaluru
Karnataka 560 001

34. Shri Krishna Byre Gowda
Minister of Agriculture
Government of Karnataka
Vidhan Soudha, Bengaluru
Karnataka 560 001

KERALA

35. Shri K.P. Mohanan — *Ex-officio*
Minister for Agriculture and
Animal Husbandry
Government of Kerala
Secretariat Annexe
Thiruvananthapuram, Kerala 695 001

36. Shri K. Babu — *Ex-officio*
Minister for Fisheries
Government of Kerala
North Block, Secretariat
Thiruvananthapuram, Kerala 695 001

MADHYA PRADESH

37. Shri Gaurishankar Chaturbhuj Bisen — *Ex-officio*
Minister of Agriculture Development
Government of Madhya Pradesh
Vallabh Bhavan
Bhopal, Madhya Pradesh 423 006

38. Sushri Kusum Mehdele — *Ex-officio*
Minister of Horticulture, Fisheries &
Animal Husbandry
Government of Madhya Pradesh
Vallabh Bhavan,Bhopal
Madhya Pradesh -423 006

MAHARASHTRA

39. Shri Eknathrao Ganpatrao Khadse — *Ex-officio*
Minister for Agriculture, Horticulture
Animal Husbandry & Fisheries
Government of Maharashtra
Mantralaya,
Mumbai, Maharashtra 400 032

MANIPUR

40. Shri Mohammed Abdul Nasir — *Ex-officio*
Minister for Agriculture and Fisheries
Government of Manipur
Secretariat
Imphal, Manipur 795 001

41. Shri Govindas Konthoujam — *Ex-officio*
Minister for Animal Husbandry
Government of Manipur
Secretariat
Imphal, Manipur-795 001

MEGHALAYA

42. Dr Mukul Sangma — *Ex-officio*
Chief Minister holding the Charge of
Agriculture, Government of Meghalaya
Meghalaya Secretariat (C)
Shillong, Meghalaya-793 001

43. Smt. Deborah C. Marak — *Ex-officio*
Minister for Animal Husbandry
Government of Meghalaya
Meghalaya Secretariat (C)
Shillong, Meghalaya-793 001

MIZORAM

44. Shri R. Lalzirliana — *Ex-officio*
Minister for Agriculture
Government of Mizoram
Aizwal, Mizoram - 796 001

45. Shri P.C. Lalthanliana — *Ex-officio*
Minister for Horticulture
Government of Mizoram
Aizwal, Mizoram 796 001

46. Shri C. Ngunlianchunga — *Ex-officio*
Minister of State for Animal Husbandry
Government of Mizoram
Aizwal, Mizoram - 796 001

47. Shri B.D. Chakma — *Ex-officio*
Minister of State for Fisheries
Government of Mizoram
Aizwal, Mizoram - 796 001

NAGALAND

48. Dr Benjongliba — *Ex-officio*
Minister of State for Agriculture

Government of Nagaland
Civil Secretariat Complex
Kohima, Nagaland 797 004

49. Shri Kejong Chang — *Ex-officio*
Minister of State for Horticulture
Government of Nagaland
Civil Secretariat Complex
Kohima, Nagaland 797 004

50. Shri S. Chubalong Kumer — *Ex-officio*
Minister of State for Animal Husbandry
Government of Nagaland
Civil Secretariat Complex
Kohima, Nagaland 797 004

51. Shri Shetoyi — *Ex-officio*
Minister of State for Fisheries
Government of Nagaland
Civil Secretariat Complex
Kohima, Nagaland 797 004

ODISHA

52. Shri Pradeep Maharathy — *Ex-officio*
Minister for Agriculture, Fisheries &
Animal Resource Development
Government of Odisha
Odisha Secretariat
Bhubaneshwar, Odisha-751 001

PUNJAB

53. Sardar Tota Singh — *Ex-officio*
Minister of Agriculture
Government of Punjab
Punjab Civil Secretariat
Chandigarh, Punjab

54. Sardar Gulzar Singh Ranike — *Ex-officio*
Minister for AH & Fisheries
Government of Punjab
Punjab Civil Secretariat
Chandigarh, Punjab

PUDUCHERRY

55. Shri M. Chandrakasu — *Ex-officio*
Minister for Agriculture
& Animal Husbandry
Government of Puducherry
Puducherry 605 001

56. Shri P. R. Siva — *Ex-officio*
Minister for Fisheries
Government of Puducherry
Puducherry 605 001

RAJASTHAN

57. Shri Prabhu Lal Saini — *Ex-officio*
Minister for Agriculture, Horticulture
Animal Husbandry & Fisheries
Government of Rajasthan
Rajasthan Secretariat
jaipur, Rajasthan 302 005

SIKKIM

58. Shri Somnath Pudyal — *Ex-officio*
Minister for Agriculture, Horticulture
Animal Husbandry & Fisheries
Government of Sikkim Secretariat
Gangtok, Sikkim 737 101

TAMIL NADU

59. Shri R. Vaithilingam — *Ex-officio*
Minister for Agriculture & Horticulture
Government of Tamil Nadu
Chennai, Tamil Nadu 600 009

60. Shri K.A. Jayapal — *Ex-officio*
Minister for Fisheries
Government of Tamil Nadu
Chennai, Tamil Nadu 600 009

61. Shri T.K.M. Chinnayya — *Ex-officio*
Minister for Animal Husbandry
Government of Tamil Nadu
Chennai, Tamil Nadu 600 009

TRIPURA

62. Shri Aghore Debbarma — *Ex-officio*
Minister for Agriculture
& Animal Resource Development
Government of Tripura
Civil Secretariat
Agartala, Tripura-799 001

63. Shri Khagendra Jamatia — *Ex-officio*
Minister for Fisheries
Government of Tripura
Civil Secretariat
Agartala, Tripura-799 001

TELANGANA

64. Shri Pocharam Srinivas Reddy — *Ex-officio*
Minister of Agriculture, Horticulture
Animal Husbandry & Fisheries
Room No.261,D-Block
Government of Andhra Pradesh
A.P. Secretariat
Hyderabad, Andhra Pradesh-500 022

UTTARAKHAND

65. Shri Harak Singh Rawat — *Ex-officio*
Minister for Agriculture & Horticulture
Government of Uttarakhand
Dehra Dun, Uttarakhand

66. Shri Pritam Singh Panwar — *Ex-officio*
Minister for Animal Husbandry & Fisheries
Government of Uttarakhand
Dehra Dun, Uttarakhand

UTTAR PRADESH

67. Shri Vinod Kumar Urf 'Pandit Singh' — *Ex-officio*
Minister of Agriculture
Government of Uttar Pradesh
UP Civil Secretariat
Lucknow, Uttar Pradesh

68. Shri Riyaz Ahmad — *Ex-officio*
Minister of State for Fisheries
Government of Uttar Pradesh
UP Civil Secretariat
Lucknow, Uttar Pradesh

69. Shri Moolchandra Chauhan
Minister of State for Horticulture
Government of Uttar Pradesh
UP Civil Secretariat
Lucknow, Uttar Pradesh

WEST BENGAL

70. Shri Arup Roy
Minister for Agriculture
Government of West Bengal
Writers' Building
Kolkata, West Bengal 700 001

71. Shri Swapan Debnath — *Ex-officio*
Minister for Animal Resources
(Independent Charge)
Government of West Bengal
Writers' Building
Kolkata, West Bengal 700 001

72. Shri Chandranath Sinha — *Ex-officio*
Minister for Fisheries
Development Department
Government of West Bengal
Writers' Building
Kolkata, West Bengal 700 001

73. Shri Krishnendu Narayan Choudhury — *Ex-officio*
Minister for Horticulture

Government of West Bengal
Writers Building
Kolkata, West Bengal 700 001

v) *Member, Niti Ayog In-charge of Agriculture.*

74. Dr Ramesh Chand
Member (Agriculture) Niti Ayog
Yojana Bhawan, New Delhi 110 001

vi) *Six members of Parliament—four elected by Lok Sabha and two elected by Rajya Sabha.*

75. Smt. Renuka Chowdhury — 2 April 2018
Member of Parliament (RS)
H.No.8-1-116, Khanapuram(V)
Khammam Urban(M), Khammam District
Andhra Pradesh 507 002

Smt. Renuka Chowdhury
Member of Parliament (RS)
76, Lodhi Estate, New Delhi 110 003

76. Shri D. Bandyopadhyay — 18 August 2018
Member of Parliament (RS)
GD - 89, Sector - III
Salt Lake, Kolkota
West Bengal 700 106

Shri D. Bandyopadhyay
Member of Parliament (RS)
C-202, SwarnaJayanti Apartments
Dr B.D. Marg, New Delhi 110 001

77. Shri Dushyant Chautala — Till the expiry of term in Lok Sabha
Member of Parliament (LS)
18, Janpath,New Delhi 110 001

78. Shri Sanjay Dhotre — -do-
Member of Parliament (LS)
AB-95, Shahjahan Road
New Delhi 110013

79. Shri Raju Shetti — -do-
Member of Parliament (LS)
226, North Avenue, New Delhi 110 001

80. Shri Ravneet Singh — -do-
Member of Parliament (LS)
28, Dr. Rajendra Prasad Road
New Delhi 110001

vii) *Director General, Indian Council of Agricultural Research.*

81. Dr S. Ayyappan — *Ex-officio*
Director General
ICAR, Krishi Bhavan, New Delhi 110 001

viii) *All Secretaries in the Ministry of Agriculture.*

82. Shri Siraj Hussain — *Ex-officio*
Secretary (Agriculture & Cooperation)
Department of Agriculture & Cooperation
KrishiBhavan, New Delhi 110 001

83. Shri Ashok Kumar Angurana — *Ex-officio*
Secretary (ADF)
Department of Animal Husbandry
Dairying & Fisheries
Krishi Bhavan, New Delhi 110 001

ix) *Secretary, Niti Ayog*

84. Shri Amitabh Kant — *Ex-officio*
CEO, Niti Ayog, Yojana Bhavan,
Sansad Marg, New Delhi 110 001

x) *Secretary, Department of Bio-Technology*

85. Prof. K. Vijay Raghavan — *Ex-officio*
Secretary, Department of Biotechnology
Block 2, 7th Floor, CGO Complex
Lodhi Road, New Delhi 110 003

xi) *Director General, Council of Scientific and Industrial Research*

86. Dr Girish Sahni — *Ex-officio*
Director General
Council of Scientific and Industrial Research
Anusandhan Bhavan
2-Rafi Ahmed Kidwai Marg, New Delhi 110 001

xii) *Chairman, University Grants Commission*

87. Prof. Ved Prakash — *Ex-officio*
Chairman
University Grants Commission
Bahadur Shah Zafar Marg
New Delhi 110 002

xiii) *Chairman, Atomic Energy Commission (or Director, Bhabha Atomic Research Centre, if nominated by the Chairman, Atomic Energy Commission).*

88. Dr Sekhar Basu — *Ex-officio*
Chairman, Atomic Energy Commission
& Secretary to the Government of India
Department of Atomic Energy
Anushakti Bhavan
Chhatrapati Shivaji Maharaj Marg
Mumbai, Maharashtra 400 001

xiv) *Member, Finance (Secretary/ Additional Secretary) in the Ministry of Finance, Government of India*

89. Shri Ajai Narayan Jha — *Ex-officio*
Special Secretary (Expenditure)
Department of Expenditure
Ministry of Finance
North Block
New Delhi 110 001

xv) *Four Vice-Chancellors of Agricultural Universities, nominated by the President.*

90. Dr Anil Kumar Singh — 18 Oct. 2017
Vice Chancellor
Rajmata Vijayaraje Scindia Krishi Vishwa Vidyalaya
Race Course Road, Gwalior
Madhya Pradesh 474002

91. Dr Madan Gopal Varshneya — 18 Aug,2017
Vice Chancellor,
Kamdhenu University,
Gandhinagar, Gujarat

92. Dr H.S. Gaur — 18 Feb,2016
Vice Chancellor,
Sardar Vallabhbhai Patel University of Agriculture & Technology,
Meerut 250110, Uttar Pradesh

93. Dr A.R. Pathak — 28 Dec, 2018
Vice Chancellor
Junagadh Agricultural University
Junagash, Gujarat 362 001

xvi) *Five Technical Representatives, namely Agricultural Commissioner, Horticultural Commissioner, Animal Husbandry Commissioner, Fisheries Development Commissioner, from the Union Ministry of Agriculture and Inspector-General of Forests, Government of Inidal*

94. Dr S.K. Malhotra
Agriculture Commissioner
Department of Agriculture & Cooperation
Ministry of Agriculture & Farmers Welfare
Krishi Bhavan
New Delhi 110 001

95. Dr S.K. Malhotra — *Ex-officio*
Horticulture Commissioner,
Department of Agriculture & Cooperation
Ministry of Agriculture.
Krishi Bhavan
New Delhi 110 001

96. Dr Suresh S. Honnappagol *Ex-officio*
Animal Husbandry Commissioner
Department of Animal Husbandry, Dairying & Fisheries,
Ministry of Agriculture,
Krishi Bhavan
New Delhi 110 001

97. Dr P. Paul Pandian *Ex-officio*
Fisheries Development Commissioner
Department of Animal Husbandry, Dairying & Fisheries, Ministry of Agriculture
Krishi Bhavan, New Delhi 110 001

98. Dr S.K. Khanduri
Inspector General of Forests (NAEB)
Minister of Environment & Forests
Paryavaran Bhawan, B-Block
CGO Complex, Lodi Road
New Delhi 110 003

xvii) *Fifteen scientists from within and outside the Council including one from the Indian Council of Medical Research*

99. Dr A. Gopalakrishnan 9 January, 2018
Director
Central Marine Fisheries Research Institute
Post Box No. 1603, Ernakulam North P.O.
Kochi (Kerala) 682 018

100. Dr D.P. Singh 9 January,2018
(Former VC, JNKVV, Jabalpur)
House No. 800, Sector-15 A
Hisar 125 001, Haryana

101. Dr G. Trivedi 9 January,2018
(Former VC, RAU, Pusa, Samastipur)
Matlupur, Via-Piar
Muzaffarpur, Bihar 843 115

102. Dr Kamala Kanta Saharia 9 January,2018
Professor (Extension Education.)
Department of Extension Education,
College of Veterinary Science, AAU,
Khanpara, Guwahati, Asom 781 022

103. Dr N.C. Gautam 9 January,2018
Vice-Chancellor
Mahatma Gandhi Chitrakoot
Gramodaya vishwavidhyalaya
Chitrakoot,
Satna 485334 (Madhya Pradesh)

104. Dr Vijay Singh Tomar 9 January,2018
Vice Chancellor
Jawaharlal Nehru Krishi Viswa Vidyalaya
Krishi Nagar, Adhartal
Jabalpur-482004, Madhya Pradesh

105. Dr K. R. Kranthi 9 January,2018
Director
Central Institute for Cotton Research
P.B.No.2, Shankarnagar P.O.,
Nagpur-440010, Maharashtra

106. Dr Umesh Chandra Sharma 9 January,2018
President, Veterinary Council of India
A-Wing, 2nd Floor, August Kranti Bhawan
Bhikaji Cama Place, New Delhi 110 066

107. Dr A.K. Singh 9 January,2018
Managing Director
National Horticultural Board
Ministry of Agriculture & Farmers
Welfare, 85, Institutional Area, Sector-18
Gurgaon (Haryana) 122 015

108. Dr Bhagwati Prasad Bhatt 9 January,2018
Director,
ICAR Research Complex for Eastern Region, ICAR Parisar
P.O.Bihar Veterinary College
Patna-800014 Bihar

109. Dr Jitendra Chauhan 9 January,2018
Head, Department of Agricultural Extension,
RBS College, Bichpuri
Agra, Uttar Pradesh 283 105

110. Dr S.S. Sengar, 9 January,2018
Dean, College of Agriculture
Korea, Chhattisgarh 497 335

111. Dr Prakash Shastri 9 January,2018
Professor (Plant Pathology)
College of Agriculture (RVSKVV)
Khandwa 450 001 (Madhya Pradesh)

112. VACANT

113. Dr Rashmi Arora, 9 January,2018
Scientist G and Head (ECD), ICMR Hqrs.,
New Delhi

xviii) *Three representatives of commerce and industry, nominated by the President.*

114. Shri Rakesh Bharti Mittal 1 Oct 2016
VC/MD, Bharti Enterprises Limited
Bharti Crescent, 1 Nelson Mandela Road
Vasant Kunj, Phase-II,
New Delhi 110 070

115. Shri Narendra Murkumbi 1 Oct,2016
Managing Director
Shree Renuka Sugars Limited
7th Floor, Devchand House
Shiv Sagar Estate,
Dr. Annie Besant Road,
Worli, Mumbai 400 018

116. Shri Jayprakash Dandegaonkar 1 Oct,2016
Vice Chairman, Maharashtra State Co-Operative Sugar Factories Federation Limited, Sakhar Bhavan, 11th Floor, Plot No. 230, Nariman Point, Mumbai (Maharashtra) 400 021

ix) *One farmer from each region of the country as mentioned in Rule 60(a) and four representatives of rural interests, nominated by the President.4 Representatives of Rural Interests*

117. Chaudhary Gyan Singh 5 March 2016
Village- Sakauti, Post- Gurukul
Narson, District-Haridwar,
Uttarakhand-247 670

118. Shri Fazle Masood 1 Oct,2016
14/627, Murad Ali Lane
Nai Basti, Lucknow
Uttar Pradesh 226 001

119. Vacant
120. Vacant
121. Vacant
122. Vacant
123. Vacant
124. Vacant

125. Shri Sudhir Kumar Bhargava
Director, Agroman Systems Pvt.Ltd.
25/2, Tardeo AC Market
Tardeo, Mumbai, Maharashtra 400 034

126. Shri Ratneshwari Prasad Singh 8 June, 2017
Village - Ratanpur,
Post - Badahrwa,
Distt. Satmadi 843 315, Bihar

127. Shri Suresh Chandel 8 April, 2018
Ex-member of Parliament,
Village - Beri, Post - Ropa
Distt,-Bilaspur. Himanchal Pradesh 174 001

128. Shri Ram Krishna Kusmaria 8 April, 2018
Ex-Agriculture Minister,
Government of Madhya Pradesh,
Village - Sakora, Post - Hinota,
Tehsil-Hata,
Distt. - Damoh, Madhya Pradesh 470 661

xx) *Four Directors of the Indian Council of Agricultural Research Institutes, nominated by the President*

129. Dr A.K. Srivastava — 21 May, 2016
Director
National Dairy Research Institute
Karnal, Haryana 132 001

130. Dr P.S. Minhas — 8 April,2018
Director
National Institute of Abiotic Stress Management
Malegaon, Baramati
Pune, (Maharashtra) 413 115

131. Dr S.M.K. Naqvi — 8 April,2018
Director
Central Sheep and Wool Research Institute
Avikanagar, P.O. Malpura
Tonk - District, Rajasthan 304501

132. Dr Bir Pal singh — 21 May,2016
Director
Central Potato Research Institute
Shimla (Himachal Pradesh)

xxi) *Secretary, Indian Council of Agricultural Research-Member-Secretary*

133 Shri Chhabilendra Roul
Addl. Secretary (DARE) & Secretary,
Indian Council of Agricultural Research
Krishi Bhavan,
New Delhi 110 001

❑

APPENDIX 2

MEMBERS OF THE GOVERNING BODY OF THE INDIAN COUNCIL OF AGRICULTURAL RESEARCH SOCIETY

Rule 35(i)
Chairman

1. Dr S. Ayyappan
   Director-General,
   Indian Council of Agricultural Research,
   Krishi Bhavan,
   New Delhi-110 001

Rule 35(ii)
***Ex-Officio* Members**
Member, Finance

2. Shri Ajay Narayan Jha — *Ex-Officio*
   Special Secretary (Expenditure)
   Department of Expenditure,
   Ministry of Finance, North Block
   New Delhi - 110 001

Rule 35(iii)
Secretary, Niti Ayog

3. Shri Amitabh Kant — *Ex-Officio*
   CEO, Niti Ayog,
   Yojana Bhavan, Sansad Marg,
   New Delhi - 110 001

Rule 35(iv)
Secretary, Agriculture

4. Shri Siraj Hussain
   Secretary (Agriculture & Cooperation)
   Department of Agriculture & Cooperation
   Ministry of Agriculture
   KrishiBhavan, New Delhi - 110 001 — *Ex-Officio*

Rule 35(v)
Secretary, Department of Animal Husbandry, Dairying & Fisheries, Ministry of Agriculture

5. Shri Ashok Kumar Angurana — *Ex-Officio*
   Secretary (ADF),
   Department of Animal Husbandry, Dairying and
   Fisheries, Ministry of Agriculture, KrishiBhavan,
   New Delhi - 110 001

Rule35(vi)
Three Scientists (including one management expert who are not employees of ICAR-nominated by the President)

6. Vacant
7. Vacant
8. Vacant

Rule 35 (vii)
Five Vice-Chancellors of Agricultural Universities-nominated by the President)

9. Dr Anil Kumar Singh — 18.10.2017
   Vice Chancellor,
   RajmataVijayarajeScindiaKrishiVishwa
   Vidyalaya,
   Race Course Road, Gwalior
   Madhya Pradesh 474 002
10. Dr H.S. Gaur — 18.02.2016
    Vice Chancellor,
    Sardar Vallabhbhai Patel University of
    Agriculture & Technology,
    Meerut 250 110, Uttar Pradesh
11. Dr Madangopal C Varshneya — 18.08.2017
    Vice Chancellor,
    Kamdhenu University,
    Gandhinagar, Gujarat 382 010
12. Dr A.R. Pathak — 28.12.2018
    Vice Chancellor
    Junagadh Agricultural University
    Junagadh-362 001, Gujarat
13. Prof. Aditya Kumar Misra — 07.09.2017
    Vice Chancellor
    Maharashtra Animal & Fishery Sciences University
    Futala Lake Road, Nagpur (Maharashtra) 440 001

Rule 35(viii)
Three Members of Parliament nominated by the President-(Two from Lok Sabha and one from Rajya Sabha)

14. Smt. Renuka Chowdhury — 02.04.2018
    Member of Parliament (RS)
    76, Lodhi Estate
    New Delhi 110 003

    Smt. Renuka Chowdhury
    Member of Parliament (RS),H.No.8-1-116
    Khanapuram(V)
    Khammam Urban(M), Khammam District
    Andhra Pradesh-507 002
15. Shri Sanjay Dhotre — 11.02.2018
    Member of Parliament
    (LS)At & Post. Paalso, (Badhe),
    Tel. Akola,
    Distt. Akola (Maharashtra) 444001

    Shri Sanjay Dhotre
    Member of Parliament (LS)
    AB-95, Shahjahan Road,
    New Delhi 110003
16. Shri Ravneet Singh — 11.02.2018
    Member of Parliament (LS)
    Village – Kotla Afghana,
    District Ludhiana- 141416

    Shri Ravneet Singh
    Member of Parliament (LS)
    H.No. 28, Dr. Rajendra Prasad Road,
    New Delhi - 110 001

Rule 35(ix)
Four Farmers/Representatives of Rural Areas nominated by the President

17. Shri Sudhir Kumar Bhargava, — 08.06.2017
    Director, Agroman Systems
    Pvt. Ltd.
    25/2, Tardeo AC Market,
    Tardeo, Mumbai (Maharashtra) 400 034
18. Shri Ratneshwari Prasad Singh — 08.04.2018
    Village- Ratanpur
    Post- Badahrwa
    Distt. Sitamarhi – 843315, Bihar
19. Shri Suresh Chandel — 08.04.2018
    Ex- Member of Parliament
    Village- Gandhi Ropa
    P.O. Beri,
    Tehsil & District (Himachal Pradesh) Bilaspur

F Preferred Contact Address:

20. Shri Suresh Chandel
    Ex- Member of Parliament
    House No. 70/5, Roura Sector-3
    Bilaspur, Himachal Pradesh
21. Dr Ram Krishna Kusmaria — 08.04.2018
    Ex- Agriculture Minister
    Govt. of Madhya Pradesh
    Village- Sakora, Post- Hinota
    Tehsil- Hata, Distt. Damoh, Madhya Pradesh

Rule 35(x)

Three Directors of Research Institutes of the Council nominated by the President

22. Dr A.K. Srivastava — 21.05.2016
    Director,
    National Dairy Research Institute
    Karnal, Haryana 132 001
23. Dr P.S. Minhas — 21.05.2016
    Director,
    National Institute of Abiotic Stress Management,
    Malegaon, Baramati
    Pune (Maharashtra) 413 115
24. Dr Bir Pal Singh
    Director — 21.05.2016
    Central Potato Research Institute
    Shimla (Himachal Pradesh) 171001

Rule 35(xi)

Four representatives of State Governments to be nominated zone-wise on a rotational basis by Director General, ICAR

25. Shri Parmesh Pandey — 15.06.2017
    Principal Secretary
    Department of Agriculture
    Government of Karnataka
    Room No. 411
    4th Floor, M.S. Building,
    Bengaluru (Karnataka) 560001
26. Shri Rajesh Verma, IAS — 15.06.2017
    Principal Secretary
    Department of Agriculture
    Government of Odisha
    Odisha Secretariat
    Bhubaneshwar (Odisha) 751001
27. Shri A.N. Solanki — 15.06.2017
    Principal Secretary
    Department of Agriculture and Co-operation,
    Government of Gujarat
    Block No. 5, First Floor
    New Sachivalaya
    Gandhinagar (Gujarat) 382010
28. Shri Amit Mishra — 15.06.2017
    Agriculture Production Commissioner,
    Department of Agriculture
    Government of Uttar Pradesh
    UP Civil Secretariat
    Lucknow (Uttar Pradesh) 226001

Rule 35(xii)

One representative of Agro and Agro-Processing Industries to be nominated by President .

29. Vacant

Rule 35(xiii)

One representative from a distinguished Non-*Governmental Organization dealing with Agriculture/ Extension nominated by President*

30. Vacant

Rule 35(xiv)

Secretary, ICAR- Member Secretary

31. Shri Chhabilendra Roul
    Additional Secretary(DARE) & Secretary, ICAR,
    KrishiBhawan,
    New Delhi- 110 001

❑

APPENDIX 3

SENIOR OFFICERS AT THE HEADQUARTERS OF THE ICAR

1. Dr S. Ayyappan
   Director General, ICAR and
   Secretary to the Government of India,
   Department of Agricultural Research and Education

2. Shri Chhabilendra Roul
   Secretary, ICAR and
   Additional Secretary to Government of India,
   Department of Agricultural Research and Education

Deputy Directors General

1. Dr A.K. Sikka (NRM)
2. Dr J.S. Sandhu (Crop Science)
3. Dr N.K. Krishna Kumar (Horticultural Science)
4. Dr K. Alagusundaram (Agricultural Engineering)
5. Dr N.S. Rathore (Agricultural Education)
6. Dr A.K. Singh (Agricultural Extension)
7. Dr Habibar Rahman (Animal Science)
8. Dr Joykrushna Jena (Fisheries Science)

O.S.D.

1. Dr (Mrs.) B. Meenakumari (Agri Edn)
2. Dr W. S. Lakra (Fy Sci.)
3. Dr R. K. Mittall (IR)

Assistant Directors General

1. Dr J.S. Chauhan (Seed)
2. Dr P.K. Chakrabarty (PP&B)
3. Dr B.B. Singh (OP)
4. Dr I.S. Solanki (F&FC)
5. Dr T. Janakiram (Hort.Sci.-I)
6. Dr S.K. Chaudhari (S&WM)
7. Dr Kanchan Kumar Singh (FE)
8. Dr R.S. Gandhi (AP&B)
9. Dr B.S. Prakash (AN&P)
10. Dr Ashok Kumar (AH)
11. Dr S.D. Singh (Inland Fisheries)
12. Dr P. Pravin (Marine Fy)
13. Dr V. P. Chahal (Extension)
14. Dr G. Venkateshwarlu (EQA&R)
15. Dr M.B. Chetti (HRD)
16. Dr P.S. Pandey (EP&HS)
17. Dr A.K. Vasisht (PIM)
18. Dr Shiv Prasad Kimothi (Cdn.)
19. Dr A.K. Vyas (HRM)
20. Dr P.K. Agrawal, ADG (NASF)

Project Director

1. Dr Rameshwar Singh

Principal Scientists

1. Dr A.K. Bawa (Principal Scientific Officer to DG, ICAR)
2. Dr A. Arunachalam (Principal Scientific Officer to DG, ICAR)
3. Dr Rajan (PP)
4. Dr S.K. Jha (OP)
5. Dr Dinesh Kumar (FFC)
6. Dr Y.P. Singh (CC)
7. Dr P.R. Chaudhary (Seeds)
8. Dr Ranvir Singh (HS)
9. Dr Manish Das (HS)
10. Dr Vikramaditya Pandey (HS)
11. Dr B.K. Pandey (HS)
12. Dr P.P. Biswas (Soils)
13. Dr S.K. Dhyani (AF)
14. Dr Adlul Islam (WM)
15. Dr B.K. Kandpal (Agro)
16. Dr M.K. Agnihotri (Controller of Exam)
17. Dr (Mrs.) Vanita Jain
18. Dr K.L. Khurana (EQA & R)
19. Dr K.P. Tripathi
20. Dr Neeraj Rana (HRD)
21. Dr (Mrs.) Nidhi Verma
22. Sh. Anil Agarwal (M Fy)
23. Dr (Mrs) Yasmeen Basade (Inland Fy)
24. Dr Devinder Dhingra (AS & PE)
25. Dr Rajan Gupta (AN)
26. Dr Vineet Bhasin (AG & B)
27. Dr (Mrs.) Jyoti Misri (AH)
28. Dr (Mrs.) Neelam Gupta (Ani Biotech)
29. Dr (Mrs.) Harjit Kaur (Agric. Extn)
30. Dr P. Adhiguru (Agric. Extn)
31. Dr N.K. Jain (HRM)
32. Dr M. K. Tripathi (PIM)
33. Dr P.K. Katiha (PIM)
34. Dr A.S. Mishra (Tech. Cdn.)
35. Dr S. Mauria (IPTM)
36. Dr Sanjeev Saxena (IPTM)

Results Framework Document (RFD) Coordination Unit

1. Dr R.K. Tomar

National Agricultural Education Project

1. Dr P. Ramasundaram, Principal Scientist and National Co-ordinator
2. Dr R.B. Sharma, Principal Scientist and National Co-ordinator

Agricultural Scientists' Recruitment Board

1. Dr Gurbachan Singh, Chairman
2. Dr V.N. Sharda, Member
3. Dr S K Bandyopadhyay, Member (up to 4.12.2015)
4. Dr A.P. Ruhil, Principal Scientist
5. Sh. J. Ravi, Secretary
6. Sh. Rajiv Mangotra, Deputy Secretary
7. Sh. S.P. Sanwal, Controller of Examination
8. Sh. K.N. Choudhary, Deputy Secretary

Directorate of Knowledge Management in Agriculture

1. Dr Rameshwar Singh, Project Director
2. Dr (Mrs.) N. Kanaka Durga, Principal Scientist
3. Dr R. Rana, Senior Scientist
4. Dr V.K. Bharti, Chief Production Officer
5. Dr Jagdeep Saxena, Editor (Hindi) and Unit Incharge
6. Dr Aruna T. Kumar, Editor (English) and Unit Incharge
7. Sh Hans Raj, Information System Officer
8. Sh S.K. Joshi, Business Manager
9. Sh Anil Sharma, Public Relations Officer

Administration

Senior Director

1. Sh. G.R. Deshbandhu (Administration)

Directors

1. Sh. Sanjay Kant, Director (Personnal)
2. Sh. N.S. Randhawa, Director (AS)
3. Sh. Devender Kumar, Director (F)
4. Sh. V.P. Kothiyal, Director (Works)
5. Sh. S.K. Mitra, Director (GAC)
6. Sh. S. Bilgrami, Director (F)

Deputy Secretaries

1. Sh. Rajiv Maheshwari
2. Sh. P. Sakthivel
3. Ms. Namrta Sharma
4. Sh. P.K. Bage
5. Sh. Kanhaiya Chaudhary
6. Sh. S.K. Behera
7. Sh. V.K. Sharma
8. Ms. Roja Sethumadhavan
9. Sh. M.K. Jain
10. Sh. Pushpendra Kumar
11. Ms. Sunita Sharma

APPENDIX 4

ICAR INSTITUTES AND THEIR DIRECTORS

National Institutes

1. Dr Trilochan Mohapatra
   Indian Agricultural Research Institute
   New Delhi 110 012
2. Dr Raj Kumar Singh
   Indian Veterinary Research Institute
   Izatnagar – 243 122, Uttar Pradesh
3. Dr A.K. Srivastava
   National Dairy Research Institute
   Karnal – 132 001, Haryana
4. Dr Gopal Krishna (Acting)
   Central Institute of Fisheries Education
   Jaiprakash Road, Seven Bungalow (Versova)
   Mumbai – 400 061, Maharashtra
5. Dr D. Rama Rao
   National Academy of Agricultural
   Research Management
   Rajendranagar, Hyderabad – 500030
   Andhra Pradesh
6. Dr P.S. Minhas
   National Institute of Abiotic Stress Management
   Malegaon, Baramati, Pune -413 115 Maharashtra
7. Dr T.R. Sharma, OSD
   Indian Institute of Agricultural
   Biotechnology, Ranchi, Jharkhand
8. Dr K.R. Kranthi, OSD
   National Institute of Biotic Stress
   Management, Raipur, Chhattisgarh
9. Dr R. Ramani, OSD
   IARI, Goriya Karma, Barhi, Dist Hazaribagh, Jharkhand

Agricultural Sciences

10. Dr S.D. Roy
    Central Island Agricultural Research
    Institute,Post Box No. 181
    Port Blair 744 101
    Andaman & Nicobar Islands
11. Dr C.B. Pandey (Acting)
    Central Arid Zone Research Institute
    Jodhpur – 342 003Rajasthan
12. Dr K.K.Singh
    Central Institute of Agricultural
    Engineering, Nabi Bagh Berasia
    Road,Bhopal – 462 038 (M.P.)
13. Dr Satish Kumar Sharma
    Central Institute of Arid Horticulture
    Bikaner 334 006, Rajasthan
14. Dr K.R. Kranthi
    Central Institute for Cotton Research
    Post Bag No. 2, Shankar Nagar P.O.
    Nagpur 440 010 (Maharashtra)
15. Dr Shailendra Rajan
    Central Institute for Sub-tropical Horticulture
    Rehmankhera, PO Kakori
    Lucknow 227 107 (Uttar Pradesh)
16. Dr Desh Beer Singh (Acting)
    Central Institute of Temperate Horticulture
    Old Air Field, Rangreth 190 007
    Jammu and Kashmir
17. Dr R.K.Gupta
    Central Institute of Post Harvest Engineering
    and Technology
    P.O. PAU Campus
    Ludhiana - 141 004, Punjab
18. Dr P.K.G. Patil (Acting)
    Central Institute for Research on Cotton Technology
    Adenwala Road, Matunga
    Mumbai – 400 019, Maharashtra
19. Dr P. Chowdappa
    Central Plantation Crops Research Institute
    Kasargod – 671 124, Kerala
20. Dr Bir Pal Singh
    (Re-employed pensioner)
    Central Potato Research Institute
    Shimla – 171 001, Himachal Pradesh
21. Dr Ch.Srinivasarao
    Central Research Institute for Dryland Agriculture
    Santoshnagar, Saidabad P.O.,
    Hyderabad – 500 059, Andhra Pradesh
22. Dr Debasis Nag
    National Institute of Research on Jute &
    Allied Fibre Technology,
    12, Regent Park, Kolkata – 700 040, West Bengal
23. Dr A.K. Nayak (Acting)
    National Rice Research Institute
    Cuttack – 753 006, Odisha
24. Dr D.K. Sharma
    Central Soil Salinity Research
    Institute,Zarifa Farm, Kachhwa
    Road,Karnal – 132 001, Haryana
25. Dr P.K. Mishra
    Indian Institute of Soil & Water Conservation
    218, Kaulagarh Road
    Dehra Dun – 248 195, Uttra Khand
26. Dr D. Damodar Reddy
    Central Tobacco Research Institute,
    Rajahmundry – 533 105 Andhra Pradesh
27. Dr S.K. Chakrabarti
    Central Tuber Crops Research
    Institute,Sreekariyam,
    Thiruvananthapuram-695 017, Kerala
28. Dr N.P. Singh
    Central Coastal Agricultural Research
    Institute,Ela, Old Goa, North Goa 403 402 Goa
29. Dr B.P. Bhatt
    ICAR Research Complex for Eastern Region
    ICAR Parisar,
    P.O. Bihar Veterinary College
    Patna – 800 014, Bihar
30. Dr S.V. Ngachan
    ICAR Research Complex for NEH
    Region, Umroi Road, Umiam, Ri-Bhoi
    Meghalaya – 793 103
31. Dr U.C. Sud
    Indian Agricultural Statistics Research Institute
    Library Avenue, Pusa Campus
    New Delhi – 110 0012
32. Dr P.K. Ghosh
    Indian Grassland & Fodder Research Institute
    Pahuj Dam, Gwalior Road
    Jhansi – 284 003, Uttar Pradesh
33. Dr M. Anandraj (Additional Charge)
    Indian Institute of Horticultural Research
    Hessaraghatta Lake Post
    Bengaluru – 560 089, Karnataka
34. Dr Narendra Pratap Singh
    Indian Institute of Pulses Research
    Kanpur – 208 024, Uttar Pradesh
35. Dr Ashok Kumar Patra
    Indian Institute of Soil Sciences
    Nabi Bagh, Berasia Road,
    Bhopal – 462 038, Madhya Pradesh
36. Dr M. Anandraj
    Indian Institute of Spices Research
    Marikunnu P.O., Calicut - 673 012 Kerala
37. Dr A.D. Pathak (Acting)
    Indian Institute of Sugarcane Research
    Rai Bareilly Road, P.O. Dilkusha
    Lucknow – 226 002, Uttar Pradesh
38. Dr K.K. Sharma (Acting)
    Indian Institute of Natural Resins and Gums
    Namkum, Ranchi – 834 010, Jharkhand

39. Dr Bijendra Singh
Indian Institute of Vegetable
Research,PB No. 01,
PO Jakhini, Shahanshapur
Varanasi 221 005 (Uttar Pradesh)
40. Dr Bakshi Ram
Sugarcane Breeding Institute
Coimbatore 641 007, Tamil Nadu
41. Dr A. Pattanayak
Vivekanand Parvatiya Krishi
Anusandhan Sansthan
Almora 263 601, Uttrakhand
42. Dr P.G. Karmakar
Central Research Institute for Jute
& Allied Fibres, Barrackpore, Kolkata 700120
43. Dr J.P. Singh (Acting)
Indian Institute of Farming System Research,
Modipuram, Meerut 250 110, Uttar Pradesh
44. Dr O.P. Yadav
Indian Institute of Maize Research
Indian Agricultural Research
Institute,Pusa, New Delhi 110 012
45. Dr Ravi Kumar Mathur
Indian Institute of Oil Palm Research
Pedavegi 534 450, West Godavari, Andhra Pradesh
46. Dr K.S. Varaprasad
Indian Institute of Oilseeds Research
Rajendranagar, Hyderabad 500 030 Andhra Pradesh
47. Dr V. Ravindra Babu
Indian Institute of Rice Research
Rajendranagar, Hyderabad 500 030 Andhra Pradesh
48. Dr (Mrs.) Indu Sharma
Indian Institute for Wheat and Barley Research
P. Box No. 158, Agrasain Marg
Karnal 132 001, Haryana
49. Dr S.K. Ambast
Indian Institute of Water Management,
Opposite Rail Vihar, Chandersekharpur
Bhubaneshwar, Odisha 751 023
50. Dr S.K. Srivastava (Acting)
Central Institute for Women in Agriculture
Plot No.50, Mauza-Jokalandi
P.O. Baramunda, Bhubaneshwar 751 003 Odisha
51. Dr O.P. Chaturvedi
Central Agro-Forestry Research Institute
Near Pahuj Dam
Jhansi 284 003, Uttar Pradesh
52. Dr M.S. Ladaniya
Central Citrus Research Institute
P.B. No. 464, Shankar Nagar P.O.
Amravatcoad, Nagpur 440 010
Maharashtra
53. Dr P.S. Birthal (Acting)
National Institute of Agricultural Economics &
Policy Research
P.B. No. 11305, DPS Marg,
Pusa, New Delhi 110 012.
54. Dr T.G. Nageswara Rao (Acting)
Indian Institute of Millets Research,
Rajendranagar, Hyderabad, Andhra Pradesh 500 030

Animal Sciences and Fisheries

55. Dr Jag Mohan Kataria
Central Avian Research Institute
Izatnagar, Bareilly, Uttar Pradesh 243 122
56. Dr Inderjeet Singh
Central Institute for Research on Buffaloes
Sirsa Road, Hisar 125 001,Haryana
57. Dr. Satish Kumar (Acting)
Central Institute of Research on
Goats,Makhdoom,
Mathura 281 122 (Uttar Pradesh)
58. Dr V.R. Suresh (Acting)
Central Inland Fisheries Research Institute
Barrackpore, West Bengal 700 120
59. Dr K.K. Vijayan
Central Institute of Brackishwater Aquaculture
75, Santhome High Road
Raja Annamalai Puram
Chennai (Kerala) 600 028
60. Dr Ravishankar C.N.
Central Institute of Fisheries Technology
Willingdon Island, Matsyapuri P.O.
Cochin 682 029, Kerala
61. Dr. P. Jayasankar
Central Institute of Freshwater
Aquaculture,
Kausalyaganga, Bhubaneshwar
Khurda 751 002, Odisha
62. Dr A. Gopalakrishnan
Central Marine Fisheries Research Institute
P.B. No. 1603, Ernakulam North
P.O.,Kochi , Kerala 682 018
63. Dr S.M.K. Naqvi
Central Sheep & Wool Research
Institute, Avikanagar 304 501, Distt.
Tonk, Rajasthan
64. Dr Raghevendra Bhatta,
National Institute of Animal Nutrition & Physiology
Adugodi, Bengaluru (Karnataka) 560 030
65. Dr Vijendra Pal Singh
National Institute of High Security
Animal Diseases, Anand Nagar
Bhopal 462021
67. Dr B.R. Shome
National Institute of Veterinary
Epidemiology and Disease Informatics
H.A. Farm Post, Hebbal
Bengaluru 560 024 (Karnataka)
68. Dr Birham Prakash
Central Institute for Research on
Cattle,P.B. No. 17, Grass Farm Road
Meerut Cantt. 250 001 (Uttar Pradesh)

APPENDIX 5

NATIONAL BUREAUX AND THEIR DIRECTORS

Agricultural Sciences

1. Dr Abraham Verghese
   National Bureau of Agricultural Insect Resources,P.B. No. 2491, H.A. Farm Post, Bengaluru, (Karnataka) 560 024
2. Dr S.K. Sharma (Acting)
   National Bureau of Agriculturally Important Micro-organisms,P.B. No. 6, Kusmaur,Maunath Bhanjan (Uttar Pradesh) 275 101
3. Dr K.C. Bansal
   National Bureau of Plant Genetic Resources, Pusa Campus, New Delhi110 012
4. Dr Surendra Kumar Singh
   National Bureau of Soil Survey and Land Use Planning, Shankar Nagar, P.O. Amravati Road, Nagpur 440 010 (Maharashtra)

Animal Sciences

5. Dr Arjava Sharma
   National Bureau of Animal Genetic Resources,P.B. No. 129, G.T. Road Bye Pass, Karnal (Haryana) 132 001
6. Dr Rehana Abidi
   Director (Acting)
   National Bureau of Fish Genetic Resources, Canal Ring Road, P.O. Dilkusha, Lucknow (Uttar Pradesh) 226 002

APPENDIX 6

PROJECT DIRECTORATES, ATARI AND THEIR DIRECTORS

Agricultural Sciences

1. Dr Radhakrishnan T.
   Directorate of Groundnut Research,
   Post Box No. 5, Ivnagar Road,
   Junagadh 362 001, Gujarat
2. Dr Dhiraj Singh
   Directorate of Rapeseed - Mustard
   Research, Sewar,
   Bharatpur 321 303, Rajasthan
3. Dr S. Rajendra Prasad,
   Directorate of Seed Research
   P.B. No. 11, Kusmaur, P.O. Kaithauli,
   Mau Nath Bhanjan – 275 101 (UP)
4. Dr V.S. Bhatia
   Directorate of Soybean Research
   Khandwa Road,
   Indore 452 017, Madhya Pradesh
5. Dr A.R. Sharma
   Directorate of Weed Research,
   Maharajpur, Adhartal,
   Jabalpur 482 004, Madhya Pradesh
6. Dr P.L. Saroj
   Directorate of Cashew Research
   Darbe, P.O. Puttur 574 202,
   Dakshina Kannada Karnataka.
7. Dr K. V. Prasad
   Directorate of Floriculture Research
   Pune
8. Dr Jitendra Kumar
   Directorate of Medicinal & Aromatic
   Plants Research,
   Boriavi, Anand 387 310,
   Gujarat
9. Dr Ved Prakash Sharma
   Directorate of Mushroom Research
   Chambaghat,
   Solan (Himachal Pradesh) 173 213
10. Dr Jai Gopal
    Directorate on Onion and Garlic
    Research,
    Rajgurunagar, Pune 410 505,
    Maharashtra
11. Dr Rameshwar Singh
    Project Directorate of Knowledge Management
    in Agriculture
    Krishi Anusandhan Bhavan I
    New Delhi 110 012

Animal Sciences

12. Dr B. Pattnaik
    Directorate of Foot-and Mouth-Disease
    IVRI Campus, Mukteshwar 263 138
    (Uttra Khand)
13. Dr R.N. Chatterjee
    Directorate of Poultry Research,
    Rajendranagar, Hyderabad 500 030
    Andhra Pradesh
14. Dr Atul Kumar Singh
    Directorate of Coldwater Fisheries
    Research, Anusandhan Bhawan,
    Industrial Area, Bhim Tal 263 136,
    Uttrakhand

Others

15. Dr (Mrs.) Ravinder Kaur
    Water Technology Centre, IARI
    New Delhi 110012

Knowledge Management

16. Dr Rameshwar Singh
    Project Director
    Directorate of Knowledge Management in Agriculture
    KAB-I, Pusa Campus
    New Delhi 110012

Agriculture Technology Application Research Institutes

17. Dr Rajbir Singh
    Agricultural Technology Application
    Research Institute,Zone-I, PAU
    Campus, Ludhiana 141004
    Punjab
18. Dr Ajoy Kumar Singh
    Agricultural Technology Application
    Research Institute,Zone-II,
    Bhumi Vihar, Block-GB,
    Sector-III, Salt Lake,
    Kolkata-700097 West Bengal
19. Dr A.K. Tripathi (Acting)
    Agricultural Technology Application
    Research Institute, Zone-III, TOP,
    Umroi Road, Barapani - 793103
    Meghalaya
20. Dr U.S. Gautam
    Agricultural Technology Application
    Research Institute,Zone-IV,
    G.T. Road, Rawatpura,
    Near Vikas Bhawan, Kanpur-208002
    Uttar Pradesh
21. Dr Y.G. Prasad
    Agricultural Technology Application
    Research Institute, Zone-V, CRIDA
    Complex, Santoshnagar,
    Hyderabad - 500 059, Andhra Pradesh
22. Dr P.P. Rohilla (Acting)
    Agricultural Technology Application
    Research Institute, Zone-VI, CAZRI
    Campus,
    Jodhpur - 342003 Rajasthan
23. Dr Anupam Mishra
    Agricultural Technology Application
    Research Institute, Zone-VII, JNKVV
    Campus, Jabalpur-484002
    Madhya Pradesh
24. Dr Sreenath Dixit
    Agricultural Technology Application
    Research Institute, Zone-VIII,
    ICAR Transfer of Technology Project,
    MRS HA Farm Post, Hebbal,
    Bengaluru - 560030, Karnataka

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APPENDIX 7

NATIONAL RESEARCH CENTRES AND THEIR DIRECTORS

Agricultural Sciences

1. Dr B. Padmanaban (Acting)
   National Research Centre for Banana,
   Thogamalai Road, Thayanur Post,
   Thiruchirapalli – 620 102, Tamil Nadu
2. Dr S.D. Swant
   National Research Centre for Grapes,
   P.B. No. 3, Manjri Farm Post,
   Solapur Road, Pune - 412 307,
   Maharashtra
3. Dr Chirantan Chattopadhyay
   National Research Centre for Integrated
   Pest Management,
   LBS Building, Pusa Campus,
   New Delhi – 110 012.
4. Dr Vishal Nath
   National Research Centre for Litchi
   Mushahari Farm, Mushahari,
   Muzaffarpur – 842 002, Bihar
5. Dr D. R. Singh
   National Research Centre for Orchids,
   Pakyong,
   Gangtok – 737 106Sikkim
6. Dr T.R. Sharma
   National Research Centre on Plant
   Biotechnology, L.B.S. Building,
   Pusa, New Delhi – 110 012.
7. Dr R.K. Pal
   National Research Centre on
   Pomegranate,
   NH-9, Byepass Road, Shelgi
   Sholapur – 413006 Maharashtra
8. Dr Balraj Singh
   National Research Centre on Seed Spices,
   Tabiji – 305 206, Ajmer, Rajasthan
9. Dr B.P. Bhat
   NRC Integrated Farming System
   Motihari (Bihar)

Animal Sciences and Fisheries

10. Dr N.V. Patil
    National Research Centre on Camel
    Jorbeer, P.B. No. 07
    Bikaner – 334 001, Rajasthan
11. Dr B.N. Tripathi
    National Research Centre for Equines,
    Hissar – 125 001, Haryana
12. Dr V.V. Kulkarni
    National Research Centre on Meat,
    Chengicherla, P.B. No. 19, Uppal PO,
    Hyderabad – 500 039 Andhra Pradesh
13. Dr Abhijit Mitra
    National Research Centre for Mithun,
    Jharnapani, P.O. Medziphema– 797 106,
    Nagaland
14. Dr D. K. Sarma
    National Research Centre on Pig,
    Rani, Guwahati – 781 131,
    Assam
15. Dr S.M. Deb
    National Research Centre on Yak,
    Dirang, West Kameng – 790 101
    Arunachal Pradesh

APPENDIX 8

ALL INDIA CO-ORDINATED RESEARCH/NETWORK RESEARCH/OTHERS/PROJECTS

1. All India Co-ordinated Research Project (AICRP) on Maize, New Delhi
2. AICRP on Nematodes in Cropping System, New Delhi
3. All India Coordinated Rice Improvement Project, Hyderabad
4. AICRP on Chickpea, Kanpur
5. AICRP on MULLaRP, Kanpur
6. AICRP on Pigeon Pea, Kanpur
7. AICRP on Wheat & Barley, Karnal
8. AICRP on Forage Crops and Utilization, Jhansi
9. AICRP Sorghum, Hyderabad
10. AICRP on Pearl Millets, Jodhpur
11. AICRP on Small Millets, Bangalore
12. AICRP on Sugarcane, Lucknow
13. AICRP on Cotton, Coimbatore
14. AICRP on Groundnut, Junagarh
15. AICRP on Soybean, Indore
16. AICRP on Rapeseed & Mustard, Bharatpur
17. AICRP on Oilseed, Hyderabad
18. AICRP on Linseed, Kanpur
19. AICRP on Sesame and Niger, Jabalpur
20. AICRP on Biocontrol of Crop Pests, Bengaluru
21. AICRP - Honeybees and Pollinators, New Delhi
22. AICRP NSP(Crops), Mau
23. AICRP Fruits (Tropical and Sub Tropical), Bengaluru
24. AICRP Arid Zone Fruits, Bikaner
25. AICRP Mushroom, Solan
26. AICRP Vegetables, Varanasi
27. AICRP Potato, Shimla
28. AICRP Tuber Crops, Thiruvanthapuram

29. AICRP Palms, Kasargod
30. AICRP on Cashew, Puttur
31. AICRP Spices, Calicut
32. AICRP Floriculture, Pune
33. AICRP on Micro Secondary & Pollutant Elements in Soils and Plants, Bhopal
34. AICRP on Soil Test Crop Response, Bhopal
35. AICRP on Long Term Fertilizer Experiments, Bhopal
36. AICRP on Salt Affected Soils & use of Saline Water, Karnal
37. AICRP on Irrigation Water Management Research, Bhubaneshwar
38. AICRP Dryland Agriculture, Hyderabad
39. AICRP on Agro-meteorology, Hyderabad
40. AICRP on Integrated Farming System, Modipuram
41. AICRP on Agroforestry, Jhansi
42. AICRP on Weed Management, Jabalpur
43. AICRP on Farm Implements and Machinery, Bhopal
44. AICRP on Ergonomics and Safety in Agriculture, Bhopal
45. AICRP on Energy in Agriculture and Agro based Industries, Bhopal
46. AICRP on Utilization Animal Energy, Bhopal
47. AICRP on Plasticulture Engineering and Technology, Ludhiana
48. AICRP on Post-Harvest Engineering and Technology, Ludhiana
49. AICRP on Goat Improvement, Mathura
50. AICRP on Improvement of Feed Sources & Nutrient Utilisation, Bengaluru
51. AICRP on Cattle Research, Meerut
52. AICRP Foot & Mouth, Mukteshwar
53. AICRP on Poultry, Hyderabad
54. AICRP ADMAS, Bengaluru
55. AICRP on Pig, Guwahati
56. AICRP Home Science

Network Research Projects

1. AIC Research Network on Potential Crops, New Delhi
2. Network Project on Transgenics
3. AINP on Soil Arthropod Pests, Durgapura, Rajasthan
4. AINP on Agricultural Acarology
5. AINP on Pesticides Residues, New Delhi
6. AINP on Arid Legumes, Kanpur
7. All India Network Research Project on Tobacco, Rajamundry
8. AINP on Jute and Allied Fibres, Barrackpore
9. AINP on Vertebrate Pest Management, Jodhpur
10. Network on Insect Biosystematics, New Delhi/Bengaluru
11. Application of Micro-organisms in Agriculture and Allied Sectors (AMAAS) +Microbial Genomic Resources repository network, Mau
12. Network O&G (included in Directorate)
13. Network on Medicinal& Aromatic Plants, Anand
14. AINP on Biofertilizer, Bhopal
15. Network Programme on Organic Farming, Modipuram
16. Network project on Harvesting, Processing and Value Addition of Natural Resins & Gums, Ranchi
17. Network Project on Conservation of Lac Insect Genetic Resources, Ranchi
18. Network project on Animal Genetic Resources, Karnal
19. Network on Sheep Improvement, Avikanagar
20. Network Project on Buffalo Improvement, Hissar
21. Network on Gastro Intestinal Parasitism, Izatnagar
22. Network on Haemorrhagic Septcamia, Izatnagar
23. Network Programme Blue Tongue Disease, Izatnagar
24. All India Network Program on Neonatal Mortality in Farm Animals(NNM), Izatnagar
25. All India Network Program on Diagnostic Imaging and Management of Surgical Condition in Animals, Izatnagar

Others

1. Technology Mission on Cotton (MM-I), Nagpur
2. Technology Mission on Jute(MM-I), Barrackpore
3. Seed Production in Agricultural Crops and Fisheries, Mau
4. National Innovation in Climate Resilient Agriculture, Hyderabad (under CRIDA Hyderabad)
5. Sheep Seed Project, Avikanagar
6. Goat Seed Project (in CIRG)
7. Veterinary Type Culture (as an integral part of NRC), Hisar
8. Poultry Seed Project, Hyderbad
9. Mega Seed Project on Pig, Guwahati
10. Krishi Vigyan Kendras
11. Strengthening and Development of Higher Agril. Education in India
12. CAU Imphal + CAU Barapani
13. Rani Lakshmi Bai CAU, Jhansi
14. RCAU Samastipur, Bihar
15. DARE(NAAS & IAUA)
16. Strengthening of ICAR Headquarters
17. National Agriculture Innovation Fund (NAIF), New Delhi
18. Attracting and Retaining Youth in Agriculture (ARYA)
19. National Agricultural Science Fund, KABJ, New Delhi 110 012

APPENDIX 9

AGRICULTURAL UNIVERSITIES

1. Acharya NG Ranga Agricultural University
   Rajendranagar, Hyderabad (Andhra Pradesh) 500 030
2. Agriculture University Mandor
   Jodhpur (Rajasthan) 342 304
3. Agriculture University Borkhera
   Kota (Rajasthan) 324 001
4. Anand Agricultural University
   Anand (Gujarat) 388 110
5. Assam Agricultural University
   Jorhat (Asom) 785 013
6. Bidhan Chandra Krishi Viswavidyalaya
   Mohanpur, Nadia (West Bengal) 741 252
7. Bihar Agricultural University
   Sabour, Bhagalpur (Bihar) 813 210
8. Birsa Agricultural University
   Kanke, Ranchi (Jharkhand) 834 006
9. Chandra Shekar Azad University of Agriculture & Technology
   Kanpur (Uttar Pradesh) 208 002
10. Chaudhary Charan Singh Haryana Agricultural University
    Hisar (Haryana) 125 004
11. Chhattisgarh Kamdhenu Vishwavidyalaya
    Anjora, Durg (Chhatisgargh) 491 001
12. CSK Himachal Pradesh Krishi Vishvavidyalaya,
    Palampur (Himachal Pradesh) 176 062
13. Dr Balasaheb Sawant Konkan Krishi Vidyapeeth
    Dapoli, Ratnagiri (Maharashtra) 415 712
14. Dr Panjabrao Deshmukh Krishi Vidyapeeth
    Krishi Nagar, Akola (Maharashtra) 444 104
15. Dr YSR Horticultural University
    Venkataramannagudem, P.B. No. 7,
    West Godavari Distt. (Andhra Pradesh) 534 101
16. Dr YS Parmar Univ of Horticulture & Forestry
    Nauni, Solan (Himachal Pradesh) 173 230
17. Govind Ballabh Pant University of Agriculture and Technology
    Pantnagar, Udham Singh Nagar (Uttara Khand) 263 145
18. Guru Angad Dev Veterinary and Animal Sciences University
    Firozpur Road, Ludhiana (Punjab) 141 004
19. Indira Gandhi Krishi Vishwavidyalaya
    Krishak Nagar, Raipur (Chhatisgargh) 492 006
20. Jawaharlal Nehru Krishi Viswa Vidyalaya
    Krishi Nagar, Adhartal, Jabalpur (Madhya Pradesh) 82 004
21. Junagadh Agricultural University
    Near Motibagh, Vanthali Road, Junagarh - 362 001 (GJ)
22. Kamdhenu University,
    Gandhinagar (Gujarat) 382 010
23. Karnataka Veterinary, Animal & Fisheries Sciences University
    PB No. 6, Nandinagar, Bidar - 585 401 (KTK)
24. Kerala Agricultural University
    Vellanikkara, Thrissur (Kerala) 680 656
25. Kerala University of Fisheries and Ocean Studies
    Papangad P.O., Kochi (Kerala) 682 506
26. Kerala Veterinary and Animal Sciences University
    Pookode, Lakkidi P.O., Wayanand (Kerala) 673 576
27. Lala Lajpat Rai University of Veterinary & Animal Sciences
    Hisar (Haryana) 125 004
28. Maharana Pratap University of Agriculture & Technology
    Udaipur 313 001 (Rajasthan)
29. Maharashtra Animal and Fishery Sciences University
    Futala Road, Telangkhedi, Nagpur - 440 001 (Maharashtra)
30. Mahatma Phule Krishi Vidyapeeth
    Rahuri, Ahmednagar - 413 722 (Maharashtra)
31. Manyavar Shri Kanshiram Ji University of Agriculture and Technology
    Chilla Road, Banda (Uttar Pradesh)210 001
32. Nanaji Deshmukh Pashu Chikitsa Vigyan Vishvavidyalaya
    South Civil Lines, Jabalpur (Madhya Pradesh) 482 001
33. Narendra Deva University of Agriculture and Technology
    Kumarganj, Faizabad (Uttar Pradesh) 224 229
34. Navsari Agricultural University,
    Eru Char Rasta, Navsari (Gujarat) 396 450
35. Orissa University of Agriculture and Technology
    Bhubaneswar (Odisha) 751 003
36. Prof. Jayashankar Teleangana State Agricultural University
    Rajendranagar, Hyderabad (Telengana) 500 030
37. Punjab Agricultural University
    Firozpur Road, Ludhiana (Punjab) 141 004
38. Rajasthan University of Veterinary and Animal Sciences
    Bijey Bhavan Place Complex (Pt Deen Dayal circle)
    Bikaner (Rajasthan) 334 001
39. Rajendra Agricultural University
    Pusa, Samastipur (Bihar) 848 125
40. Rajmata Vijayaraje Scindia Krishi Vishvwa Vidhyalaya
    Race Course Road, Gwalior (Madhya Pradesh) 474 002
41. Sardar Ballabh Bhai Patel Univ. of Agricutlure & Technology
    Roorkee Road, Modipuram, Meerut (Uttar Pradesh) 250 110
42. Sardarkrushinagar Dantiwada Agricultural University
    Sardarkrushinagar, Dantiwada (Gujarat) 385 506
43. Sher-e-Kashmir University of Agricultural Sciences & Technology
    Shalimar Campus, Srinagar(Jammu and Kashmir) 190 025
44. Sher-e-Kashmir Univ of Agricultural Sciences & Technology,
    Main Campus, Chatha,
    Jammu (Jammu and Kashmir) 180 009
45. Sri Karan Narendra Agriculture University
    Jobner (Rajasthan) 303 329
46. Sri Konda Laxman Teleangana State Horticulture University
    Rajendra Nagar, Hyderabad (Telengana) 500 030
47. Sri P. V. Narasimha Rao Telengana State University for Veterinary, Animal and Fisheries Science
    Rajendra Nagar, Hyderabad (Telengana) 500 030
48. Sri Venkateswara Veterinary University
    Tirupati (Andhra Pradesh) 517 502
49. Swami Keshwanand Rajasthan Agricultural University
    Beechwal, Bikaner (Rajasthan) 334 006
50. Tamil Nadu Agricultural University
    Lawley Road, Coimbatore (Tamil Nadu) 641 003
51. Tamil Nadu Fisheries University
    First Line Beach Road,
    Nagapattinam (Tamil Nadu) 611001
52. Tamil Nadu Veterinary & Animal Sciences University
    Madhavaram Milk Colony Campus
    Chennai (Tamil Nadu) 600 051
53. University of Agricultural Sciences
    GKVK Campus, Bengaluru (Karnataka) 560 065
54. University of Agricultural and Horticultural Sciences
    No. 126, Navile, Shimoga (Karnataka) 577 204
55. University of Agricultural Sciences
    PB No. 329, Raichur (Karnataka) 584 102
56. University of Agricultural Sciences
    Yettinagudda Campus, Krishi Nagar
    Dharwad (Karnataka)580 005

57. University of Horticultural Sciences
Bagalkot (Karnataka) 587 103
58. UP Pandit Deen Dayal Upadhaya Pashu Chikitsa Vigyan Vishwa Vidhyalaya Evam Go Anusandhan Sansthan
Mathura (Uttar Pradesh) 281 001
59. Uttar Banga Krishi Viswavidyalaya
P.O. Pundbari, Cooch Behar - 736 165 (West Bengal)
60. Uttarakhand University of Horticulture and Forestry
Bharsar, Pauri Garhwal - 246 123 (Uttara Khand)
61. Vasantrao Naik Marathwada Krishi Vidapeeth
Parabhani (Maharashtra) 431 402
62. West Bengal University of Animal & Fishery Sciences
KB Sarani, Kolkata (West Bengal) 700 037

Deemed University

1. Indian Agricultural Research Institute
Pusa, New Delhi - 110 012.
2. Central Institute of Fisheries Education
Versova, Andheri (West)
Mumbai (Maharashtra) 400 061
3. Indian Veterinary Research Institute
Izatnagar, Barielly (Uttar Pradesh) 243 122
4. National Dairy Research Institute
Karnal (Haryana) 132 001
5. Sam Higginbottom Institute of Agriculture, Technology & Sciences
Rewa Road, Allahabad (Uttar Pradesh) 211 007

Central Agricultural University

1. Central Agricultural University
Iroisemba Imphal (Manipur) 795 004
2. Rani Lakshmi Bai Central Agricultural University
Jhansi (Uttar Pradesh).

Central Universities with Agriculture Faculty

1. Aligarh Muslim University
Aligarh (Uttar Pradesh) 202 002
2. Banaras Hindu University
Varanasi (Uttar Pradesh) 221 005
3. Nagaland University
Lumani (Nagaland)
4. Visva Bharti University
Shanti Niketan, Birbhum (West Bengal) 731 235

APPENDIX 10

Total number of employees in the ICAR and its research institutes and number of Scheduled Castes, Scheduled Tribes and Other Backward Classes

S.No.	Class of post	Total posts sanctioned	Total employees in position	SC employees		ST employees		OBC employees	
				No.	% to total employees	No.	% to Total employees	No.	% to total employees
1.	**Scientific Posts**								
a.	Scientist	4,397	4,059	531	13.08	213	5.25	721	17.76
b.	Senior Scientist	1,159	948	88	9.28	17	1.79	152	16.03
c.	Principal Scientist	757	645	61	9.45	5	0.78	50	7.75
d.	RMP Scientist	172	137	3	2.19	1	0.73	2	1.45
	Total	**6,485**	**5,789**	**683**	**11.79**	**236**	**4.08**	**925**	**15.98**
2.	**Technical Posts**								
a.	Category I	3,993	2,870	540	18.82	282	9.83	393	13.69
b.	Category II	2,650	2,205	357	16.19	146	6.62	312	14.15
c.	Category III	514	479	97	20.25	24	5.01	65	13.57
	Total	**7,157**	**5,554**	**994**	**17.90**	**452**	**8.14**	**770**	**13.86**
3.	**Administration Posts**								
(a)	Category "A" posts: Senior Registrar/Director/Dy. Secretary/Under Secretary/ CAOs/SAOs/AOs/ CF&AO/SF&AO/F&AO/Legal Adviser/Director (OL)/ DD(OL)/AD(OL)PPS	336	281	1	18.15	15	5.34	14	4.98
(b)	Category "B" posts: AF&AO/AAO/PS/SO/AD(OL)/ ALA/Assistant/PA/Sr. Sales Assistant/JAO/ALA	1,239	919	188	20.45	81	8.81	75	13.57
(c)	Category "C" posts: UDC/Steno/LDC	3,302	2,590	445	17.18	195	7.53	318	12.28
	Total	**4,877**	**3,790**	**684**	**18.04**	**291**	**7.68**	**407**	**10.74**
4.	**Supporting skilled-Staff**	**8,419**	**5,487**	**1574**	**28.69**	**458**	**8.34**	**729**	**13.29**

APPENDIX 11

ICAR AWARDS

AWARDS	AWARDEES
Sardar Patel Outstanding ICAR Institution Award 2014	**ICAR's Large Institutes** Central Research Institute for Dryland Agriculture, Hyderabad (Telengana) 502 324 **ICAR's Small Institutes** National Research Centre on Equines, Hisar (Haryana) 125 001 **SAUs and DUs** Assam Agricultural University, Jorhat (Asom) 785 013
Chaudhary Devi Lal Outstanding All India Coordinated Research Project Award 2014	**1. Best AICRP** All India Coordinated Research Project on Palms Central Plantation Crops Research Institute Kasaragod (Kerala) 671 124 **2. Best AICRP Centre** AICRP Centre Ambajipeta (Andhra Pradesh)
Norman Borlaug Award 2014	**Prof. (Dr) Nagendra Kumar Singh** National Professor B.P. Pal Chair (Genetics & Plant Breeding), New Delhi
Rafi Ahmed Kidwai Award for Outstanding Research in Agricultural Sciences 2014	**Crop and Horticultural Sciences** **Dr Arvind Kumar** Senior Scientist, IRRI, South Asia Hub, ICRISAT, Patancheru Hyderabad (Telengana) 502 324 **Natural Resource Management and Agricultural Engineering** **Prof. Kamlesh Narayan Tiwari** Professor, Department of Agricultural & Food Engineering Indian Institute of Technology Kharagpur (West Bengal) 721302 **Animal and Fisheries Sciences** **Dr Sunita Grover** Principal Scientist and Head, Dairy Microbiology DivisionNational Dairy Research Institute Karnal (Haryana) 132001
Lal Bahadur Shastri Outstanding Young Scientist Award 2014	**Crop and Horticultural Sciences** **Dr Aditya Pratap** Senior Scientist, Crop Improvement Division, Indian Institute of Pulses Research, Kanpur (Uttar Pradesh) 208 024 **Animal and Fisheries Sciences** **Dr A.Kumaresan** Senior Scientist(Animal Reproduction)Livestock Research CentreNational Dairy Research InstituteKarnal (Haryana) 132 001 **Social Sciences** **Dr Shaik N.Meera** Senior Scientist (Agriculture Extension) Transfer of Technology and Training Section Directorate of Rice Research (ICAR) Rajendranagar, Hyderabad (Telengana) 500 030
Panjabrao Deshmukh Outstanding Woman Scientist Award 2014	**Dr (Mrs.) Prameela Krishnan** Principal Scientist, Division of Agricultural Physics Indian Agricultural Research Institute, New Delhi 110 012 **Dr (Mrs) Nirmala B. Yenagi** Professor, Department of Food Science and Nutrition College of Rural Home ScienceUniversity of Agricultural Sciences Dharwad (Karnataka) 580 005

AWARDS	AWARDEES
	Dr (Mrs.) Anupama Principal Scientist, Division of Agricultural Chemicals, Indian Agricultural Research Institute, New Delhi 110 012
Bharat Ratna Dr C. Subramaniam Award for Outstanding Teachers 2014	**Crop and Horticultural Sciences** **Dr Subhash Chander** Professor and Principal Scientist Division of Entomology, Indian Agricultural Research Institute, New Delhi 110 012
	Natural Resource Management and Agricultural Engineering **Dr Rangaraju Visvanathan** Professor (Agricultural Processing)Anbil Dharamalingam Agricultural College and Research Institute TNAU, Navalur Kuttappattu, Tiruchirappalli (Tamil Nadu) 620 009
	Animal and Fisheries Sciences **Dr Bimlesh Mann** Principal Scientist and Head Dairy Chemistry Division National Dairy Research Institute Karnal (Haryana) 132 001
Fakhruddin Ali Ahmed Award for Outstanding Research in Tribal Farming Systems 2014	**Dr Suresh Kumar D. S.** Principal Scientist, Division of Livestock Production, ICAR Research Complex for NEH Region, Umroi Road Umiam (Meghalaya) 793103
	Dr G. Kadirvel (Associate) Senior Scientist ICAR Research Complex for NEH Region, Umroi Road Umiam (Meghalaya) 793103
	Dr Sunil Doley (Associate), Senior Scientist ICAR Research Complex for NEH Region, Umroi Road Umiam (Meghalaya) 793103
	Dr P. K. Bharti (Associate) Scientist ICAR Research Complex for NEH Region, Umroi Road Umiam (Meghalaya) 793103
	Dr Badal Bhattacharya All India network Project on White Grubs and other Soil Arthropod Pests, Department of EntomologyAssam Agricultural University Jorhat (Asom) 785013
	Dr Satyendra Kumar Dutta (Associate) All India network Project on White Grubs and other Soil Arthropod Pests, Department of Entomology Assam Agricultural University Jorhat (Asom) 785013
Jawaharlal Nehru Award for P.G. Outstanding Doctoral Thesis Research in Agricultural and Allied Sciences 2014	**Crop Science** **Dr Divya Balakrishnan** Scientist (Plant Breeding and Genetics)Directorate of Rice Research Hyderabad (Telengana) 502 324
	Dr Niharika Mallick Scientist (Plant Breeding)Division of Genetics Indian Agricultural Research Institute, New Delhi 110 012
	Biotechnology (Plant/ Animal/ Fisheries) **Dr Shallu Thakur** VPO. Chowki Khalet, Tehsil: Palampur District Kangra (Himachal Pradesh) 176 061

AWARDS	AWARDEES
	Dr Rehna Augustine Chirayil, Kozha P.O., Kottayam (Kerala)686 633
	Crop Protection **Dr Sandeep Kumar** Department of Plant Pathology AICRP on MULLaRP, Centre for Pulses Research Berhampur (Odisha)761 001
	Dr Nandita Sahana Department of Biochemistry, Faculty of Agriculture Uttarbanga Krishi Viswavidyalaya, P.O. Pundbari Coochbehar (West Bengal) 736 165
	Natural Resource Management **Dr Saman Preet Ahuja** 7FF, MIG Flats, F-Block, Bhai Randhir Singh Nagar Ludhiana (Punjab) 141 004
	Dr Venkanna Kandula Division of Resource Management Central Research Institute on Dryland Agriculture Santosh Nagar, P. O. Saidabad Hyderabad (Andhra Pradesh) 500 059
	Horticultural Science **Dr Govind Kumar Rai** Scientist, Department of Biotechnology C.G.O., Complex, Lodhi Road, New Delhi 110 003
	Dr Pooja Bohra Scientist , Division of Horticulture and Forestry Central Island Agricultural Research Institute, Post Box No. 181 Port Blair (Andaman & Nicobar Islands) 744 101
	Agriculture Engineering **Dr Ashish Kumar Srivastava** Assistant professor/ScientistSG College of Agriculture and Research Station, Kumhrawand,Jagdalpur (C.G.) 494 001
	Animal Science **Dr Revanaiah Yogisharadhya** Senior Technical OfficerNational Institute of Veterinary Epidemiology and Disease Informatics (NIVEDI)ICAR Campus, Ramagondanalli, Yelahanka Bengaluru (Karnataka) 560 064
	Dr Vikrant Singh Chouhan ScientistP and C Division, IVRI Izatnagar, Bareilly, (Uttar Pradesh) 243 122
	Fisheries Science **Dr Neeraj Kumar** Scientist, National Institute of Abiotic Stress Management , Malegaon, Baramati Pune (Maharashtra) 413 115
	Dr Vikas Pattath Ayyappan Pattath House, Thazhkkad P.O.Trichur (Kerala) 680 697
	Social Sciences **Dr Sanjit Maiti** Scientist NRC on YakDirang, West Kameng District (Arunachal Pradesh) 790101
	Dr Venkatesh Palanisamy Scientist, Division of Agricultural Economics Indian Agricultural Research Institute, Pusa, New Delhi 110 012

AWARDS	AWARDEES
Jagjivan Ram Abhinav Kisan Puruskar / Jagjivan Ram Innovative Farmer Award (National/Zonal) 2014	**National** **Shri Dipen Kumar Mukundbhai Shah** 879, Shah's Street, Near Rameshwar Temple Ta &Distt. Anand, P.O. Kunjrao (Gujarat) 388 335
Zone 1	**Major Manmohan Singh Verka** D-107, Ranjit Avenue, Amritsar-142001, Punjab
Zone 2	**Smt. Anita Kumari,** W/o Sh. Sanjay Kumar, Vill.-Anantpur, P.O. Madhopur P.S.Chandi (Nalanda) 803 108
Zone 4	**Sh. Sethpal Singh** Vill.-Nandifiorjpur, Post-Nandifirojpur District-Saharanpur (Uttar Pradesh)
Zone 7	**Sh Subrat Ranjan Prusti** Nalini, 3/A, Budheswari Area Bhubaneshwar (Odisha) 751 006
Zone 8	**Sh Prakash K.S.** Sharanappa N, Kuremaganahalli, Chatnahalli (Post), Harapanahalli (Tq), District Davanagere (Karnataka) 583 125
N.G. Ranga Farmer Award for Diversified Agriculture 2014	**Shri Gurpreet Singh Shergill** Village Majhal Khurd, P.O.-Panjola, Dist.- Patiala, Punjab
Dr Rajendra Prasad Puruskar for technical books in Hindi in Agricultural and Allied Sciences 2014	**Crop and Horticultural Sciences** D. R. Bhardwaj, Indian Institute of Vegetable Research, P.B. No.1, Varanasi (Uttar Pradesh) 221 005
	NRM and Agricultural Engineering **Dr Shiv Prasad** Indian Agricultural Research Institute New Delhi 110 012
	Aarti Bhatia (Associate) Indian Agricultural Research Institute New Delhi 110 012
	Nivita Jain (Associate) Indian Agricultural Research Institute New Delhi 110 012
Swami Sahajanand Saraswati Outstanding Extension Scientist Award 2014	**Dr Rakesh Kumar Yadav** Subject Matter Specialist (PP) RajmataVijayaraje Scindia Krishi Vishwa Vidhyalaya Krishi Vigyan Kendra, Jhabua (Madhya Pradesh)
	Dr S.K. Meti Professor and Head Department of Agricultural Extension University of Agricultural Sciences Raichur (Karnataka) 580 002
Best Krishi Vigyan Kendra Awards 2014 (National & Zonal) National	**Krishi Vigyan Kendra, Hadonahalli** Thubagere Hobli, Doddaballapura Taluk Bangalore Rural District Karnataka-561205
Zone I	**Krishi Vigyan Kendra, Kulluat Bajaura** Dist.Kullu (Himachal Pradesh) 751251
Zone II	**Krishi Vigyan Kendra, Saran**, Manjhi, PO-Manjhi, District-Saran (Bihar) 841 313

AWARDS	AWARDEES
Zone III	**Krishi Vigyan Kendra, Nalbari**, P.O. Milanpur Nalbari (Asom) 781337
Zone IV	**Krishi Vigyan Kendra, Sargatia** Seorahi, Kushinagar-274406,Uttar Pradesh
Zone V	**Krishi Vigyan Kendra**, **Yagantipalle Village**, Banaganapallemandal Kurnool district (Andhra Pradesh)
Zone VII	**Krishi Vigyan Kendra, Surguja**, Ajirma, Post-Raghwapuri, Tehsil-Ambikapur, Dist. Surguja (Chhattisgarh)
Zone VIII	**Krishi Vigyan Kendra, Palakkad**, Mele Pattambi(PO), Palakkad District (Kerala) 679 306
Vasantrao Naik Award for Research Application in Agriculture 2014	**Dr B.K. Ramachandrappa** Chief Scientist, AICRP for Dryland Agriculture University of Agricultural Sciences GKVK Campus Bengaluru (Karnataka) 560 065 **Dr M.A. Shankar (Associate)** AICRP for Dryland Agriculture University of Agricultural Sciences GKVK Campus Bengaluru (Karnataka) 560 065 **Dr M.N. Thimmegowda (Associate)** AICRP for Dryland Agriculture University of Agricultural Sciences GKVK Campus Bengaluru (Karnataka) 560 065 **Dr A. Sathish (Associate)** AICRP for Dryland Agriculture University of Agricultural Sciences GKVK Campus Bengaluru (Karnataka) 560 065 **Mr B.N. Jagadeesh (Associate)** AICRP for Dryland Agriculture University of Agricultural Sciences GKVK Campus Bengaluru (Karnataka) 560 065 **Dr Ch. Srinivasa Rao (Associate)** Director Central Research Institute for Dryland Agriculture Santoshnagar, Saidabad P.O. Hyderabad (Andhra Pradesh) 500059
NASI-ICAR Award 2014	**Dr Ravindra Naik** Senior Scientist Central Institute of Agricultural Engineering Industrial Extension Project Centre Coimbatore (Tamil Nadu) 641 003
Hari Om Ashram Trust Award 2012-13	**Crop and Horticultural Sciences** **Dr Amaresh Chandra** Principal Scientist& Head Indian Institute of Sugarcane Research Lucknow (Uttar Pradesh) 226 002 **Dr Radha Jain(Associate)** Principal Scientist Indian Institute of Sugarcane Research Lucknow (Uttar Pradesh) 226 002 **Dr S. Solomon (Associate)** Director, Division of Plant Physiology and Biochemistry, Indian Institute of Sugarcane Research Lucknow (Uttar Pradesh) 226 002

AWARDS	AWARDEES
	Natural Resource Management and Agricultural Engineering **Dr Ch. Srinivasa Rao** Director Central Research Institute for Dryland Agriculture Santoshnagar, Saidabad P.O. Hyderabad (Andhra Pradesh) 500059
	Dr B. Venkateswarlu (Associate) Vice Chancellor Vasantrao Naik Marathwada Krishi Vidyapeeth Parbhani (Maharashtra) 431 402
	Animal and Fisheries Sciences **Dr Jashbhai Bhikhabhai Prajapati,** Professor & Head, Department of Dairy Microbiology SMC College of Dairy Science Anand Agricultural University Anand (Gujarat) 388110
Chaudhary Charan Singh Award 2014	**Sh. Arvind Kumar Singh** Assistant Editor, Rajya Sabha Television- **Electronic**
	Shri Surendra Prasad Singh Deputy Bureau Chief, National Bureau, *Dainik Jagran*, New Delhi - **Print Media**
	Sh. Arvind Kumar Singh Principal Correspondent, *Hindustan*, HT-Group, 18-0, K.G. Marg, New Delhi- For Hindi Journalism -**Print Media**
	Smt. Gargi Parsai Associate Editor, *The Hindu*, New Delhi, G-5 Press Apartments, 23 IP Extension, Delhi- For English Journalism - **Print Media**
	Smt. Madhvi Sally Special Correspondent, *The Economic Times*, New Delhi, K-6, Fine Home Apartments, Beside Supreme Enclave, Mayur Vihar Phase I, New Delhi- For English Journalism-**Print Media**
	Shri Jai Prakash Singh Senior Producer Annadata, ETV Network, 1st Floor, SP-3 Building, Romoji Film City, Hyderabad (Andhra Pradesh) 501512-**Electronic Media**
Awards for best workers of the ICAR Administrative category	**Sh. Avinash Kalanke** Upper Division Clerk Directorate of Soybean Research Khandwa Road, Indore (Madhya Pradesh) 452 001
	Smt. Lizette Noronha Private Secretary, Central Coastal Agricultural Research Institute, Ela, Old Goa, Goa-403402
	Sh. Brishketu Singh Assistant, National Onstitute of High security Animal Diesease, (OIE Reference Lab for avian Influenza), Anand Nagar, Kolkata Road, Bhopal Madhya Pradesh 462 021
	Smt. Suman Khanna Srenographer (Hindi + English), Indian Agriculktural Statistical Research Institute, Library Avenue, Pusa, New Delhi

AWARDS	AWARDEES
	Shri Ravi Prakash Under Secretary (Protocol) ICAR Hqrs., Krishi Bhawan, New Delhi
	Shri Chiranjee Lal Assistant and Confidential Assistant to Director, National Dairy Research Institute, Deemed University, Karnal , Haryana 132001
Technical category	**Dr Randhir Singh** Chief Technical Officer, Central Soil Salinity Research Institute Zarifa Farm, Kachhwa Road Karnal, Haryana 132 001
	Shri Harish Chandra Yadav Senior Technical Officer, Indian Veterinary Research Institute, Izatnagar-243122, Uttar Pradesh
Supporting category	**Shri Trilok Singh Balmiki** Skilled Supporting Staff, National Research Centre for Orchids, Pakyong-737106, Sikkim
	Shri Manak Lal Kiradu Skilled Supporting Staff, NRC on Camel, Post Bag No. 7, Jorbeer, Bikaner-334001, Rajasthan
	Shri P. Chidambaram Skilled Supporting Staff, Central Institute for Cotton Research R.S. Coimbatore
	Shri Anga Dhanaraju Skilled Supporting Staff, Indian Institute of Oil Palm research Pedavegi-534450, West Godavari Dist. (Andhra Pradesh)
	Sh. Rampal Saini Skilled Supporting Staff, Dairy Technology Division, National Dairy Research Institute Karnal-132001, Haryana
	Sh. Prahlad Singh Skilled Supporting Staff, Directorate of Soyabean Research, Khandwa Road, Indore-452001, Madhya Pradesh

APPENDIX 12

RESULTS-FRAMEWORK DOCUMENT FOR DEPARTMENT OF AGRICULTURAL RESEARCH AND EDUCATION (2014-2015)

RFD
Results-Framework Document
for
Department of Agricultural Research and Education
(2014-2015)

Section 1
Vision, Mission, Functions and Objectives

Vision

Harnessing science and technology to ensure sustained accessibility to food, nutrition, livelihood security and natural resource management.

Mission

Interfacing agricultural research and technology, higher education and front-line extension initiatives with institutional, infrastructural and policy support for sustainable growth of agriculture.

Functions

1 To develop Public-Private-Partnerships in developing seeds, planting materials, vaccines, feed formulations, value added products, agricultural machinery etc.
2 To serve as a repository in agriculture sector and develop linkages with national and international organizations as per the needs and current trends.
3 To plan, coordinate and monitor research for enhancing production and productivity of agriculture sector.
4 To enhance quality of higher education in agriculture sector.
5 Technology generation, commercialization and transfer to end users.
6 Human resource development and capacity building.

Objectives

1 Utilizing frontier research in identified areas/programs for improved harnessing of genetic resources and biotechnology usage for agriculture and development of plant varieties.
2 Development and strengthening of higher agricultural education.
3 Improving natural resource management and input use efficiency.
4 Frontline agricultural extension through technology assessment and demonstration.
5 Farm mechanization, post-harvest management and value addition.
6 Assessment and monitoring of fishery resources.
7 Knowledge management in agriculture.
8 IP management and commercialization of technologies.
9 To develop and sustain excellence in basic and strategic research for providing knowledge support in the NARS for technology solution.
* Efficient Functioning of the RFD System.
* Enhanced Transparency / Improved Service delivery of Ministry/Department.
* Reforming Administration.
* Improve compliance with the Financial Accountability Framework.

Section 2

Inter se Priorities among Key Objectives, Success indicators and Targets

Objectives	Weight	Actions		Success indicator	Unit	Weight	Target/Criteria Value				
							Excellent 100%	Very Good 90%	Good 80%	Fair 70%	Poor 60%
[1] Utilizing frontier research in identified areas/programs for improved harnessing of genetic resources and biotechnology usage for agriculture and development of plant varieties	17	[1.1] Collection, characterization, conservation and development of genetic resources	[1.1.1]	Germplasm conserved under long term storage (other crops)	Number	1.36	5500	5000	4500	4000	3500
			[1.1.2]	Germplasm collected (horticultural crops)	Number	1.36	460	400	340	280	220
		[1.2] Evaluation of genetic resources / improved varieties for suitable crop husbandry practices	[1.2.1]	Germplasm / breeding lines evaluated	Number	1.36	39000	37000	35000	33000	31000
		[1.3] Development of improved varieties suited to diverse agro-ecologies	[1.3.1]	Varieties identified by AICRP Varietal Identification Committees (food, fodder and cash crops)	Number	1.36	50	45	40	35	30
			[1.3.2]	Varieties identified by AICRP Varietal Identification Committees (oilseeds & pulses)	Number	1.36	19	17	15	13	11
			[1.3.3]	Varieties identified by AICRP Varietal Identification Committees (fruits, vegetables, flowers and spices)	Number	1.36	22	20	18	16	14
		[1.4] Production of breeder seed, other seeds and planting materials	[1.4.1]	Quantity of breeder seed produced (other crops)	Quintals	1.7	90000	85000	80000	75000	70000
			[1.4.2]	Quantity of breeder seed produced (horticultural crops)	Quintals	1.19	36750	36250	35750	35250	34750
			[1.4.3]	Planting materials produced annually	Number (in lakhs)	1.19	41	39	37	35	33

	Objectives	Weight		Action		Success Indicator	Unit	Weight	Target/Criteria Value				
									Excellent 100%	Very Good 90%	Good 80%	Fair 70%	Poor 60%
			[1.5]	Cloning and characterization of genes	[1.5.1]	Genes cloned and characterized	Number	1.19	15	12	9	6	3
			[1.6]	Identification of genetic markers and production of diagnostic kits for livestock and poultry diseases diagnosis, adulterants and environmental pollutants	[1.6.1]	Genetic markers identified and diagnostics kits developed	Number	1.19	5	4	3	2	1
			[1.7]	Production of piglets (8-12 weeks of age)	[1.7.1]	Provisioning of piglets to farmers and development agencies	Number	1.19	3000	2800	2600	2400	2200
			[1.8]	Production of day old as well as 6 weeks old chicks	[1.8.1]	Provisioning of day old / 6 weeks old chicks to farmers and development agencies	Number (in lakhs)	1.19	6.4	6.2	6	5.8	5.6
2	Development and strengthening of higher agricultural education	17	[2.1]	Accreditation / Extension of accreditation of agricultural universities	[2.1.1]	Universities granted accreditation / extension of accreditation	Number	1.70	8	7	6	5	4
			[2.2]	Grant of ICAR International fellowships to Indian and foreign students	[2.2.1]	Fellowships awarded (subject to availability of competent candidates)	Number	2.55	15	14	13	12	11
			[2.3]	Grant of JRF and SRF to students	[2.3.1]	Fellowships granted every year (subject to availability of competent candidates)	Number	3.40	665	645	625	605	585
			[2.4]	Supporting experiential learning units	[2.4.1]	Establishment of experiential learning units	Number	1.70	25	23	21	19	17
			[2.5]	Release of funds	[2.5.1]	Amount released as per allocation	Percent	3.40	100	90	80	70	60

	Objectives	Weight		Action		Success Indicator	Unit	Weight	Target/Criteria Value				
									Excellent 100%	Very Good 90%	Good 80%	Fair 70%	Poor 60%
			[2.6]	Capacity building and faculty up-gradation	[2.6.1]	Faculty trained	Number	2.55	1950	1900	1850	1800	1750
			[2.7]	Creation / continuation of the centres under Niche Area of Excellence (NAE)	[2.7.1]	Continued support for the existing centres and establishment of new centres of NAE	Number	1.70	27	25	23	21	19
3	Improving natural resource management and input use efficiency	16	[3.1]	Soil resource characterization and mapping	[3.1.1]	Soil resource maps including thematic maps developed at different scales	Number	2.40	20	18	16	14	12
			[3.2]	Integrated nutrient management (INM)	[3.2.1]	Technologies for improving soil health and nutrient use efficiencies	Number	2.72	8	7	6	5	4
					[3.2.2]	Developing INM packages for different agro-eco regions of the country	Number	2.72	10	9	8	7	6
			[3.3]	Integrated water management (IWM)	[3.3.1]	Technologies for enhancing water / irrigation use efficiencies	Number	1.76	5	4	3	2	1
					[3.3.2]	Technologies for water harvesting storage and groundwater recharge	Number	1.76	4	3	2	1	0
			[3.4]	Climate resilient agriculture	[3.4.1]	Development/identification of varieties/breeds for climate resilience at different locations	Number	2.40	10	9	8	7	6
					[3.4.2]	Programs organized for developing trained manpower in research and technology dissemination	Number	1.12	30	25	20	15	10
					[3.4.3]	Awareness building on climate change in agriculture, horticulture, livestock, fisheries etc. amongst stake holders through trainings / demonstrations	Number	1.12	110	100	90	80	70
4	Frontline agricultural extension through technology assessment and demonstration	9	[4.1]	Capacity building for technology application	[4.1.1]	On-farm trials and frontline demonstrations conducted by KVKs	Number	4.5	110000	100000	90000	80000	70000

	Objectives	Weight		Action		Success Indicator	Unit	Weight	Target/Criteria Value				
									Excellent 100%	Very Good 90%	Good 80%	Fair 70%	Poor 60%
					[4.1.2]	Farmers, farm women, rural youth and extension personnel trained by KVKs	Number (in lakhs)	4.50	14	13.5	13	12.5	12
5	Farm mechanization, post-harvest management and value addition	6	[5.1]	To develop / refine equipments for crop production and processing	[5.1.1]	Equipment developed/ refined	Number	1.50	22	21	20	19	18
			[5.2]	Testing of commercial prototypes / technologies	[5.2.1]	Commercial test reports	Number	1.50	16	15	14	13	12
			[5.3]	Process protocols for product development, storage, safety and improved quality	[5.3.1]	Process protocols developed	Number	1.50	16	14	12	10	8
			[5.4]	Development / refinement of agro-products	[5.4.1]	Value-added products	Number	1.50	18	17	16	15	14
6	Assessment and monitoring of fishery resources	5	[6.1]	Fish resources assessment and eco-system monitoring	[6.1.1]	Number of explorations/ surveys carried out	Number	5.00	125	120	115	110	105
7	Knowledge management in agriculture	5	[7.1]	Dissemination of knowledge through print / electronic mode	[7.1.1]	Print and electronic publication / products brought out	Number	5.00	252	245	238	231	224
8	IP management and commercialization	5	[8.1]	Patents and other IPR titles	[8.1.1]	Applications filed	Number	2.50	90	80	70	60	50
	of technologies		[8.2]	Partnership development including licensing of ICAR technologies	[8.2.1]	Partners identified	Number	2.50	140	130	120	110	100
9	To develop and sustain excellence in basic and strategic research for providing knowledge support in the NARS for technology solution	5	[9.1]	To create awareness of the need and nature of basic / strategic research in agriculture	[9.1.1]	Success rate of concept notes submitted	Percent	1.25	12	10	8	6	4
					[9.1.2]	Success rate of full proposals finally selected	Percent	1.25	80	70	60	50	40

	Objectives	Weight		Action		Success Indicator	Unit	Weight	Target/Criteria Value				
									Excellent 100%	Very Good 90%	Good 80%	Fair 70%	Poor 60%
			[9.2]	Partnership development	[9.2.1]	Number of non-NARS partners participating in concept note submission	Number	1.25	140	130	120	110	100
			[9.3]	Outcome of research done in the projects	[9.3.1]	Technologies / methodologies developed	Number	1.25	5	4	3	2	1
*	Efficient Functioning of the RFD System	3		Timely submission of Draft RFD for 2015-2016 for Approval		On-time submission	Date	2.00	5/3/ 2015	6/3/ 2015	9/3/ 2015	10/3/ 2015	11/3/ 2015
				Timely submission of Results for 2013-2014		On-time submission	Date	1.00	1/5/ 2014	2/5/ 2014	3/5/ 2014	6/5/ 2014	7/5/ 2014
*	Enhanced Transparency / Improved Service delivery of Ministry/Department	3		Rating from Independent Audit of implementation of Citizens' / Clients' Charter (CCC)		Degree of implementation of commitments in CCC	%	2.00	100	95	90	85	80
				Independent Audit of implementation of Grievance Redress Management (GRM) system		Degree of success in implementing GRM	%	1.00	100	95	90	85	80
*	Reforming Administration	8		Update departmental strategy to align with revised priorities		Date	Date	2.00	1/11/ 2014	2/11/ 2014	3/11/ 2014	4/11/ 2014	5/11/ 2014
				Implement agreed milestones of approved Mitigating Strategies for Reduction of potential risk of corruption (MSC)		% of Implementation	%	1.00	100	90	80	70	60
				Implement agreed milestones for implementation of ISO 9001		% of implementation	%	2.00	100	95	90	85	80
				% of Responsibility Centres with RFD in RFMS		Responsibility Centres covered	%	1.00	100	95	90	85	80
				Implement agreed milestones of approved Innovation Action Plans (IAPs)		% of implementation	%	2.00	100	90	80	70	60

	Objectives	Weight	Action	Success Indicator	Unit	Weight	Target/Criteria Value				
							Excellent 100%	Very Good 90%	Good 80%	Fair 70%	Poor 60%
*	Improve compliance with the Financial Accountability Framework	1	Timely submission of ATNs on Audit paras of C&AG	Percentage of ATNs submitted within due date (4 months) from date of presentation of Report to Parliament by CAG during the year.	%	0.25	100	90	80	70	60
			Timely submission of ATRs to the PAC Sectt. on PAC Reports.	Percentage of ATRS submitted within due date (6 months) from date of presentation of Report to Parliament by PAC during the year.	%	0.25	100	90	80	70	60
			Early disposal of pending ATNs on Audit Paras of C&AG Reports presented to Parliament before 31.3.2014.	Percentage of outstanding ATNs disposed off during the year.	%	0.25	100	90	80	70	60
			Early disposal of pending ATRs on PAC Reports presented to Parliament before 31.3.2014	Percentage of outstanding ATRS disposed off during the year.	%	0.25	100	90	80	70	60

Section 3

Trend Values of the Success Indicators

	Objectives	Weight	Action		Success Indicators		Unit	Actual value for FY 12/13	Actual value for FY 13/14	Target value for FY 14/15	Projected value for FY 15/16	Projected value for FY 16/17
1	Utilizing frontier research in identified areas/programs for improved harnessing of genetic resources and biotechnology usage for agriculture and development of plant varieties	17	[1.1]	Collection, characterization, conservation and development of genetic resources	[1.1.1]	Germplasm conserved under long term storage (other crops)	Number	3909	5000	5000	5000	5000
					[1.1.2]	Germplasm collected (horticultural crops)	Number	315	400	400	405	410
			[1.2]	Evaluation of genetic resources / improved varieties for suitable crop husbandry practices	[1.2.1]	Germplasm / breeding lines evaluated	Number	2500	35000	37000	37000	37000
			[1.3]	Development of improved varieties suited to diverse agro-ecologies	[1.3.1]	Varieties identified by AICRP Varietal Identification Committees (food, fodder and cash crops)	Number	0	35	45	45	45
					[1.3.2]	Varieties identified by AICRP Varietal Identification Committees (oilseeds & pulses)	Number	0	15	17	17	17
					[1.3.3]	Varieties identified by AICRP Varietal Identification Committees (fruits, vegetables, flowers and spices)	Number	18	18	20	21	22
			[1.4]	Production of breeder seed, other seeds and planting materials	[1.4.1]	Quantity of breeder seed produced (other crops)	Quintals	99270	85000	85000	85000	85000
					[1.4.2]	Quantity of breeder seed produced	Quintals	36000	36000	36250	36500	36750

	Objective	Weight	Action		Success indicator		Unit	Actual value for FY 12/13	Actual value for FY 13/14	Target value for FY 14/15	Projected value for FY 15/16	Projected value for FY 16/17
						(horticultural crops)						
					[1.4.3]	Planting materials produced annually	Number (in lakhs)	40.5	41	39	39.1	39.2
			[1.5]	Cloning and characterization of genes	[1.5.1]	Genes cloned and characterized	Number	5	13	12	12	14
			[1.6]	Identification of genetic markers and production of diagnostic kits for livestock and poultry diseases diagnosis, adulterants and environmental pollutants	[1.6.1]	Genetic markers identified and diagnostics kits developed	Number	0	0	4	4	5
			[1.7]	Production of piglets (8-12 weeks of age)	[1.7.1]	Provisioning of piglets to farmers and development agencies	Number	2779	1950	2800	3300	3800
			[1.8]	Production of day old as well as 6 weeks old chicks	[1.8.1]	Provisioning of day old / 6 weeks old chicks to farmers and development agencies	Number (in lakhs)	6.17	6.5	6.2	6.4	6.6
2	Development and strengthening of higher agricultural education	17	[2.1]	Accreditation / Extension of accreditation of agricultural universities	[2.1.1]	Universities granted accreditation/extension of accreditation	Number	7	6	7	8	8
			[2.2]	Grant of ICAR International fellowships to Indian and foreign students	[2.2.1]	Fellowships awarded (subject to availability of competent candidates)	Number	14	14	14	14	14
			[2.3]	Grant of JRF and SRF to students	[2.3.1]	Fellowships granted every year (subject to availability of competent candidates)	Number	658	640	645	650	655
			[2.4]	Supporting experiential learning units	[2.4.1]	Establishment of experiential learning units	Number	25	21	23	30	32

	Objective	Weight	Action		Success indicator		Unit	Actual value for FY 12/13	Actual value for FY 13/14	Target value for FY 14/15	Projected value for FY 15/16	Projected value for FY 16/17
			[2.5]	Release of funds	[2.5.1]	Amount released as per allocation	Percent	0	0	90	90	90
			[2.6]	Capacity building and faculty up-gradation	[2.6.1]	Faculty trained	Number	958	1850	1900	1950	2000
			[2.7]	Creation/continuation of the centres under Niche Area of Excellence (NAE)	[2.7.1]	Continued support for the existing centres and establishment of new centres of NAE	Number	22	22	25	28	30
3	Improving natural resource management and input use efficiency	16	[3.1]	Soil resource characterization and mapping	[3.1.1]	Soil resource maps including thematic maps developed at different scales	Number	0	19	18	19	20
			[3.2]	Integrated nutrient management (INM)	[3.2.1]	Technologies for improving soil health and nutrient use efficiencies	Number	4	8	7	8	8
					[3.2.2]	Developing INM packages for different agro-eco regions of the country	Number	9	14	9	9	9
			[3.3]	Integrated water management (IWM)	[3.3.1]	Technologies for enhancing water / irrigation use efficiencies	Number	5	3	4	5	5
					[3.3.2]	Technologies for water harvesting storage and groundwater recharge	Number	8	3	3	4	4
			[3.4]	Climate resilient agriculture	[3.4.1]	Development/identification of varieties/breeds for climate resilience at different locations	Number	11	9	9	10	10
					[3.4.2]	Programs organized for developing trained manpower in research and technology dissemination	Number	0	25	25	27	30
					[3.4.3]	Awareness building on	Number	150	120	100	105	110

	Objective	Weight	Action		Success indicator		Unit	Actual value FY 12/13	Actual value FY 13/14	Target value FY 14/15	Projected value for FY 15/16	Projected value for FY 16/17
						climate change in agriculture, horticulture, livestock, fisheries etc. amongst stake holders through trainings / demonstrations						
4	Frontline agricultural extension through technology assessment and demonstration	9	[4.1]	Capacity building for technology application	[4.1.1]	On-farm trials and frontline demonstrations conducted by KVKs	Number	0	0	100000	110000	115000
					[4.1.2]	Farmers, farm women, rural youth and extension personnel trained by KVKs	Number (in lakhs)	0	0	13.5	14	14.5
5	Farm mechanization, post-harvest management and value addition	6	[5.1]	To develop / refine equipments for crop production and processing	[5.1.1]	Equipment developed/refined	Number	19	21	21	22	22
			[5.2]	Testing of commercial prototypes / technologies	[5.2.1]	Commercial test reports	Number	12	12	15	16	16
			[5.3]	Process protocols for product development, storage, safety and improved quality	[5.3.1]	Process protocols developed	Number	12	12	14	15	15
			[5.4]	Development / refinement of agro-products	[5.4.1]	Value-added products	Number	16	14	17	18	18
6	Assessment and monitoring of fishery resources	5	[6.1]	Fish resources assessment and eco-system monitoring	[6.1.1]	Number of explorations/ surveys carried out	Number	128	120	120	130	140
7	Knowledge management in agriculture	5	[7.1]	Dissemination of knowledge through print / electronic mode	[7.1.1]	Print and electronic publication / products brought out	Number	0	249	245	251	257
8	IP management and commercialization of technologies	5	[8.1]	Patents and other IPR titles	[8.1.1]	Applications filed	Number	105	107	80	90	100
			[8.2]	Partnership development including licensing of ICAR technologies	[8.2.1]	Partners identified	Number	163	150	130	140	150

	Objective	Weight	Action		Success indicator		Unit	Actual value for FY 12/13	Actual value for FY 13/14	Target value for FY 14/15	Projected value for FY 15/16	Projected value for FY 16/17
9	To develop and sustain excellence in basic and strategic research for providing knowledge support in the NARS for technology solution	5	[9.1]	To create awareness of the need and nature of basic / strategic research in agriculture	[9.1.1]	Success rate of concept notes submitted	Percent	10	18	10	12	13
					[9.1.2]	Success rate of full proposals finally selected	Percent	80	67	70	72	75
			[9.2]	Partnership development	[9.2.1]	Number of non-NARS partners participating in concept note submission	Number	132	0	130	135	140
			[9.3]	Outcome of research done in the projects	[9.3.1]	Technologies/methodologies developed	Number	0	4	4	5	6
*	Efficient Functioning of the RFD System	3		Timely submission of Draft RFD for 2015-2016 for Approval		On-time submission	Date			6/3/2015		
				Timely submission of Results for 2013-2014		On-time submission	Date			2/5/2014		
*	Enhanced Transparency/ Improved Service delivery of Ministry/Department	3		Rating from Independent Audit of implementation of Citizens' / Clients' Charter (CCC)		Degree of implementation of commitments in CCC	%			95		
				Independent Audit of implementation of Grievance Redress Management (GRM) system		Degree of success in implementing GRM	%			95		
*	Reforming Administration	8		Update departmental strategy to align with revised priorities		Date	Date			2/11/2014		
				Implement agreed milestones of approved Mitigating Strategies for Reduction of potential risk of corruption (MSC).		% of Implementation	%			90		
				Implement agreed milestones for implementation of ISO 9001		% of implementation	%			95		

	Objective	Weight	Action	Success indicator	Unit	Actual value for FY 12/13	Actual value for FY 13/14	Target value for FY 14/15	Projected value for FY 15/16	Projected value for FY 16/17
			% of Responsibility Centres with RFD in RFMS	Responsibility Centres covered	%			95		
			Implement agreed milestones of approved Innovation Action Plans (IAPs).	% of implementation	%			90		
*	Improve compliance with the Financial Accountability Framework	1	Timely submission of ATNs on Audit paras of C&AG	Percentage of ATNs submitted within due date (4 months) from date of presentation of Report to Parliament by CAG during the year.	%			90		
			Timely submission of ATRs to the PAC Sectt. on PAC Reports.	Percentage of ATRS submitted within due date (6 months) from date of presentation of Report to Parliament by PAC during the year.	%			90		
			Early disposal of pending ATNs on Audit Paras of C&AG Reports presented to Parliament before 31.3.2014.	Percentage of outstanding ATNs disposed off during the year.	%			90		
			Early disposal of pending ATRs on PAC Reports presented to Parliament before 31.3.2014	Percentage of outstanding ATRS disposed off during the year.	%			90		

Section 4: Acronyms

AICRP	All India Coordinated Research Project
APEDA	Agricultural and Processed food Products Export Development Authority
AUs	Agricultural Universities
BIS	Bureau of Indian Standards
DADF	Department of Animal Husbandry, Dairying and Fisheries
DBT	Department of Bio Technology
DKMA	Directorate of Knowledge Management in Agriculture
DNA	Deoxyribonucleic Acid
DoAC	Department of Agriculture and Cooperation
DST	Department of Science and Technology
DU	Deemed to be University
e-Resources	Electronic Resources
FACE	Free Air Carbon-dioxide Enrichment
FATE	Free Air Temperature Enrichment
FLD	Front line Demonstrations
ICAR	Indian Council of Agricultural Research
ICMR	Indian Council of Medical Research
ICT	Information and Communication Technology
INM	Integrated Nutrient Management
IP	Intellectual Property
IPNS	Integrated Plant Nutrient Supply Systems
IPR	Intellectual Property Rights
IWM	Integrated Water Management
JRF	Junior Research Fellow
KVK	Krishi Vigyan Kendra
MoRD	Ministry of Rural Development
MoWR	Ministry of Water Resources
NAE	Niche Area of Excellence
NARS	National Agricultural Research System
NFBSFARA	National Fund for Basic, Strategic and Frontier Application Research in Agriculture
NGO	Non-Governmental Organization
NHB	National Horticulture Board
NHM	National Horticulture Mission
OFT	On-Farm Trials
PGs	Post Graduates
R and D	Research and Development
SAUs	State Agricultural Universities
SNP	Single Nucleotide Polymorphism
SRF	Senior Research Fellow
SVUs	State Veterinary Universities
UG	Under Graduate

Description and Definition of Success Indicators and Proposed Measurement Methodology

S. No.	Success indicator	Description	Definition	Measurement	General Comments
1 [1.1.1]	Germplasm conserved under long term storage (other crops)	Diverse germplasm is the basic requirement to bred new improved varieties.	Basic genetic resource for crop improvement.	Number of Germplasm/ lines conserved.	May not increase with every passing year.
2 [1.1.2]	Germplasm collected (horticultural crops)	Germplasms are genetic resources of horticultural crops which are source for genetic variability.	Germplasm is collection of cultivars, landraces, wild species etc. for conservation and utilization.	Number	Germplasm material serve as base for utilization in crop improvement programs for breeding new varieties.
3 [1.2.1]	Germplasm / breeding lines evaluated	Source material for the improved varieties to be evaluated.	Material generated from the basic germplasm.	Number of breeding lines evaluated	May not increase with every passing year.
4 [1.3.1]	Varieties identified by AICRP Varietal Identification Committees (food, fodder and cash crops)	Breeding lines are evaluated along with checks in multilocation trials through All India Coordinated Research Projects of crops (other than oil seeds & pulses) and the best performing	Best performing entries identified as a new variety for release.	Number of such varieties identified	Targets for varieties identified given in Section 2 and their respective trend values in Section 3 may vary as the identification of varieties depend upon the availability of superior material with

S. No.	Success indicator	Description	Definition	Measurement	General Comments
		entries compared to checks are identified as new improved varieties for release.			respect to yield, quality, resistance/ tolerance to biotic and abiotic stresses over the existing varieties.
5	[1.3.2] Varieties identified by AICRP Varietal Identification Committees (oilseeds & pulses)	Breeding lines are evaluated along with checks in multilocation trials through All India Coordinated Research Projects related to oil seeds and pulses and the best performing entries compared to checks are identified as new improved varieties for release.	Best performing entries identified as a new variety for release.	Number of such varieties identified	Targets for varieties identified given in Section 2 and their respective trend values in Section 3 may vary as the identification of varieties depend upon the availability of superior material with respect to yield, quality and resistance/ tolerance to biotic and abiotic stresses over the existing varieties.
6	[1.3.3] Varieties identified by AICRP Varietal Identification Committees (fruits, vegetables, flowers and spices)	Varieties/ cultivars produced by careful breeding and selection for desirable characteristics.	A variety/ cultivar is a plant or grouping of plants selected for desirable traits.	Number	Varieties are result of breeding improvements can include high yield, quality, better disease resistance, drought tolerance, fruit size, etc.
7	[1.4.1] Quantity of breeder seed produced (other crops)	Produced from nucleus seed, breeder seed is the starting point in seed chain of producing quality seeds for farmers.	Genetically pure seed produced under direct control of plant breeder and which provides the source for the initial and recurring production of foundation seed.	Quantity produced (Quintals)	Quantity may vary as per indent from DoAC.
8	[1.4.2] Quantity of breeder seed produced (horticultural crops)	Propagating material directly controlled by the originating or sponsoring plant breeder of the breeding program or institution.	Breeder seed, whose production is personally supervised by a qualified plant breeder and is source for foundation and certified seed.	Weight in Quintals	Breeder seed shall be genetically so pure as to guarantee that in the subsequent generation quality shall be maintained.

S. No.	Success indicator	Description	Definition	Measurement	General Comments
9	[1.4.3] Planting materials produced annually	Production of planting material of vegetatively propagated horticultural crops.	It is a process of vegetative means by which new individuals arise without production of seeds or spores.	Number of saplings/plants (in lakhs)	In a wide sense, planting material arise from vegetative propagation include cutting, vegetative part apomixis, layering, division, budding, grafting and tissue culture.
10	[1.5.1] Genes cloned and characterized	This is an important step in unraveling the role of individual genes.	Total No. of genes cloned and characterized.	Number	-
11	[1.6.1] Genetic markers identified and diagnostics kits developed	A genetic marker may be a short DNA sequence, such as a sequence surrounding a single base-pair change (SNP) or a long one, like microsatellites. The development of diagnostic kits involves delineation of process(es) for detection of specific diseases of livestock and poultry as well as adulterants and environmental pollutants in milk, meat, water, soil and value added products, etc.	A genetic marker is a gene or DNA sequence with a known location on a chromosome that can be used to identify individuals or species. To develop sensitive tests for detection of causative agents for specific diseases of livestock and poultry as well as adulterants and environmental pollutants in milk, meat, water, soil and value added products, etc.	Number	Genetic markers may be described as a tool to identify as a variation which may arise due to mutation or alteration in the genomic loci. Development of new diagnostics will be need based dependent on occurrence / emergence / prevalence / severity of a disease whereas kits for detection for adulterants and environmental pollutants will be to ensure quality production, procurement and value addition of animal produce / products to minimize economic losses.
12	[1.7.1] Provisioning of piglets to farmers and development agencies	The quality germplasm of piglets supplied will be raised and used by the farmers as means of nutritional security and economic returns and by the State Animal	The piglets being provisioned will serve as the basic unit (seed) for production, reproduction, maintenance and preservation.	Number	The provisioning of piglets of high reproductive efficiency (preferably with a pregnancy rate not less than 70%) of the sows (female pigs) and other inputs like

S. No.		Success indicator	Description	Definition	Measurement	General Comments
			Husbandry Departments for enhancing production/ productivity on their farms and for multiplication and production of quality germplasm.			quality management, balanced feed, health cover for optimum growth to be monitored initially weekly weights up to weaning and thereafter fortnightly monitoring of weight and growth rate till the piglets are ready for sale to farmers/ development agencies.
13	[1.8.1]	Provisioning of day old / 6 weeks old chicks to farmers and development agencies	The quality germplasm of chick /fertile eggs supplied will be reared by the famers for egg/meat production for better economic returns. The chicks of parent line provisioned to government farms will serve as the replacement stock for enhancing production/ productivity and for multiplication and production of quality germplasm.	The chicks/ fertile eggs/ being provisioned will serve as the basic unit (seed) for production, reproduction, maintenance and preservation.	Number (in lakhs)	Provisioning of day old/6 weeks old chicks and hatching eggs would require production of more than 70% fertile eggs from the breeding population and thereby hatchability of 75%. The target can be successfully reached if the standard management practices, quality feeding schedule, health schedule with closed monitoring of the environment and management standards is done during the growth period of the chicks and of the parent population.
14	[2.1.1]	Universities granted accreditation / extension of accreditation	Educational quality and reforms to be measured from the number of universities accredited and need based reforms undertaken.	Accreditation is periodically undertaken to ensure education quality by Accreditation Board, ICAR.	Number	
15	[2.2.1]	Fellowships awarded (subject to	International fellowships to	The fellowships are awarded in	Number	

S. No.	Success indicator		Description	Definition	Measurement	General Comments
		availability of competent candidates)	both Indian and foreign students are awarded in cutting edge areas for showcasing strength of Indian agriculture.	competitive mode based on merit.	Number	
16	[2.3.1]	Fellowships granted every year (subject to availability of competent candidates)	JRF/SRF fellowships are awarded for attracting and retaining talented youths towards higher agricultural education through All India Examination.	JRF/SRF (PGs) fellowships are meant for Master and Doctoral programme respectively in Agriculture and Allied Sciences in competitive mode.	Number	
17	[2.4.1]	Establishment of experiential learning units	Experiential learning units are being established across AUs for providing hands on training and developing entrepreneurship skills amongst youth at UG level.	Experiential learning units are in different areas of Agriculture and Allied Sciences at college level for Under Graduate students.	Number	
18	[2.5.1]	Amount released as per allocation	ICAR provides grant for development and strengthening of higher agricultural education to Agricultural Universities for the infrastructure development including students' amenities and facilities, modernization of laboratories and classrooms and to facilitate course-curriculum delivery and quality assurance with enabling environment and ICT support on yearly basis.	ICAR development grant to Agricultural Universities emphasizes quality education, its relevance and usefulness.	Percent	
19	[2.6.1]	Faculty trained	Capacity building and	The training programmes	Number	

S. No.	Success indicator		Description	Definition	Measurement	General Comments
			faculty upgradation in need based areas of agriculture and allied sciences to be measured from the number of trained personnel through summer-winter schools/short courses, Centres of Advanced Faculty trainings and niche area centres.	are key to sustain quality of agricultural education through updating of knowledge and skill of faculty.		
20	[2.7.1]	Continued support for the existing centres and establishment of new centres of NAE	Creation/ continuation of Niche Area of Excellence for scaling up of research capabilities of the universities and promote human resource development.	Basic elements of Niche Areas of Excellence are quality of human resource, adequate infrastructure, access to latest information and well developed educational technology system.	Number	
21	[3.1.1]	Soil resource maps including thematic maps developed at different scales	Soil resource inventory & characterization is prerequisite for developing land use planning.	Soil resource maps are the record of soil units delineated on the basis of similar properties in a readable format.	Mapping will be done at different scale using geo referenced data.	This will ensure effective monitoring and judicious use of land resources.
22	[3.2.1]	Technologies for improving soil health and nutrient use efficiencies	The nutrient use efficiency in the country is very low and fertilizer being a costly input, this has to be increased to reduce the use of fertilizer vis-à-vis cost of production.	Nutrient efficiency can be defined in agronomic, economic, or environmental terms with an aim to get maximum yield benefit with reduce rate of application without harming the environment.	Nutrient use efficiency is measured in terms of partial factor productivity (kg crop yield per kg nutrient applied) or agronomic efficiency (kg crop yield increase per kg nutrient applied) or apparent recovery efficiency (kg nutrient taken up per kg nutrient applied); and physiological efficiency (kg	Augmenting nutrient use efficiency will facilitate reduction in use of costly chemical fertilizer, fertilizer subsidy burden and environmental pollution. Several technological interventions like soil test based fertilizer applications, use of organics (enriched composts, efficient biofertilizer

S. No.		Success indicator	Description	Definition	Measurement	General Comments
					yield increase per kg nutrient taken up).	strains, crop residue recycling, green manuring), inclusion of legume crops, mulching, resource conservation technologies (RCTs), slow releasing fertilizers, nitrification inhibiters, fertilizer responsive cultivars, 4Rs (right dose, source, time & method of application) and nano-formulations can improve soil health vis-à-vis nutrient use efficiency to a large extent.
23	[3.2.2]	Developing INM packages for different agro-eco regions of the country	INM is practiced encompassing conjunctive use of both chemical and organic nutrient sources for improving soil health & sustaining higher productivity.	Integrated Nutrient Management refers to the maintenance of soil fertility and plant nutrient supply at an optimum level for sustaining the desired productivity through optimization of the benefits from all possible sources of organic, inorganic and biological components in an integrated manner.	Developing Integrated Plant Nutrient Supply Systems (IPNS) for different crops/ croppings.	To ensure balance fertilization and sound soil health.
24	[3.3.1]	Technologies for enhancing water / irrigation use efficiencies	Improving irrigation/water use efficiency is aimed to save water for bringing more area under irrigation.	Irrigation efficiency is the index of irrigation performance while water use efficiency is defined as yield/unit of crop water use.	To be measured in terms of irrigation water use and evapo-transpiration.	This will increase the crop water productivity. Several technological interventions like water conservation measures, conjunctive use of surface and ground water, multiple use of water, efficient micro-irrigation techniques,

S. No.		Success indicator	Description	Definition	Measurement	General Comments
						land configuration, irrigation scheduling, improved delivery system including nano techniques, mulching, resource conservation technologies, crop diversification and developing/ identifying cultivars requiring less water can improve water and irrigation use efficiency to a considerable extent.
25	[3.3.2]	Technologies for water harvesting storage and groundwater recharge	Harvested rainwater is harvested through bio engineering measures and used for augmenting ground water level.	Groundwater recharge is a hydrologic process where water moves downward from surface water to groundwater.	Groundwater recharge measurement will be studied through development of location specific filter systems.	Groundwater recharge technique shall help in minimizing surface runoff and augmenting groundwater table.
26	[3.4.1]	Development/ identification of varieties/breeds for climate resilience at different locations	State of art facilities like phenomics, FACE and FATE and other advanced techniques will be employed in identifying the germplasm tolerant to biotic and abiotic stresses. Similar efforts will be made in case of livestock and fisheries for identifying breeds/species tolerant to various stresses.	Germplasm/ varieties/ livestock breeds/fisheries species that can tolerate biotic and abiotic stresses.	Number of germplasm/ varieties/ livestock breeds/ fisheries species	Increased frequency of occurrence of weather aberrations have necessitated the need for identifying tolerant germplasm/ varieties/ livestock breeds/fisheries species.
27	[3.4.2]	Programs organized for developing trained manpower in research and technology dissemination	Staff of NARS and NGOs will be exposed to state-of-art facilities/ techniques/ tools developed within the country/abroad for pursuing	Enhancing the knowledge of scientists and officials in understanding climatic variability and coping strategies.	Number of training programmes	Human capital development in coping with changing climatic scenario.

S. No.	Success indicator		Description	Definition	Measurement	General Comments
			advance research and technology dissemination.			
28	[3.4.3]	Awareness building on climate change in agriculture, horticulture, livestock, fisheries etc. amongst stake holders through trainings / demonstrations	The knowledge and skills of primary and secondary stakeholders shall be enhanced by organizing exposure visits to on-farm trials/ demonstrations conducted by SAUs and KVKs.	Exposure to advanced techniques in understanding and managing climatic risks.	Number of programmes	Skill enhancement of primary and secondary stakeholders.
29	[4.1.1]	On-farm trials and frontline demonstrations conducted by KVKs	Trials and demonstrations conducted for technology testing and proving the technology potential production	On-farm trials aims at testing new technologies under farmers condition and management, by using farmers own practice as control. Frontline demonstration is the field demonstration conducted on farmers field under the close supervision of Scientists.	Number	
30	[4.1.2]	Farmers, farm women, rural youth and extension personnel trained by KVKs	Capacity building activities related to knowledge and skill improvement/ development programmes conducted for farmers, farm women, rural youth and extension personnel.	Training is a process of acquisition of new skills, attitude and knowledge in the context of preparing for entry into a vocation or improving once productivity in an organization or enterprise.	Number	
31	[5.1.1]	Equipment developed / refined	Development of need based farm equipment.	R and D work on farm mechanization.	Number of equipment developed	
32	[5.2.1]	Commercial test reports	Type of Machinery	Equipment or products for testing	Number of reports as per BIS standards	
33	[5.3.1]	Process protocols developed	Methodology to carry out a process	Development of methods to complete a process	Acceptable standard of process	

S. No.		Success indicator	Description	Definition	Measurement	General Comments
34	[5.4.1]	Value-added products	Development of new products from the raw agro-produces	Development of different products from agro-produce	End-product	
35	[6.1.1]	Number of explorations / surveys carried out	Explorations/ surveys are carried out to identify new fishery resources and locating potential fishing zones.	Newer fishery resources and potential fishing areas identified.	Number	
36	[7.1.1]	Print and electronic publication / products brought out	Dissemination of knowledge products like knowledge books, periodicals, journals etc. published through print, electronic mode etc.	Print publications are carriers of knowledge to masses including students, scientists, researchers, policy makers, farmers etc. e-Resources are computer readable products for transfer of knowledge to the target user groups in agricultural and allied sciences.	Number	
37	[8.1.1]	Applications filed	Filing of Patents and other IPR titles for protection of IP.	Protection of IPs in the form of Patents and other IPR titles.	Number	
38	[8.2.1]	Partners identified	With respect to commercialization of technologies and services for promoting partnerships with both public and private sector agencies, it is envisaged to bring commercial ethos in agricultural research system. The increasing numbers of partnerships over the years points towards emphasis on transfer of knowledge, skills and technologies, thereby contributing to improved socioeconomic impact from contribution of ICAR.	Partnership development includes licensing of ICAR's technologies and/ or services.	Number	
39	[9.1.1]	Success rate of concept notes submitted	By creating awareness through workshops, it is expected that the		Number of concept notes received	

S. No.	Success indicator		Description	Definition	Measurement	General Comments
			participants of workshop & through then their colleague will be encouraged to submit more meaningful research concepts which will lead to increase in % of submitted concept notes that are selected for full project development.			
40	[9.1.2]	Success rate of full proposals finally selected	Based on the selected concept notes full proposal are developed. The proponents are actually helped by NFBSFARA in full proposal developments. Thus, the % reflects the success of efforts of NFBSFARA & the awareness of the proponents.		Percent	
41	[9.2.1]	Number of non-NARS partners participating in concept note submission	One of the main aims of the NFBSFARA is to bring in all expertise in NARS & non-NARS institutions in the country that can contribute to agricultural research. The number of non-NARS scientists getting interested in contributing to agricultural research will be a strong measure of fulfillment of that aim.		Number	
42	[9.3.1]	Technologies / methodologies developed	Certain ideas & technologies may be directly developed from the project which is reflected in patents filed & usable technology & methodology developed.		Number	

Section 5

Specific Performance Requirements from other Departments

Location Type	State	Organisation Type	Organisation Name		Relevant Success Indicator	What is your requirement from this organisation	Justification for this requirement	Please quantify your requirement from this Organisation	What happens if your requirement is not met
Central Government		Departments	Department of Agriculture and Cooperation	[1.4.1]	Quantity of breeder seed produced (other crops)	Indent for quantity of breeder seed	Variety wise indent for breeder seed comes from DoAC	Quantity of breeder seed is produced as per indent received from DoAC	Less or more quantity of breeder seed will be produced as per indent received from DoAC
State Government	All States	Others	Others	[1.6.1]	Genetic markers identified and diagnostics kits developed	For up-scaling and monitoring, support for development of new diagnostics and their validation under field conditions and improvisation	Monitoring and surveillance of livestock and poultry disease and quality assurance of animal produce / products thereby reducing economic losses	Cannot be quantified	Development of genetic markers and diagnostics will be need based dependent on occurrence / emergence / prevalence / severity of a disease likely to result in high economic loss
			Others	[1.7.1]	Provisioning of piglets to farmers and development agencies	Requisition for pig seed	Variety-wise indent for pig seed	Quantity of pig seed is produced as per the indent	Does not affect as the activities of the Division are basically research oriented and production and supply is demand driven based on the management / production capacities of the indenters. However, in case of disease outbreak (e.g. Swine fever), the activity is likely to be affected

Location Type	State	Organisation Type	Organisation Name	Relevant Success Indicator		What is your requirement from this organisation	Justification for this requirement	Please quantify your requirement from this Organisation	What happens if your requirement is not met
			Others	[1.8.1]	Provisioning of day old / 6 weeks old chicks to farmers and development agencies	Requisition for poultry seed	Variety-wise indent for poultry seed	Quantity of poultry seed is produced as per the indent	Does not affect as the activities of the Division are basically research oriented and production and supply is demand driven based on the management / production capacities of the indenters. However, in case of disease outbreak (e.g. Bird flu), the activity is likely to be affected
			Others	[5.1.1]	Equipment developed / refined	Financial support to disseminate the technology through Front-line demonstrations and technology transfer	Technology transfer through demonstrations in the farmers' field	Cannot be quantified as it is dependent on demand	Technology transfer will suffer
			Others	[5.2.1]	Commercial test reports	Machinery/Samples for testing	Commercial testing of equipment/machinery/ samples	Machinery/samples in a year	The activity will fall short of targets
			Others	[4.1.1]	On-farm trials and frontline demonstrations conducted by KVKs	Technology & Methodology backstopping from SAUs & ICAR Instt., collaboration for technology dissemination and making available Technology needs & feedback.	Newly developed technologies and proven technologies needed for conducting OFT and FLD respectively are the research outcome from SAUs and ICAR Research Institutes. Continuous technology backstopping is very much essential for the KVKs to plan their on-farm trials and frontline	Continuous supply and updation of technologies. Providing information about the technology requirement and problems of the farmers. Carrying out refinement in the technologies based on the feedback and outcome of OFT & FLD trials.	The OFT and FLD activities will suffer for the want of recent technologies and innovations. The support of State Department of Agriculture, Animal Husbandry etc. for wider dissemination of technologies in the field is very much required, lack of which will constraint the up scaling process.

Location Type	State	Organisation Type	Organisation Name		Relevant Success Indicator	What is your requirement from this organisation	Justification for this requirement	Please quantify your requirement from this Organisation	What happens if your requirement is not met
							demonstrations. Feed back and information on technological needs help to develop need based OFT and FLDs.		
			Others	[4.1.2]	Farmers, farm women, rural youth and extension personnel trained by KVKs	Availability of training methodologies and new knowledge content for training. Sponsoring of trainees and nominations of Extension personnel. Communicating the training needs. Providing the information about problem magnitude and feedback about the usefulness of the programs.	For planning and organizing the training programme, the details of training needs, the knowledge and operational skills are very much essential. SAUs & ICAR Research Instt. are the source of such knowledge content and skills which forms the course materials for the training programs.	The details of knowledge content and skills for the adoption of recommended technologies by the farmers in their fields. Active participations of farmers, extension personnel's and rural youths.	The participation of farmers, extension personnel from State Department and rural youth are very much essential for organizing the training programmes. Without adequate enrolment of the participation, training programmes can not be organized. Lack of adequate information about recent knowledge and skills required for the adoption of newly recommended technologies will constraints the designing of training programmes.
			Others	[7.1.1]	Print and electronic publication / products brought out	Subscription and utilization of the various knowledge products like books, newsletter, journals by the host organizations like SAUs, KVKs, ICAR Institutes etc. Management of the subscribed knowledge products by the host organizations for their wider dissemination among their staff, students etc.	The ICAR institutes and State Agricultural Universities conduct research, teaching and capacity building activities for which updation of recent knowledge, innovations, research findings are must. These are the organization utilizes the knowledge products created by DKMA.	Subscription of the knowledge products published/brought out by the DKMA.	Unless, the SAUs and ICAR Institutes take adequate steps for subscribing and effective utilization of various knowledge products, it is not feasible to reach the users like students, researchers, academic staff, extension functionaries etc.

Section 6

Outcome/Impact of activities of department/ministry

	Outcome/Impact of Department/Ministry	Jointly responsible for influencing this outcome / impact with the following department (s) / ministry(ies)	Success Indicator	Unit	2012-2013	2013-2014	2014-2015	2015-2016	2016-2017
1	Use of quality seed	DoAC	Quantity of breeder seed produced	Quintals	135270	121000	121250	121500	121750
2	Human resource deveopment		Fellowships granted every year (subject to availability of competent candidates)	Number	658	640	645	650	655
			Faculty trained	Number	958	1850	1900	1950	2000
3	Better utilization of natural resources		Technologies developed/ refined for improving soil health, nutrient use efficiencies and water productivity	Number	9	11	11	13	13
4	Farm mechanization	DoAC, Ministry of Agriculture, State Deptt. of Agriculture	Implements developed/refined	Number	19	21	21	22	22

Acronyms

ABST	: Antibiotic Sensitivity Test
AcMNPV	: Autographa Californica Multiple Nucleopoly-hedrovirus
ADF	: Acid Detergent Fibre
AFC	: Age at First Calving
AFLP	: Amplified Fragment Length Polymorphism
AGID	: Agar Gel Immunodiffusion
AI	: Artificial Insemination
AICRP	: All India Coordinated Research Project
AINP	: All India Network Project
ALV	: Avian Leukosis Virus
ASAM	: Alkaline Sulfite Anthraquinone Methanol
ASEAN	: Association of South-East Asian Nations
ASF	: African Swine Fever
ASRB	: Agricultural Scientists' Recruitment Board
ATIC	: Agricultural Technology Information Centre
AUTM	: Association of Universities for Technology Management
BAIF	: Bhartiya Agro-Industrial Foundation
BCM	: Billion Cubic Metres
BHU	: Banaras Hindu University
BOD	: Biochemical Oxygen Demand
BTV	: Blue Tongue Virus
BVDV	: Bovine Viral Diarrhoea Virus
CAFT	: Centres of Advanced Faculty Training
CAU	: Central Agricultural University
CAZRI	: Central Arid Zone Research Institute
CCHF	: Crimean Congo Hemorrhagic Fever
CeRA	: Consortium for e-Resources in Agriculture
CFT	: Complement Fixation Text
CGIAR	: Consultative Group on International Agricultural Research
CIAE	: Central Institute of Agricultural Enginnering
CIARI	: Central Island Agricultural Research Institute
CIBA	: Central Institute of Brackish Water Aquaculture
CIFE	: Central Institute of Fisheries Education
CIMMYT	: Centro International de Mejormento de Maize Trigo
CMS	: Cytoplasmic Male Sterility
CP	: Crude Protein
CPE	: Cumulative Pan Evaporation
CRRI	: Central Rice Research Institute
CSEV	: Classical Swine Fever Virus
CSFL	: Coloured Synthetic Female Line
CSML	: Coloured Synthetic Male Line
CPC	: Corn Protein Concentrate
CSFL	: Synthetic Coloured Female Line
CWM	: Chicken Waste Meal
DAS	: Days After Sowing
DAT	: Days After Transplanting
DRWA	: Directorate of Research of Women in Agriculture
EEE	: Eastern Equine Encephalitis
EHV	: Equine Herpes Virus
EIA	: Enzyme Immuno Assay
ELISA	: Enzyme-linked Immunosorbent Assay
EPN	: Entomopathogenic Nematode
ETL	: Economic Threshold Level
EXPSS	: Expert System on Seed Spices
FAD	: Fatty Acid Desaturase
FAO	: Food and Agriculture Organization
FCR	: Feed Conversion Rate
FEC	: Faecal Egg Count
FMD	: Foot-and-Mouth Disease
FSH	: Follicle-stimulating Hormone
FYM	: Farmyard Manure
GADVASU	: Guru Angad Dev Veterinary and Animal Sciences University
GBNV	: Groundnut Bud Necrosis Virus
GBPUAT	: Govind Ballabh Pant University of Agriculture and Technology
GDP	: Gross Domestic Production
GEF	: Global Environmental Facility
GHG	: Greenhouse Gases
GIS	: Geographical Information System
GML	: Gramapriya Male Line
GPA	: Global Plan of Action
GPS	: Global Positioning System
HAPA	: Hybridization-supplemented Apomixis Components Partitioning Approach
HDPE	: High Density Polyethylene
HF	: Holstein Friesian
HPNA	: Highly Pathogenic Notifiable Avian Influenza
HPTLC	: High Performance Thin Layer Chromatography
HRR	: Head Rice Recovery
HSP	: Heat Shock Protein
IAA	: Integrated Agri-aquaculture
IBR	: Infectious Bovine Rhinotracheitis
ICARDA	: International Centre for Agricultural Research in Dry Areas
ICMV	: Indian Cassava Mosaic Virus
ICRISAT	: International Crops Research Institute for Semi-Arid Tropics
ICT	: Information and Communication Technologies
IFS	: Integrated Farming System
IHC	: Immuno-histochemistry
IPM	: Integrated Pest Management
IPNS	: Integrated Plant Nutrient System
IPR	: Intellectual Property Rights
ITK	: Indigenous Technical Knowledge
JE	: Japanese Encephalitis
JNKVV	: Jawaharlal Nehru Krishi Vishwa Vidyalaya
KVAFSU	: Kerala Veterinary, Animal Sciences and Fisheries University
KVK	: Krishi Vigyan Kendra
LDPE	: Low Density Polyethylene
LLO	: Listeriolysin-O
LPNA	: Low Pathogenic Notifiable Avian
LRI	: Land Resource Inventory
MAb	: Monoclonal Antibody
MAS	: Molecular Marker-assisted Selection
MAT	: Macroscopic Agglutination Test
MoU	: Memorandum of Understanding

MPP : Methane Production Potential
MPUAT : Maharana Pratap University of Agriculture and Technology
MRSA : Methicillin Resistant *Staphylococcus aureus*
MSCs : Mesenchymal Stem Cells
MW : Molecular Weight
NABG : National Agricultural Bioinformatics Grid
NADRES : National Animal Disease Referral Expert System
NAE : Niche Area of Excellence
NARD : National Agricultural Research Database
NARS : National Agricultural Research Systems
NASF : National Agricultural Science Fund
NBSS&LUP : National Bureau of Soil Survey and Land Use Planning
NDF : Non-detergent Fibre
NDRI : National Dairy Research Institute
NDVSU : Nanaji Deshmukh Veterinary Science University
NEH : North-Eastern Hills
NET : National Eligibility Test
NGOs : Non-Government Organizations
NIABI : Network of Indian Agri-business Incubators
NICRA : National Initiative on Climate Resilient Agriculture
NISAGENET : National Information System on Agricultural Education Network
NRC : National Research Centre
NRCC : National Research Centre on Citrus
NSP-Ab : Non Structural Protein Antibody
NTS : National Talent Scholarship
NUE : Nitrogen Uptake
NWPSI : Network Project on Sheep Improvement
OBCs : Other Backward Classes
PCR : Polymerase Chain Reaction
PIADC : Plum Island Animal Disease Center
PG : Post-graduate
PME : Priority Setting, Monitoring and Evaluation
PPGSE : Plausible Potato Growing Seasons Estimator
PPR : *Peste des Petitis Ruminants*
PRRSV : Porcine Reproductive and Respiratory Syndrome Virus
QTL : Quantitative Trait Loci
RAWE : Rural Agricultural Work Experience
RCCARI : Research Centre of Central Avian Research Institute
RDF : Recommended Dose of Fertilizers
RE : Revised Estimate
RFD : Results-Framework Document
RFLP : Restricted Fragment Length Polymorphism
RH : Relative Humidity
RMP : Research Management Positions
RNFE : Rural non-farm Employment
RVF : Rift Valley Fever
SAARC : South Asian Association for Regional Co-operation
SAUs : State Agricultural Universities
SCSMV : Sugarcane Streak Mosaic Virus
SiRNA : Small interferring RNA
ShRNA : Small hairpin RNA
SNP : Single Nucleotide Polymorphism
SOD : Super Oxide Dismutase
SPR : Surface Plasmon Resonance
SRF : Senior Research Fellowship
SSD : Surface and Subsurface Drainage
SRI : System of Rice Intensification
SSB : Spawning Stock Biomass
SWYMOD : Surface-Water Yield Model
TANUVAS : Tamil Nadu University of Veterinary and Animal Sciences
TDN : Total Digestible Nutrient
TFP : Total Factor Productivity
TLCV : Tomato Leaf Curl Virus
TLR-1 : Toll Like Receptor-1
TMU : Total Milk Yield
TOT : Transfer of Technology
TSP : Tribal Sub-Plan
TSS : Total Soluble Solids/Sugars
TTV : Transfusion Transmitted Virus
UG : Under-graduate
UGC : University Grants Commission
UV : Ultra Violet
VACV : Vaccinia Virus
VS : Vesicular Stomatitis
VNTR : Variable Number Tandem Repeats
VPKAS : Vivekananda Parvatiya Krishi Anusandhan Sansthan
VRFA : Variable Rate Granular Fertilizer Applicator
WB : Western blot test
WNF : West Nile Fever

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