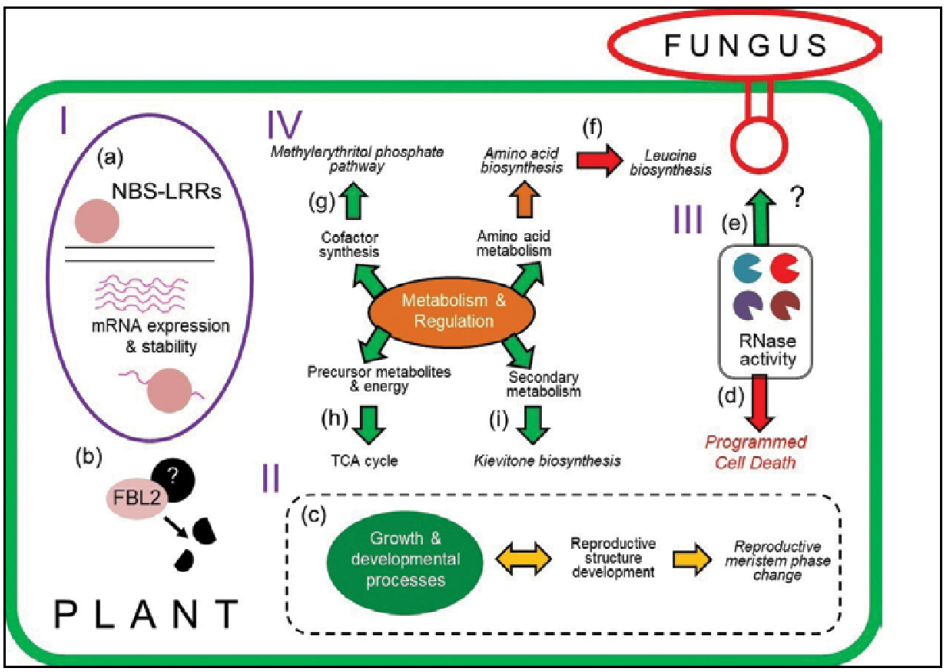
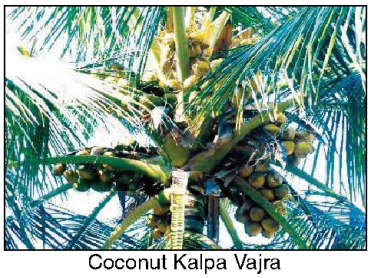


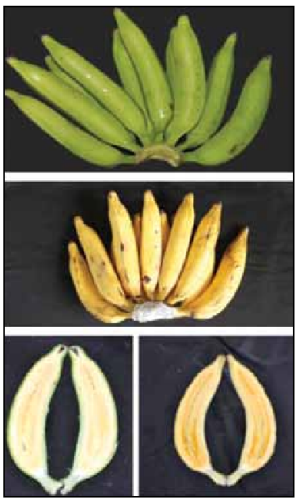
Schematic representation of the role of maize constitutive gene network in fungal resistance.

Improved varieties of various horticultural crops

Narendera Bael-11



Coconut Kalpa Vajra



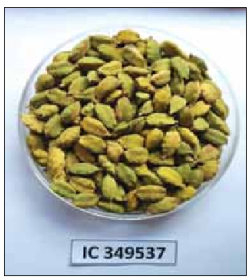
Fruits of Kaveri Kanchan (NCR 17)

Nethra Jumbo 1cashew hybrid

SreeKaveri Cassava

Potato MP / 09-45

tannia variety IGSGTN-1



Small cardamom IC 349537

genic-SSR markers for winged bean was developed from the publicly available RNA seq data sets and 58811 unigenes were assembled, and 4,107 perfect SSRs were identified. Effect of Zn deficiency was evaluated in BKS-41 (high seed zinc) and Sadabahar (low seed zinc). Higher shoot length, root length, longer root hair zone, high root hair density, higher relative chlorophyll content and dry weight were observed in BKS-41 as compared to Sadabahar under zinc deficient condition. The study to identify

regulatory genes associated with RFOs biosynthesis in peanut (*Arachis hypogaea*) suggested Raffinose Synthase (RS) for the differential accumulation of RFOs. four varieties of faba bean, i.e. *Swarna Suraksha*, *Swarna Safal*, *Swarna Gaurav* and *Pusa Sumeet* were evaluated as a natural source of L-Dopa. Higher amount of L-Dopa was found in immature leaf and flowers. A screening method was designed for amylose estimation in maize kernels. The proposed method is rapid and simple for screening of maize kernels with varied amylose amounts, and gets completed in 1 min. Meta-QTL analysis for fungal disease resistance in maize revealed 128 QTLs associated with resistance against 12 fungal diseases (SLB, NCLB, BLSB, GLS, HS, FSR, FER, GER, AER, PLS, CS, SDM) across the maize genome. Application for an Indian patent (Application No. 202211015547) on rapid differentiation of normal maize from Quality Protein Maize was filed. The developed method requires 5 minutes for differentiating normal maize from QPM, when a milled sample is provided. Genome editing for early flowering and seed size displayed increase in leaf size, stem length and seed weight in edited chickpea lines as compared to their normal control types. Full-length gene sequence of grasspea oxalyl-CoA synthetase and ODAP synthase, enzymes functional in OAP synthesis in grass pea, were identified and submitted to Genbank with accession No. MH469748 and MZ127288, respectively. Two QTLs/genomic region on chromosome 2 and 8 were mapped for Fusarium wilt resistance in pigeonpea.

CRISPR/Cas technology was utilized to edit the cytokinin oxidase (*OsCKX2)* gene of indica rice cultivar controlling the grain number in order to increase the yield of Samba Mahsuri. The genome-edited To lines showed 200 to 496 grains/panicle in comparison to ~150 grains/panicle in wild-type or non-edited Samba Mahsuri plants while T1 lines showed desired characters like strong culm and early maturity. To create novel variants for morphological, physiological, and biotic stress tolerance traits, induced mutations were created in the background of Samba Mahsuri (BPT 5204). The mutant lines showed enhanced tolerance to important biotic stresses (YSB, ShB and BLB). Multiple abiotic stress responsive genes were identified using transcriptomics in sugarcane. A chromosome-level reference genome assembly (2.93 Gb; 97.66% Coverage) of Indian Tea (*Camellia assamica* var. Masters cv. TV-1) genome was generated anchoring 99.4% of super-scaffold level assembly into 15 clusters or pseudomolecules by Hi-C data with the size of clusters ranging from 303.18 Mb to 119.95 Mb. A novel abiotic stress responsive gene LOC_Os06g10210 (*OsCHI2*) isolated from a drought tolerant rice cv. Nagina 22 (N22) which showed upregulation in response to drought stress was identified. miR156 site in *Ideal Plant Architecture 1* (*IPA1*) gene in rice variety, Swarna, was edited. Panicle architecture and spikelets/panicle improved significantly in edited lines. Presence of Protein Body 1 and 2 under different post-harvest processing conditions of grains of high protein rice CR Dhan 310 was identified. In order to identify the high resistant starch rice, 100 rice lines were analyzed which revealed ariation in the range of 0.28% to 2.94% with Gayatri rice line showing the highest resistant starch content of 2.94% over the years (2019 to 2022).

To screen large number of genotypes for vivipary, laboratory method was proved efficient considering the correlation with field observation data, outstanding genotypic difference and convenience of testing. Mutants of BPT 5204 with robust root system architecture, early seedling vigour index, and higher yield under limiting water conditions identified which are suitable for the dry direct seeding under aerobic system of rice cultivation. Genomes of rice restorer line KMR3 (salinity-sensitive) and its salinity tolerant introgression line IL50-13 were sequenced. Draft genome of yellow stem borer *Scirpophaga, incertulas* an agriculturally important pest with 46,057 genes and estimated size of 308 Mb was generated. During 2021-22, breeder seed production in field crops was 101617.5 quintals against the indent of 77260.1 quintals and total production of quality seed was 349596.6 quintals against the target of 312584.7 quintals. In addition, 234.5 lakh planting material and 5.4 lakh tissue culture plantlets were produced against the targets of 174.3 and 4.7 lakh, respectively.

In horticultural crops, 122 varieties were notified for cultivation under different agroclimatic conditions. These included 15 varieties of fruits, 1 of plantation crops, 97 of vegetables, 2 of tropical tubers and 7 of spices. The molecular linkage maps of two grape varieties (Carolina Black Rose and Thompson Seedless) were developed. Genome assembly of Indian pomegranate cv. Bhagawa was released. Varietal signature for genetic purity of spices were identified and identity of nutmeg varieties IISR Vishwashree, IISR Keralashree and Sindhushree was established. Marker free late blight resistant transgenic line KJ66 of potato was

identified. A total 1047 activation tagged lines were generated in potato cv. Kufri Jyoti and Kufri Chipsona 1 using activation tagging vector pSKI015. Targeted editing of potato genome was done to develop variety specific True Potato Seed (TPS). A total of 16 lines of potato with mutation within MiMe genes (StOSD, StREC8 and StSP011) were generated. Molecular identification and diversity of 25 *Pleurotus* mushrooms were investigated. Seven new hybrid strains of *Pleurotus* were developed by mating single spores from *Pleu rotusos treatus* (DMRP 30) and *Pleurotus florida* (DMRP 49). The biological efficiency was recorded maximum for hybrid P18102 (79.00%) in two flushes compared to parents and check on pasteurized wheat straw.

2. Livestock Improvement: The evidence of selection signatures in the datasets of 284 individuals of Tharparkar cattle along with 11 other indigenous and exotic cattle breeds were demonstrated. Significant candidate genes were identified related to various important traits such as ADRB2 in Tharparkar; HERC5, SCC25A48 in Gir; CA8 in Ongole and KIAI217 in Sahiwal for milk production; PARN in Holstein; ZBTB20 in Sahiwal; and APBB1 in Tharparkar for reproduction; SP110 in Brown Swiss; HSP90AB1 in Tharparkar and Red Sindhi for thermo-tolerance trait.

The influence of X-linked genes on the sperm functional parameters and field fertility rate in the cattle and Murrah buffalo bulls was studied. The sperm transcriptome studies revealed that the total number and the expression levels of X-linked genes in the mature sperm were very low in both species, and only 23.3% of these genes were commonly expressed between them. The X- linked genes related to embryonic organ development and reproduction were enriched in cattle and buffalo sperm, respectively. The expression levels of X-linked genes in cattle RPL10 and ZCCHC13, and buffalo AKAP4, TSPAN6, RPL10 and RPS4X were significantly correlated with sperm kinematics. Evidently, the expression level of RPL10 and RPS4X was significantly correlated with the field fertility rate in cattle and buffalo, respectively. Multivariate regression models and receiver operating curve analysis suggested that the expression levels of X-linked genes may be useful in predicting the bull fertility rate.

An egg yolk-free, ready to use, semen extender for cattle and buffalo with higher shelf-life (≥18 months, 4°C) for cryopreservation of buffalo semen was developed for the first time in India. The post-thaw progressive motility of cryopreserved buffalo sperm in the new egg-yolk free semen extender was significantly higher. A farm-to-fork block chain-based buffalo meat traceability system, BuffTrace, was developed for buffalo meat industry in collaboration with a private company. The system helps in collection of post-slaughter information and retrieval of the traceability information based on the label details.

CARI-Prabal

The complete mitochondrial genome sequences of 88 Indian sheep representing 22 breeds/ population were analyzed for the first time to get a comprehensive picture of the maternal diversity in the sheep genetic resources of India. The mitochondrial DNA sequence of all Indian sheep was observed to be 16617 bp long and contained 37 genes, including 13 protein coding genes, 2 rRNA genes, 22 tRNA genes, and a control region. Network Project on Sheep Improvement (NWPSI) and Mega Sheep Seed Project (MSSP) with major objective of improvement of indigenous sheep breeds were initiated.

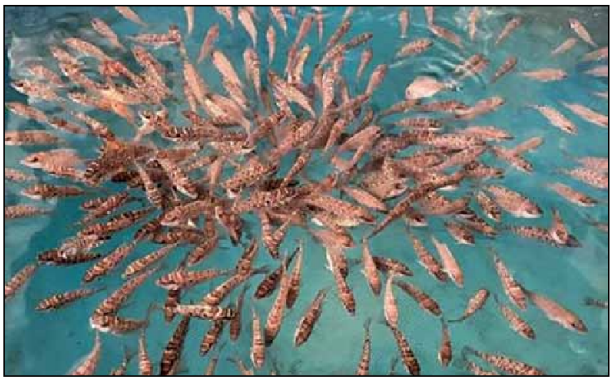
Concurrent transcriptome and methylome analysis of pig breeds (Mali and Hampshire) with varying muscularity was done to obtain insights into myogenesis. Muscle transcriptome identified 20226 mRNAs out of which 15170 were present across the samples. Developed economic and nutritionally balanced silage-based pig feed following standard procedure from vegetable wastes adding jaggery (gur) at the rate of 3 kg per 100 kg raw chaffed

vegetable waste for suitable anaerobic fermentation in silage bags. A total of 1,934 liquid boar semen doses were produced and supplied for artificial insemination in pigs at the farmers' field and organized farms.

Three climate resilient dual type hardy birds, CARI-Dhawal, CARI-Prabal and CARI-Saloni were developed for efficient egg and meat production. To overcome the antibiotic growth promoters used in poultry feed, CARI-HERBIGROW, a natural product was developed with the property of antioxidants, immune enhancer, stress reducer and helps chicken to improve overall production.CARI–HERBISTRESSMIN, a phytogenic feed additive was developed by CARI to reduce effect of heat stress and improve immunity of birds during hot and hot-humid summer. Alternatives for antibiotic growth promoters (AGPs) in feed and alternate protein meal and biofortified maize in poultry diet (black soldier fly (BSF) larva meal) were also developed.

Inhibin alpha gene editing by CRISPR/Cas in Nicobari indigenous chicken led to efficiency of production. The egg production up to 72 weeks of age increased by 203% from 261 eggs in edited birds as compared to 128 egg in control birds. Immunochromatography-based chicken detection kit (ICDK) was developed for the authentication of chicken. Genomic diversity was estimated in Arunachali yak population based on data generated using ddRAD sequencing. Three indices, viz. nucleotide diversity (0.041 in 200 bp windows), effective population size (Ne = 83) and runs of homozygosity (>90% were short and medium length) revealed that the genomic diversity in Arunachali yak breed as of now is optimum.

3. Fish Improvement: Successful natural spawning of green snapper, *Lethrinus nebulosus,* was achieved in recirculatory aquaculture system (RAS). It is a large tropical marine fish species that grows to 80 cm in length and 8.4 kg in weight. *Lethrinus nebulosus* were collected from wild and developed into functional broodstock in 10 t RAS system. Simple non-invasive breeding and culture protocols were developed for four indigenous ornamental fishes of the Western Ghat, viz. *Pethia setnai, Pethia nigripinnis, Dawkinsia tambraparniei* and *Dawkinsia arulius*. Similarly, breeding technique were standardized for two endangered species of genus *Dawkinsia*, viz. *Dawkinsia tambraparniei*, the Tambraparniei barb and *Dawkinsia arulius*, the Arulius barb. Two



Hatchery produced seeds of *Lethrinus nebulosus*

backyard recirculating aquaculture system (RAS) models of rearing tanks size 3 and 7 cubic metre with production capacity of 30 kg per m^3 were designed, fabricated and validated for small-scale farming of rainbow trout by the farmers of hill states to reduce the initial cost of investment.

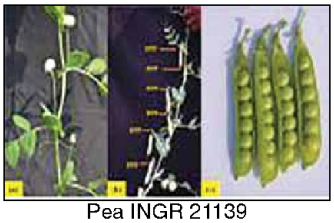
4. Genetic Resources: Total 890 accessions (450 cultivated and 440 wild) including unique landraces of cereals, pulses, oilseeds, vegetables and germplasms of wild edible fruits and wild relatives of the cultivated crops were collected through 18 explorations. Under National Gene bank, 5,152 accessions of orthodox seed species added for long-term storage resulting into the total of 4,62,923 accessions in its present base collection. In Cryogene bank, 404 accessions of seeds and pollen genomic resources of different crop species were cryopreserved, making the total collection of 12,480 accessions. Total of 41,557 accessions were imported from 37 countries and 14,641 entries from trails/nurseries from CG centres. Imported samples numbering 133,673 were processed for quarantine clearance. One plant quarantine database and two web-based applications were developed. ICAR-NBAIM, the nodal agency for developing DNA fingerprints of microbial cultures to be registered as biopesticides developed fingerprints of more than 487 samples for accurate identity. A total of 26 microbes were accessioned under safe deposition and 72 cultures were sold to academia and companies fetching ₹ 291600 revenue to the institute.

In horticulture, a total of 3,346 accessions were collected and 26 accessions showing unique traits were registered as novel genetic stock. Five genotypes of longan of fruit size (8.1 – 8.5g/fruit), an oilpalm cross progeny number 483 (599NATP × 33D) promising for more oil to bunch ratio (21.37%) and 175 fungal mushroom accessions were identified. A QR coded gene bank exclusively for wild genetic resources of banana established at

ICAR-NRC-Banana, Tiruchirappalli. This is the first of its kind in India for conservation of genetic diversity and identify resistant sources to various biotic and abiotic stresses in banana.

Germplasm accessions of horticultural crops showing unique traits


Banana 22060


Pea INGR 21139


Tomato INGR 21150


Radish INGR 21220


Chrysanthemum INGR 21108


Tuberose INGR 22056

In livestock, 10 new breeds of indigenous livestock species, Kathani cattle (Maharashtra), Sanchori cattle (Rajasthan) and Masilum cattle (Meghalaya); Purnathadi buffalo (Maharashtra); Sojat goat (Rajasthan), Karauli goat (Rajasthan) and Gujari goat (Rajasthan); Banda pig (Jharkhand), Manipuri Black pig (Manipur) and Wak Chambil (Meghalaya) were registered making total number of registered indigenous breeds to 212. A total of 44,860 semen doses of 17 native livestock breeds, including nine of cattle (Red Sindhi, Badri, Red Kandhari, Nimari, Deoni, Gaolao, Bhijarpuri, Ghumsari, Khariar) and 8 of goat (Ganjam, Jamnapari, Beetal, Berari, Osmanabadi, Sirohi, Sangamneri and Barbari) were cryopreserved. Also, 1,020 somatic cell vials of 7 native breeds--Purnea, Mewati, Hariana and Shweta Kapila of cattle, Konkan Kanyal of goat; Doom and Purnea of pig were added for cryopreservation. Presently,

Newly registered livestock breeds


Purnathadi buffalo


Sanchori cattle


Karauli goat


Banda pig

National Gene Bank has repository of 61 native breeds/populations of livestock and poultry in form of semen, and 28 in form of somatic cells. Under the Mission Zero Non-descript AnGR, 22 new populations of native livestock and poultry have been identified. These are being characterized in their respective breeding tracts.

In fisheries, 3 freshwater species *Amblycepsh molaii* from Kawlchaw river, Mizoram; *Pangasius icaria,* from Cauvery river, Karnataka; and *Tor sattalensis* from Sattal Lake, Uttarakhand and 5 marine fish/shrimp *Eptatretus wadgensis*,

Marine fish/shrimp species


Amblycepsh molaii sp. nov.

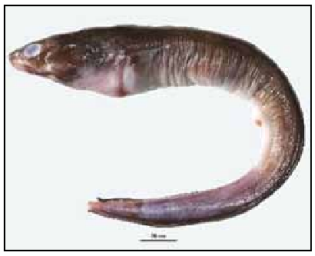

Pangasius icari


Tor sattalensis


Eptatretus wadgensis

Dussumieria modakandai sp. nov

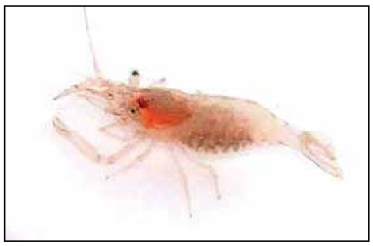
Ariosoma melanospilos



Ariosoma albimaculatum

Ariosoma indicum

Ariosoma maurostigma



Actinimenes koyas

Dussumeria modakandai, Ariosomaalbi maculatum, Ariosoma melanospilos and *Actinimene skoyas* were discovered. Canary top wrasse, *Halichoeres leucoxanthus,* previously distributed in Maldives, Myanmar, Chrismas Island (Australia), Thailand and Western Indonesia was found for the first time in Indian waters. For the first time, recorded catch of marine/deep sea fish species like *Aluterus monoceros, Antennarius indicus, Ariomma indica, Diodom hystrix, Labotes surinamensis, Nemipterus randalli, Priacanthus prolixus, Seriolina nigrofasciata,* in Hooghly- Matlah estuary. Indian oil sardine's whole genome assembly is 1.077 GB (31.86 Mb scaffold N50) in size with repeated content of 22.84%. The sequences were deposited in NCBI, GeneBank. The cell lines from rainbow trout heart and snow trout muscles were developed, authenticated and deposited in ICAR-NBFGR National Repository of Fish Cell Lines.

5. Crop Management: Application of consortium of methane utilizing bacteria (MUB) formulation comprising of *Methylobacterium oryzae* MNL7 and *Paenibacillus polymyxa* MaAL 70 through seedling root dip technology and as spray reduced methane emission by 5 to 25% in flooded rice. Rise in temperature by 1.7^{0}C with elevated CO_2 showed an increase in grain yield across two wheat varieties. Elevated CO_2 (ECO_2) with elevated O_3 (EO_3) alleviated the negative effect of ozone on grain yield. Durum and bread wheat were exposed to leaf compost (LC) and vermicompost (VC) enriched with polyvinyl chloride (PVC) and poly propylene (PP). The microplastics in the farm inputs altered the nutrient availability and uptake. Satellite based crop health indices were developed for whole of India. The spatial layer of active fire points of rice residue burning (October-December) was uploaded on ICAR KRISHI Geoportal on daily basis. Near real time crop condition monitoring was developed using google earth engine platform and moderate resolution satellite data.

Real time soil moisture-based irrigation scheduling of green pea revealed water saving of 44-50% against surface irrigation practice. Conservation practice, permanent beds with residue recorded highest grain yield of *kharif* crops followed by zero tillage and CT. Sugarcane based Integrated farming system developed by ICAR-IISR fetched additional income of ₹ 2,65,902.5/ha in autumn planted sugarcane and ₹ 2,63,020/ha in spring planted sugarcane. The wireless smart trap developed for real time pest monitoring in cotton showed a weekly mean trap catch of 19.8 (*P. gossypiella)*, 6.18 (*S. litura*), 0.19 (*H. armigera*) and 0.08 (*E. vittella*) during 2021-22.

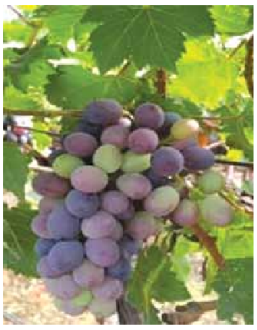
Four mVOCs formulations evaluated @ 5 ppm concentration on the attraction of 4 sucking pests -whiteflies, jassids, aphids, and thrips in cotton using yellow sticky traps (YST) trapped 232%, 1517%, 709%, and 237% higher whiteflies, jassids, aphids, and thrips, respectively as compared to the control. Insect bioassay (*in vitro*) conducted to study the efficacy of the native strain of the *M. rileyi* on FAW indicated M. *rileyi* as potential microbial agent for management of the fall armyworm in sorghum. The survey conducted to understand the infestation and distribution of common bruchid species in legumes, indicated 5 bruchid species infesting pulses, 3 of which were *Callosobruchus*. Among *Callosobruchus* species, *C. analis* was distributed on 50% of the samples and locations, followed by *C. maculatus* and *C. chinensis*.

The formulations based on two Trichoderma species having excellent quality to protect the rice

CICR Wireless Smart Trap

Untreated control

Bio Pulse + Sulphur



Eco-pesticide + Sulphur

Effect of microbial technologies on disease incidence in grape

plant against soil and seed-borne diseases and excellent growth promotion capability developed and tested at farmers' fields. They were highly effective in maize, finger millet, niger and rice. Entomopathogenic nematode (EPN) biopesticide formulation technology was commercialized to 5 companies with a license fee of ₹10 lakhs. Efficacy of fungicide against rice bakanae disease was tested. Spraying of propiconazole @ 2 ml l of water at 15 DAT resulted in the lowest incidence of bakanae disease and higher yield of rice.

Soil application of mycorrhizal consortium @ 20 kg along with 500 kg of compost/ha at the time of sugarcane planting proved an effective bio-control of parasitic weed *Striga* spp. in sugarcane. A multi-residue analysis method was developed for simultaneous determination of 30 herbicides in agricultural commodities using LC-MS/MS. Similarly, a multi-residue analysis method using TLC with the detection limit of <0.01 µg/g was also developed for determination of herbicide combination products namely, pretilachlor + pyrazosulfuron, cyhalofop-p-butyl + penoxsulam and traifmaone + ethoxysulfuron. A user friendly multi-lingual mobile app named 'Herb Cal' for application of herbicides was developed. After entering the herbicide information such as crop, area, dose and herbicide formulation to be used, the app automatically calculates the amount of herbicide and quantity of water to be taken for spray. Biological control of alien invasive weed *Salvinia molesta* in a 20 ha *Salvinia* infested pond in village Padua of Katni district was achieved by releasing 2000 adult weevils of a host specific insect *Cyrtobagous saliviniae*. With the increase of bioagent population 50, 80 and 100% control of *S. molesta* was achieved by 8, 11 and 18 months, respectively.

In grapes, microbe-based technologies, Eco-pesticide, Bio-Pulse, UBSTH-501 and Bio-Care 24 were evaluated against *Erysiphe necator* grape powdery mildew and integrated these technologies with a safer fungicide (sulfur). The percent disease index (PDI) reduced significantly in grape leaves treated with Eco-Pesticide®/sulfur (22.37) followed by Bio-Pulse®/sulfur (22.62) and Bio-Care 24®/sulfur (24.62). An efficient technology for multiplication of clonal rootstock of apple through cutting under greenhouse conditions using soilless rooting medium was standardized. Field application of Nanoparticles of iron and zinc showed a significant increase in leaf Fe and Zn content after 14 and 28 days of application over conventional fertilizers. The performance of Crimson Seedless, Manjari Kishmish and Manjari Medika grapevines grafted on Dogridge and 110R was found superior over other rootstocks. A microbial consortium CISHD ecomposer has potential to accelerate the composting rate. DRIS indices and critical leaf nutrient concentrations were developed for oil palm plantations. Coconut-based Integrated Farming System (CBIFS) realized a net return of ₹ 6,53,853/ha.

Application of customized fertilizers in sweet potato was best for higher tuber yield (22.74 t/ha) compared to present POP (19.67 t/ha). Low cost technology for the paddy straw mushroom cultivation was developed. Vertical farming was standardized for growing important high value flower crops by utilization of 11 feet vertical space of the polyhouse. Nutritional and chemical finger prints of popular turmeric varieties were developed. The effects of nanoZnO (nZnO) on the compositional and functional responses of bacterial communities in soils were examined using high throughput sequencing. Microbial consortia for enhancing the growth and yield of cumin and coriander was identified. Organic nutrient management practices for Sarpagandha were developed. New insect- pests in banana (Fall armyworm, *Spodoptera frugiperda;* Bondar's nesting whitefly, *Paraleyrodes bondari* and bagworm, *Manatha albipes* were identified. Litchi stink bug (*Tessaratoma javanica*) and

the Flower webber were recorded as emerging insect pest attaining major pest status of litchi. An algorithm based on object detection approach was developed for surveillance of rhinoceros beetle infestation using unmanned aerial vehicle (UAV or drone).

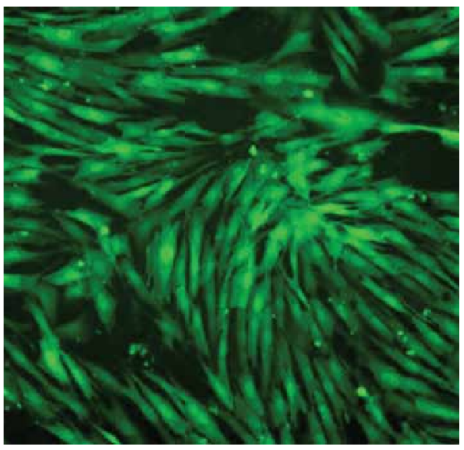
An entomopathogenic fungus isolated from infected *H. theivora* was identified as *M. anisopliae* TMBMA1 and found effective in mirid management in cocoa. Competitive regulation and biological control of rugose spiralling whitefly by the Bondar's nesting whitefly (BNW) during 2021 was observed. Incidence of Fusarium wilt disease, tropical race 4 (Foc TR4) in banana in West Bengal was identified. Citrus microbiome was utilized in rejuvenating Khasi Mandarin plants affected by important citrus diseases. Etiology of emerging diseases in plantation crops was established. A rapid and novel mycelium inoculation technique for inducing *Ganoderma lucidum* infection in coconut and arecanut seedlings was developed. A native plant growth promoting isolate of *Trichoderma asperellum* (isolate AT172) having antagonistic activity against arecanut basal stem rot pathogen *G. lucidum* was identified and characterized.

The cashew leaf blight disease caused by *Neopestalotiopsi sclavispora* was identified for the first time in cashew. RPA-lateral flow assay (RPA-LFA) method was standardized for the on-site detection of the piper yellow mottle virus infecting black pepper. Singleplex and duplex recombinase polymerase amplification (RPA) assays were optimized for specific and sensitive detection of *Pythium* spp. and *Ralstonia pseudosolanacearum* from ginger rhizomes. Marker free late blight resistant transgenic line KJ66 was identified. Prototype of a remote operated unmanned ground (UGV) vehicle was designed and developed for spraying of agrochemicals on potato crop. Sodium alginate-based bead formulation of fungal mycelia and conidia for long term storage of fungal cultures were developed.

6. Livestock Management: Thirteen healthy buffalo calves (seven males and six females) were produced from semen of two cloned bulls. This technology will lead to future sustainable milk production in the country. Prototype of intra-vaginal wireless sensor device was developed for remote monitoring of calving process in dairy cows. This could help in predicting the calving time in cattle. NADRESv2, a dynamic geographic information and remote sensing-enabled expert system maintained by ICAR-NIVEDI was updated in the NADRES database, and a total of 5655 predictions for major livestock diseases were communicated to State Animal Husbandry Departments and Department of Animal Husbandry and Dairying (DAHD), GoI, in the form of risk maps, bulletins, and post-prediction maps for necessary preparedness. Nation-wide sampling plans for sero-surveillance and sero-monitoring of foot and mouth disease (FMD), brucellosis, *Peste des Petits Ruminants* (PPR) and classical swine fever (CSF) for each state/UTs of the country were formulated and provided to DAHD, GoI, for strengthening the surveillance system. Screening of serum samples (32,257) for important livestock diseases from different animal species submitted to various NADEN units and State Animal Husbandry Departments was carried out. The sero-diagnostic services were provided for infectious bovine rhinotracheitis (IBR), trypanosomiasis and pasteurellosis with 28.9%, 49% and 4.5% positivity, respectively in ruminants. Brucella post-vaccination sero-monitoring is one of the major activities to evaluate the impact of the control program. Towards this, a total of 14,611 sera collected from different states were screened, of which, 64.45% were positive for anti- brucella antibodies.

Under FMD sero-surveillance, 98,185 bovine serum samples from around the country were analyzed and an overallsero-positivity in 16.6% of the tested samples was reported. The state FMD centers were provided with three main test kits (3AB3 indirect DIVA ELISA for 1,75,583 samples, Solid Phase Competitive ELISA (SPCE) for 1,56,778 samples, and Sandwich ELISA for 3893 samples. Clinical samples (2824) were analyzed for serotype identification in 378 FMD outbreaks. During 2021, all three FMD virus serotypes were documented, with serotype O leading the outbreak scenario followed by serotype A. Overall, the disease incidences have increased compared to previous year. A total of 113 FMD virus isolates (102 O, 10 A and 1 Asia 1) revived in BHK-21 cell system were added to the National Repository of FMD Virus maintained at International Centre for FMD, Bhubaneswar and Mukteswar Laboratory. PPR Ab Check kit for the detection of PPR Virus nucleocapsid protein antibodies in the serum samples and PPR Ag Check kit for the detection of PPR virus in Clinical specimens of sheep and goats; Recombinant nucleocapsid protein based indirect ELISA kit for detection of Anti SARS CoV-antibodies in canines (CAN-CoV-2 iELISA

kit) and Multi recombinant proteins based ELISA Kit for diagnosis of Trypanosoma evansi infection in animals; TaqMan-probe-based realtime RT-PCR assays (RT-qPCR) for pan-serotype detection of FMDV; Recombinase polymerase assay for detection of African swine fever virus in pigs; Multiplex PCR to differentiate Mycobacterium tuberculosis complex species; Rapid colorimetric assay for detection of the extended spectrum β-lactamase producing bacteria; Lateral flow assays (LFAs) for detection of CD virus antigen and antibody were developed. Among the vaccines, Ancovax for SARS-CoV2 infection; LSD vaccine named Lumpi-ProVacInd against LSD; Inactivated Low Pathogenic Avian Influenza (H9N2) vaccine for chickens; Thermostable serotype O vaccine for FMD were developed. Mesenchymal stem cells (MSCs) with or without egg shell membrane, bioactive collagen gel, collagen powder, platelet rich plasma, and MSC laden Nano-scaffolds of hydroxyapatite and multiwalled carbon nanotubes were evaluated for skin wound, bone and nerve healing in animal models, and showed promising results. p38 mitogen activated protein kinase inhibition suppresses buffalopox virus (BPXV) protein synthesis by targeting p38-MNK1-eIF4E signaling pathway. The P60-SB239063 virus exhibited significant resistance to SB239063 as compared to the P60-Control virus. This is a rare evidence, wherein a virus was shown to bypass the dependency on a critical cellular factor under selective pressure of a drug. An online database management system named MHC Database was created (http://www.mhcdbms.in/) to allow easy access and use of immune polymorphism data. This system also allows user to upload as well as download the indigenous Ovar MHC allelic database for sheep breeds in FASTA format. CRISPR/CAS9 mediated knock-in of human Erythropoietin gene in the goat fibroblast cells was done and the transgenic goat fetal fibroblast cells expressed hEPO gene fused with green fluorescent protein (GFP) gene. ICAR-NRCE, Hisar is actively involved in glanders surveillance, providing diagnostic support, capacity building of state diagnostic laboratories/ RDDLs. For rapid and efficient execution of surveillance activities, Hcp1 ELISA kit developed by NRCE is being used for glanders diagnosis. A total of 1737 equine serum samples from 8 states were tested for equine infectious anemia (EIA), equine influenza (EI), Equine Herpes Virus-1 (EHV-1), Japanese Encephalitis/ West Nile Virus (JEV/ WNV), *Trypanosoma evansi* (Trypanosomiases), piroplasmosis Salmonella, *Abortus equi* and brucellosis. Highest sero-prevalence was observed for equine piroplasmosis (38.40%) followed by EHV-1 (7.80%), JE/WNV (7.40%), and *Trypanosoma evansi* (2.15%). Stallion seminal plasma proteins were profiled and the proteins and pathways associated with sperm motility were identified. Purification, molecular characterization and ligand binding properties of the major donkey seminal plasma protein (DSP-1) isolated from donkey (*Equus hemionus*) seminal plasma was done. Transgenic chickens were produced through sperm mediated gene transfer (SMGT) method with an efficiency of 5.4%. In the transgenic birds, human interferon alpha 2b gene was introduced at the germ line stage in the chicken genome. The transgenic hens laid 132 eggs with an average content of 30-40 mg of interferon alpha 2b protein in each egg. Characterization of colostrum of native cattle and yak of high-altitude region of Leh-Ladakh was done in comparison to Sahiwal (SAC). Samples from LSD suspected outbreaks in 20 States/UTs of the country were tested to identify laboratory confirmed cases of LSDV infection for undertaking prevention and control measures against LSD in India. A total 2456 bovine (cattle



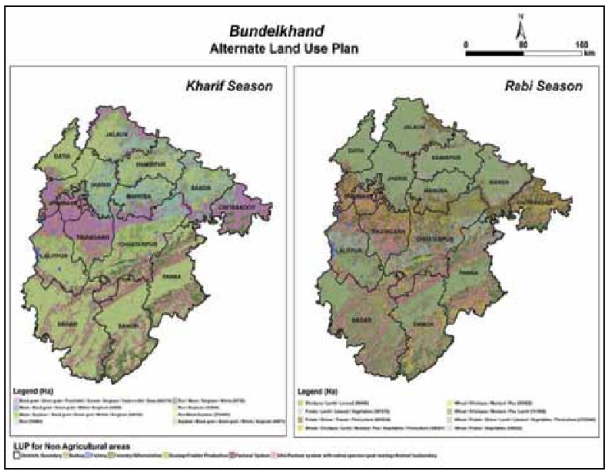
Transgenic goat fetal fibroblast cells expressing hEPO gene fused with green fluorescent protein (GFP) gene

MCRV infected *S. serrata* displaying grey colour shell discolouration

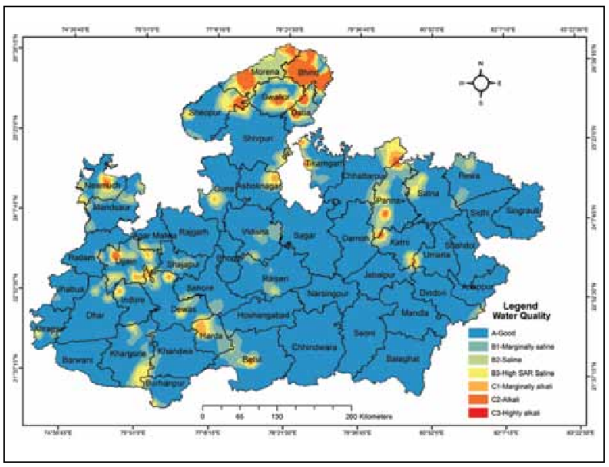
and buffalo) samples were tested, of which, 1156 cattle samples from 19 States/UTs tested positive for LSDV. First whole genome analysis of Indian African swine fever viruses revealed potential genetic determinants to differentiate closely related ASFV circulating in Asia. Global alignment of the complete genome sequences showed nucleotide identity of 99.96% amongst the two Indian isolates (IND/AS/SD-02/2020 and IND/AR/SD-61/2020). The results showed the importance of the 14 ORFs in understanding the evolution of ASFV in Asian countries and their divergence from prototype ASFV Georgia/2007. Whole Genome Sequencing of 12 Bovine coronaviruses isolated from cow (3) and buffalo (9) nasal and faecal samples collected in 2020-21 revealed two different subgroups: subgroup GIa having 9 viruses cluster from across the world and GIb subgroup having 3 other viruses cluster which has majorly the isolates of France in 2017. A food-grade meat decontaminant spray was developed by using the extracts of Ashwagandha roots and Guava leaf spray which could reduce the microbial load many folds in retail fresh chicken. Phytochemicals (thymol and cinnamaldehyde) conjugated silver nanoparticles (AgNPs) were tested for their efficacy against Enteroaggregative *Escherichia coli* (EAEC) and non-typhoidal Salmonella. Assays revealed the antimicrobial activity of the encapsulated compounds (EAgC and EAgT) and appeared to be safe.

7. Fisheries Management: A web-GIS application for location-specific riverine fisheries management was developed. It provides an interactive and user-friendly interface which contains environmental data of 300 sampling stations covering 20 major rivers of India. The portal's database and customized reports will facilitate various researchers, planners and policymakers to make judicious planning/strategies for the betterment of fisheries resources. Mud crab, *Scylla serrata,* is an economically important crustacean species which is also being cultured. Mud Crab Reo Virus (MCRV) is an emerging viral pathogen in mud crab culture. On RT-PCR screening, MCRV were detected in gills and hepatopancreatic tissues. Herpes viralha ematopoietic necrosis disease (HVHND) is caused by CyHV-2, which causes severe mortality in goldfish. A rapid and sensitive RPA (Recombinase Polymerase Amplification) assay, coupled with lateral flow dipsticks (LFD) was developed by designing specialized RPA primer, LFA primers and probes. The RPA-LFD assay developed presents a simple, rapid and sensitive method for point-of-care diagnosis of CyHV-2, especially under resource limited conditions. A Coliphage cocktail for controlling antimicrobial resistant (AMR) *E. coli,* containing 10 coliphages, selected based on their broad host range, varied location and their ability to lyse AMR *E. coli* was developed. The Coliphage cocktail has a phage titer of ~10^{12} to 10^{14} pfu/ml and can be used for the control of *E. coli* and AMR *E. coli* on food contact surfaces. The Coliphage cocktail can be stored under chilled conditions (<4ºC) condition for a minimum period of 3 months.

8. Soil and Water Productivity: Micro level



Proposed alternate land use plan for Bundelkhand



Groundwater quality map of Madhya Pradesh for irrigation

agricultural land-use planning, soil and water conservation, water harvesting, storage and groundwater recharge, improvement in water productivity and nutrients use efficiency, integrated nutrient management, resource conservation technologies, chemical free agriculture, integrated farming system, waste-water use, dryland, hill and coastal agriculture, weed management, precision agriculture, climate resilient agriculture, abiotic stress management was given special thrust. The land resource inventory (1:10,000 scale) for Bundelkhand region prepared for sustainable land use, spectral signature library of the soils of India for quick and inexpensive acquisition of surface soil properties, potential crop planning zones of Telangana, and land suitability analysis for turmeric in Kerala under projected climate change scenarios were accomplished. The groundwater quality map of M.P. for irrigation and groundwater recharge plan for Korba and Janjgir-Champa districts in the upper Mahanadi Basin developed. ICAR-CSSRI and NTPC joint study on efficiency of flue gas desulfurization gypsum (FGDG) revealed 8-11% decline in saline soil pH after one year of FGDG surface application (0-15 cm depth) and neutralization of soil alkalinity improved paddy yield by ~40%. A Solar Irrigation Pump Sizing Tool (SIPS) was developed for large scale adoption by farmers and support the PM-KUSUM initiatives. To promote organic farming, packages for 5 cropping systems for Gujarat, Rajasthan and Uttarakhand were developed. ICAR-NIASM developed beta version of the Abiotic Stress Information system (ASIS) consisting of modules on Atmospheric and Soil Stress information for generating query based geo-spatial maps. The new salt tolerant varieties in rice (CSR 76) and mustard (CS 61 and CS 62) were developed.

9. Mechanization and Energy Management: A tractor operated side trencher was developed to make trench up to 300 mm depth. The effective field capacity and field efficiency of the trencher were 0.2 ha/h and 71%, respectively when operated to dig a trench of 300 mm deep in 3 m wide vineyard at 2.0 km/h forward speed. The cost of operation of tractor operated side trencher is about ₹ 560/hr. It economizes the cost of operation, labour and time by 72, 94 and 80%, respectively as compared to manual digging of trench with hand tools. The tractor operated FYM applicator of 1 tonne capacity was developed for placing FYM near the plant. The cost of operation of tractor operated FYM applicator is about ₹ 645/hr which saves labour, time and cost of operation by 98, 80 and 88%, respectively as compared to manual method. Manual operations of raised bed forming, drip lateral and plastic mulch laying, and planting seeds in a plastic mulch requires about 29 man-days/ha. A tractor operated drip lateral and plastic mulch layer-cum-planter was developed to perform raised bed formation, drip lateral and plastic mulch layingetcin single pass of the tractor. The total cost of equipment is ₹3,00,000 with operational cost of ₹1,500/hr. The payback period of equipment is 1.9 years. A self-propelled walk-behind maize harvester for snapping the maize cobs from the maize plants and simultaneously cutting the plants has been developed. The effective field capacity of the harvester is 0.2 ha/hr and the cost of operation of the maize harvester is ₹ 2,850/ha. The saving in cost of operation, time and labour are 25, 96 and 91%, respectively compared to manual harvesting. A remote-controlled electronic system was developed for ride-on rice transplanter to reduce human drudgery. It can be remotely operated at a distance of 200 m. The field capacity of remote-controlled ride-on rice transplanter is 0.24 ha/hr. To ease the digging of garlic, a tractor operated harvester was developed which can harvest garlic crop planted on raised beds. The harvesting efficiency of the harvester is 97% and bulb damage is <0.5%. A small tractor-mounted hydraulic pruner for orchards was developed with the pruning capacity of 120 plants/hr. The cost and operating cost of the pruner is ₹ 4,50,000 and ₹ 4,910/ha, respectively. ICAR-CIAE had developed a low-cost SPAD meter 2.0. It measures SPAD values for crops such as rice, wheat, maize, etc. with leaves up to 1 mm thickness. The SPAD values, measured with the device, can be used to generate recommendations for top-dressing of nitrogen fertilizer dose. A small tractor operated boom sprayer was developed for orchard crops. The cost of the spraying system is ₹ 30,000. The discharge rate of boom sprayer is 608 l/hr at 0.3 MPa pressure. The application rate and turning time of the spraying system was 475 l/ha and 12 s, respectively. A power tiller operated groundnut digger was developed with field capacity of 0.07-0.11 ha/h and digging efficiency of 97.6%. A tractor operated potato digger developed which performs three operations, viz. digging of potato tubers (two rows), separation of potatoes from soil and collection of potatoes in the collection unit. The average field capacity and output capacity are 0.12 ha/hr, 2700 kg/hr for sandy loam soil and 0.11 ha/hr, 2685 kg/hr for loamy soil, respectively. A digital flume with the Internet of Things (IoT) connectivity

Unmanned Rice Transplanter

SPAD Meter 2.0

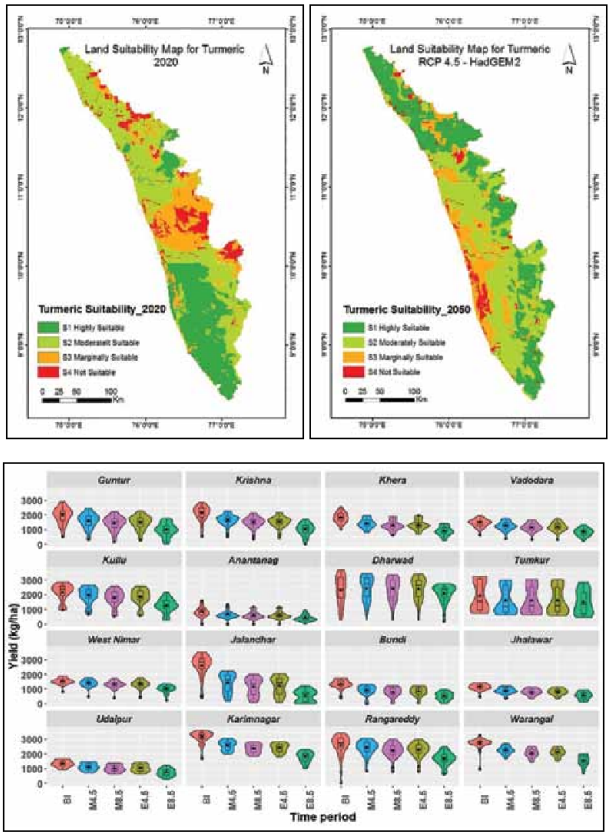
was developed and tested to continuously measure the flow rates in open channels. Utilizing the IoT, the developed digital flume measures the discharge and transmits data wirelessly for storage on cloud (ThingSpeak). It was tested in the field under varying discharge conditions in the field channel. It can be utilized for irrigation water measurement in the field channel for management of available irrigation water.

10. Post-Harvest Management and Value-Addition: Post-harvest treatments machine for pre-cooling, washing, warm water treatment, anti-microbial treatment, anti-browning, and pulsed light treatment to the freshly harvested fruits and vegetables was developed. It also has an inspection conveyor to sort out the deformed and damaged products. The capacity of the machine is 1.2 t/hr for capsicum,1.0 t/hr for apple at a linear belt speed of 5 m/min.The peeling machine for medicinal tuber crops was developed with peeling efficiency of ~ 92% for *Safed musli* and 55% for *Shatavari* and capacity of ~15-20 kg/hr which is 30 times higher than manual operation. An electronic sensing system (e-Nose) has been developed in collaboration with C-DAC Kolkata for the real-time health monitoring of the onions, potatoes, and tomatoes in storage. The machine for popping of sorghum, amaranth, finger millet, kodo millet, and other small grains including rice, and corn developed with a capacity of 1.4-2 kg/hr and 60-70% popping recovery for sorghum and amaranth. To provide easy, fast and non-destructive method for detection of pea flour adulteration in *besan*, near infra-red spectroscopy (NIRS) model was developed which can be used to predict adulteration of *besan* with pea flour. A novel process based on microbial precipitation process to produce protein isolates/concentrates from oilseed cakes/meals was developed. This method increased 5% yield as compared to the chemical process. The protein produced is superior in terms of solubility, wettability, water absorption capacity and degree of hydrolysis. Multi-nutrient biscuits with high satiety value, appealing taste and 21% higher acceptability on a sensory scale over commercial biscuits were prepared. The cake formulation consists of malted *ragi*, *amaranth* and sprouted soybean forming gluten free flour, banana and yoghurt as egg replacer complex and cholesterol free vegetable oil instead of saturated fat which makes it rich in protein (5 g), minerals (1.4 g), iron (4.5 mg) with good antioxidant activity for 100 g of cake. This is a unique egg less preparation and best suited for people who have gluten allergy. Re-using the existing fibres and textiles, reduces the need for newly manufactured fibres and saves water, energy, dyes and chemicals, which reduces the carbon footprint. The fibres were extracted from pre-consumer cotton knitted fabric waste and converted into yarn by blending this recycled cotton fibre (RF) with virgin cotton (VC) fibre in different blend proportions.The blending in 50:50 (RF:VC) provided better yarn properties and more suitable for home textiles applications such as bed linen, furnishing fabrics, interior decoration accessories etc. Electro spun nanofiber-based micronutrient delivery matrix was developed to enhance the nutrient use efficiency, as compared to bulk nutrient application. The needle electrospinning machine was used to produce zinc sulphate impregnated electro spu nanofiber mat. The banana pseudo stem has potential for extraction of textile fibres, sap for dyeing and finishing, and other portion for making paper-based products. Semi-solid banana plant biomass was used for making paperboard, similar to paper with higher areal density and they are comparable with conventional handmade paper. Application of activated carbon derived from jute stick, NINFET-JAC, as an alternative to graphitized carbon black, was found effective for pesticide residue analysis in various crops like okra, spinach, pomegranate, tea etc. Sheep wool contains about 95% keratins which have huge applications in medical and pharmaceutical industries. Coarser grade wool having no textile use can be used for

Electronic nose (e-Nose) Near Infra-Red spectroscopy (NIRS)

extraction of keratin. ICAR-NINFET had developed a microbial protocol for keratin extraction from animal hair. Fibre producing species of nettle are European nettle and Himalayan nettle. NINFET has developed 100% nettle, nettle/viscose (75:25, 50:50, 25:75), and nettle/polyester (75:25, 50:50, 25:75) blended yarn and also union fabrics using cotton yarn in warp and these nettle-based yarns in the weft. These blended fabrics are suitable for fashion apparel, garments, shawls, stole, scarf, saree etc.

11. Climate Resilient Agriculture: In recent years, land-atmosphere coupling in many parts of the world had been identified to have raised temperatures and aridity. Studies using consistent methodology and metrics from multiple data sources established that the drying land surface turns into a source of heat generation and drought exacerbation due to reduced evaporative cooling and increases atmospheric heating from sensible heat flux. The land suitability for turmeric cultivation in Kerala was analyzed using Had GEM2 Model based on the Representative Concentration Pathway (RCP)-4.5 for climate projection scenario of turmeric in 2050. The projections revealed increase in highly suitable area by 5% from 28% to 33% and decrease of 4% from 11% to 7% in non-suitable areas of turmeric which could positively contribute to its production. The spatio-temporal changes in maize yield were studied using multi-model ensemble climate change projection derived from 30 general circulation models in 16 major maize growing districts of India. The projected reduction in maize yield is 16% to 46% under RCP4.5 and 21-80% under RCP8.5 without adaptation strategy. The combined adaptation strategies might reduce the loss in yield or even increase by 5-15% under RCP4.5 scenario. Rice-based IFS model for lowland conditions of West Coast and IFS model for dryland of



Land suitability maps of turmeric in Kerala for 2020 and 2050.

Karnataka and transitional plain of Luni basin was developed. Swarna Unnat Dhan (IET 27892), rice variety with multiple stress tolerance developed for irrigated transplanted condition of Bihar, Odisha, West Bengal, Madhya Pradesh and Maharashtra. Genome editing technology (CRISPR-Cas9) was used to create loss of function in mutants of the drought and salt Tolerance (DST) gene, a zinc finger transcription factor, in rice cultivar MTU 1010. Three homozygous mutants developed with reproductive stage tolerance to salinity stress. These lines were evaluated further for yield under drought stress and non-stress conditions. Under drought

Genome editing of DST gene enhanced tolerance to drought stress (-75KPa) of rice. Photographs shows drought stress effect on visible appearance of plants (left panel) and grain yield of plants (right panel). WT, MTU1010; D2bp, genome edited line of MTU1010.

stress (-75 KPa), genome edited mutants showed significantly higher grain yield as compared with MTU 1010.

12. Human Resource Development: Strengthening and development of higher agricultural education and quality assurance of AUs through accreditation and ranking process are the two major areas supported by ICAR. The strengthening of ICT facilities in AUs, emphasis on capacity building of the students and faculties through various training programmes under ICAR scheme as well as NAHEP helped enhance the capabilities of the faculties in various upcoming areas and improved the publications. AUs were also supported for encouraging holistic development of students, through creation of placement cells, support for sports facilities. The centralized admissions and national/international fellowships by ICAR helped improve academic ecosystem, and encouraged merit across AUs. National Professorial Chairs and National Fellow Scheme for promotion of excellence in research, Emeritus Scientist/ Emeritus Professor Schemes as a structural method of utilizing skill bank of the outstanding superannuated professionals in various disciplines to address faculty shortage. NAARM contributes immensely on wide range of issues of national and global importance apart from various courses on capacity building. The Academy has also been promoting online and digital education, startups for agripreneureship.The key components of NAHEP, viz. Centres for Advanced Agricultural Sciences and Technology (CAAST), Institutional Development Plan (IDP), and Innovation Grants have contributed to enhanced entrepreneurship opportunities and other reforms in AUs.

Graduation Ceremony at NAARM

Ranking of Agricultural Universities initiated by ICAR

13. Social Science: The impact of different risk management strategies on farm productivity and its resilience to climatic shocks was estimated. Measures were categorized into risk-mitigating, risk- transferring and risk-coping strategies. A Study was under taken to estimate productivity and risk effects of crop insurance vis-à-vis irrigation to explain the low uptake of crop insurance. Both crop insurance and irrigation positively impact farm productivity, but their gains differ significantly. The structure of rural employment is undergoing a change. The withdrawal of the agricultural workforce has further accelerated, and an additional 28 million workers left between 2011-12 and 2017-18. In the recent decade, the agricultural sector has experienced all-time high growth of 3.5%, and the growth has been driven by the animal husbandry and fisheries. The feasibility of a uniform water pricing policy and a differentiated water pricing policy was assessed. A notable shift in cropping patterns will take place when a volumetric and differential water pricing policy is adopted. Possibilities of reducing import dependence to meet the edible oil demand by increasing domestic production, adopting yield-enhancing technologies, and raising import tariffs, was investigated.

A general method of construction of row-column designs with two rows for orthogonal estimation of main effects and two factor interactions in minimum number of runs was given for orthogonal parameterization. An alternative sampling methodology for estimation of area and production of horticultural crops developed by ICAR was adopted by Department of Horticulture, Government of Haryana. Developed a support vector machine-based prediction model for predicting GIGANTEA proteins in plants. Based on the developed methodology, a prediction server GIpred was also established which is freely accessible (http://cabgrid.res.in:8080/gipred/) for proteome-wide recognition of GIGANTEA proteins. Developed machine learning-based models for identification of abiotic stress responsive miRNAs and Pre-miRNAs in plants. Developed a comprehensive machine learning based computational model for discovery of DNA binding proteins in plants (PlDBPred) that play crucial roles in numerous cellular processes.

Developed prediction server PlDBPred which is publicly accessible at https://iasri-sg.icar.gov.in/pldbpred/. The miRNA profile prediction system was implemented as a webserver available at https://scbb.ihbt.res.in/miRbiom-webserver/and also the standalone version available at Github (https://github.com/SCBB-LAB/miRbiom). Citation analysis of publication during 2007-2020 showed increase in that total number of publications, total citations, average citation per paper, impact factor per paper, number of papers in journals with impactfactor≥4. ASRB-Online Application & Scorecard Information System (ASRB- OASIS) application (http://www.asrb.org.in/) was developed for inviting online applications for the RMP positions and Non-RMP positions. Academic Management System (AMS), a web-based application, aimed at automating administrative and academic activities of agricultural was adopted in 56 agricultural universities. ICAR carried out research activities focusing on farm women nutrition, livelihood enhancement, technological empowerment, drudgery reduction and entrepreneurship development. In rural areas, the participation of women (6yr+age) in overall agriculture, crop sector and livestock sector were 22.4, 13.3 and 10.7 % and their contribution were 30.8, 27.2 and 45.8 %, respectively. The survey conducted to understand the knowledge level of farm women on nutritional aspects indicated that nutritional awareness among farm women increased to 60 % as compared to the pre-project status of 15.5 %. A pan-India nutri-smart village project was designed for promoting nutritional awareness, education and behavioural change in rural areas involving farm women and school children through local recipes to overcome malnutrition, implementing nutrition sensitive agriculture through homestead agriculture and nutri-gardens. Twenty-eight capacity building programmes were organized for potential women entrepreneurs in the identified areas which benefitted 902 rural women.

14. Basic and Strategic Research: Genome editing technology (CRISPR-Cas9) was used to create loss of function mutants of the drought and salt tolerance (*DST*) gene, a zinc finger transcription factor, in rice cultivar MTU 1010. *DST* gene mutants showed >25% increase in grain yield under normal conditions due to increase in reproductive tillers per plants and grain number per panicle. Phenotypic variance of 436 rice accessions from the sequenced panel of 3,000 rice genome accessions was assessed at multiple locations to identify superior donors and alleles for spikelet fertility and low grain chalkiness under thermal stress. Three rice accessions with consistently high spikelet fertility under high temperature, seven accessions with low chalk and eight accessions with cold tolerance were identified.

A panel of 150 diverse accessions from the 3K rice genome panel of IRRI was assembled and extensively phenotyped in the Phenomics Facility under well-watered (100% FC) and limited water (60% FC) conditions to identify QTLs for subcomponent traits of WUE. Fine mapping and marker-assisted breeding for alternative dwarfing genes *Rht14* and *Rht18* was done to develop semi dwarf wheat genotype suitable for conservation agriculture. Germplasm comprising 400 accessions including wild relatives and progenitors of wheat phenotyped for heat stress tolerance was genotyped using 35K Axiom SNP chip to identify the novel genes/QTLs. In order to identify the genomic regions and genes for drought and heat tolerance in groundnut, eight parents and 500 lines of the MAGIC population, 432 RILs of TMV2 × TMV2-NLM and 250 RILs of JL 24 × 55-437 were subjected to DNA sequencing.

The maize genotypes, viz. CML 44 BBB (3.0), DML 163-1 (3.5), IML 16-248 (4.0) were found promising against Fall Armyworm *Spodoptera frugiperda*. In order to impart resistance against Papaya Ring Spot Virus (PRSV), a high throughput papaya transformation and regeneration protocol towards genome editing of the eIF4E gene family was established and CRISPR/Cas9 mediated editing of eIF4E gene family was undertaken.

Targeted editing of the potato genome to develop variety specific True Potato Seed (TPS). A total of 285 banana mats/genotypes collected from different groves of North Eastern (NE) states were characterized for endogenous banana streak viruses (eBSV), which indicated the prevalence of distinct/ novel alleles having similarity to endogenous banana streak OL virus (eBSOLV), banana streak IM virus (eBSIMV), banana streak GF virus (eBSGFV) and *Musa balbisaina* PKW type activable alleles, the allelic positions of which make them activable. Full genome sequence of a new badnavirus banana streak MH virus (BSMHV) associated with streak disease of banana cultivar *MeteiHei* (ABB) grown in Manipur was achieved. Soil Zn application as nano-ZnO (nZnO) or bulk ZnO (bZnO) induced marked shifts in bacterial community structure, with dominance of *Sphingomonas* and *Nitrospira* under nZnO exposed soils, while *Bryobacter*, *RB41*, *Candidatus solibacter* and *Flavi solibacter* dominated under bZnO exposed soils. A sensor was developed for the efficient detection of Cr (VI) in water with a linearity range 100 ppb to 1 ppm. The sensor was incorporated into a hand-held prototype device. Another aptamer-based biosensor was developed for the detection of fish pathogenic bacteria *Aeromonas veronii*. The sensor is able to specifically detect *Aeromonas veronii* and shows no cross-reactivity with other bacteria.'Ekcel decomposer' consortia was prepared; and the drum type composting unit and shredder machine viz. 'EkcelCompostr'and 'EkcelShredr'were also fabricated, which help in accelerating the decomposition of different bio-waste. The 'Ekcel decomposer capsule' was also developed and released. The four bio filters were designed and prototypes were developedfor safe wastewater irrigation. Thirteen clones of 6 superior breeding male and one elite buffalo female were produced. A calf of an earlier cloned bull Hisar-Gaurav was also successfully re-cloned. A targeted immobilization method was developed, using iron nano particles conjugated with the developed antibodies (polyclonal), to immobilize the Y-Chromosome bearing spermatozoa. Cattle embryos produced through developed immobilization technique resulted in production of 72- 76% of female embryos. Similarly, a model for assessment of sperm-oviduct binding was developed for cattle. CRISPR/CAS9 guided functional analysis of genes regulating early embryonic survival in buffalo was done. An inexpensive, yet efficient, methodology for microinjection of CRISPR/Cas9 constructs into mouse zygotes was developed. Two approaches were attempted for the production of embryos. The embryo production rates (30-35%) were similar to non-edited control cells. The transfection and handmade cloning protocols were optimized in goats. indigenous transfection buffer was developed and tested in buffalo and goats. Developed buffer has 20-25% genome editing efficiency, and can be efficiently used to deliver CRISPR components/ transfection materials into any mammalian somatic cells.

A recombinant nucleocapsid protein (NP) based indirect enzyme-linked immunosorbent assay (iELISA) kit Can-CoV-2 ELISA Kit'was developed for detection of antibodies against SARS- CoV-2 in canines. The assay is 95.66% sensitive and 93% specific. The phytochemical conjugated silver nanoparticles (AgNPs) were encapsulated to achieve targeted delivery using chitosan-alginate polymers by ionic gelation methodto combat antimicrobial resistance in poultry. All the tested encapsulated leads appeared to be safe (secondary cell line-based MTT assay and commensal gut lactobacilli. Evaluation of selenium in the diet of male growing goats under endotoxin-induced stress conditions indicated thatcrude protein digestibility tended to

Progenies born through artificial insemination using semen of cloned bull

Can-CoV-2 ELISA Kit'

behigh in higher selenium-fed animals, however, no effects on growth, nutrient intake, and digestibility were reported.

Dendritic cell platforms for *in vitro* and *in vivo* studies of antigen processing and presentation in cattle for combined vaccine antigens using FMD virus and *Pasteurella multocida* as model were generated. To exploit the adjuvant potential of mesoporous silica nanoparticles (MSN) to thermo stabilize the PPR vaccine virus (PPRV), four types of MSN were synthesized and characterized. Captive brood stocks of hilsa, *Tenualosa ilisha* were developed at three locations with fresh water system at Rahara, intermediate water system at Kolaghat and brackish water system at Kakdwip. Females collected from both captive and river were in similar stage of reproductive maturity while the captive male (av. body weight 122.33 ± 3.38 g) showed advanced maturation (GSI 2.24 ± 0.025) compared to wild male (238.67 ± 4.67 g) with maturing phase (GSI 0.768 ± 0.002). An automated anesthetic device was developed for safe handling and performing procedures related to reproductive interventions under stress condition and tested on wild and pond-reared hilsa. It can deliver optimum amount of anesthetic solution with desired flow over the gills through buccal cavity. Two qRT-PCR assays targeting TiLV genome segments 1 and 10 were standardized and employed to determine the viral load in liver, brain and spleen tissues of experimentally-infected tilapia. The assays detected higher viral load in liver than that determined in spleen and brain at all-time points post-infection. The study revealed an increasing trend in the viral load in the early stages of infection and a steady decline in the later stages. Further, the newly designed real-time PCR assay targeting TiLV genome segment 10 showed high sensitivity and can be used for the reliable detection of the virus. The four models of technology delivery through FPO were developed for seed production, vegetable production, organic farming and natural resource management for eastern region of India. The communication pattern of FPO and Non-FPO farmers was assessed through Social Network Analysis. The cohesiveness, sparsity and degree of influence of FPO were better than non-FPO farmers. An android mobile application-CIBA ShrimpKrishiApp was developed and launched for handholding the shrimp farmers to make real-time based informed decisions at farm level. The app is free and available in four languages, viz. English, Hindi, Tamil and Telugu.

15. Information, Communication and Publicity Services: The SPARROW, an online system for Annual Performance Appraisal Report (APAR) of non-scientific ICAR employees introduced in 2022 for filling, submission, reporting

Dashboard of ICAR-SPARROW

KISAN SARATHI

and reviewing of APAR. Similarly, eHRMS, ICAR eOffice, ICAR DARPAND ashboard, Land Record Management Information System, KISAN SARATHI, NePPA, etc have been developed for facilitating the official work.

16. Technology Assessment, Demonstration and Capacity Development: During the period under reporting, 7 new KVKs were established taking the total number of KVKs in the country to 731. A total of 6,198 technological options in different crops were assessed at farmers' fields under 31,532 trials at 14,155 locations focusing on varietal evaluation, INM and IPM thematic areas. About 1,097 technological options pertaining to nutrition and other thematic areas in livestock production and management at 2,516 locations through 6,210 trials; 471 technologies under farm and non-farm enterprises at 1,040 locations through 6,124 trials; and 371 technologies pertaining to farm women under 3,222 trials at 756 locations were also assessed. Health and nutrition and value addition were the major thematic areas of technologies assessed with an aim to promote women empowerment.

The demonstrations on improved technologies of pulses and oilseeds numbering 48,473 and 46519 on 17973.95 ha and 18301.31 ha respectively were conducted during reporting period. Among

Kisan Sanghoshti

33,588 cereal crops, 10661 FLDs were conducted on 231 technology options in wheat varieties and management technologies in 3724.04 ha area; in rice 504 varietal and technology options under 18848 FLDs in 4625.52 ha; 3616 FLDs on 131 varietal and technology options in maize on 1074.76 ha area. Among 3,030 FLDS on millets, 48 varietal and technology options were demonstrated on finger millet by 52 KVKs in 1278 FLDs. Varieties and technologies on pearl millet (35) and sorghum (35) demonstrated in 633 and 500 FLDs, respectively. In pulses, total 12206 FLDs were conducted on 533 varietal and production technologies options. It included 3463 FLDs on chickpea, 2461 on blackgram, 1911 on green gram, 1702 on Lentil and 1415 on pigeon pea. A total of 9353 FLDs on 439 varieties and management technologies of oilseed crops conducted including 2311 on mustard, 2088 on rapeseed, 1636 on soybean, and 1507 on groundnut. In horticultural crops, altogether, 27215 FLDs were conducted on 1635 varieties and technologies comprising of vegetables (18514), fruits (3628), spices (3071), flowers (594) and medicinal and aromatic crops (143) in 5342.1 ha area. In commercial crops, 1530 FLDs in sugarcane and 1074 FLDs in cotton were conducted. Demonstrations on forage crops such as berseem, maize, sorghum, Napier grass, etc., were conducted at 3738 farmers' fields on an area of 495.3 ha. KVKs conducted 7973 FLDs on 310 hybrids covering an area of 2375 ha in cereals, millets, oilseeds, pulses, fodder crops, commercial crops and horticultural crops. Total 777 technology options on improved tools and farm implements were demonstrated in 17121 demonstrations covering an area of 9750.37 ha. In animal husbandry & dairying and fisheries, 16983 and 1617 demonstrations were conducted. KVKs conducted 16880 demonstrations on 20 enterprises which facilitated establishment of 23383 enterprise units. Total of 21.16 lakh farmers/farm women, rural youth and extension personnel were trained on various aspects through 69550 training programmes including the sponsored training courses. Besides, KVKs also organized 5.68 lakh extension programmes and disseminated the latest technologies of agriculture and allied sectors among 163.54 lakh participants (160.38 lakh farmers and 3.42 lakh extension personnel).

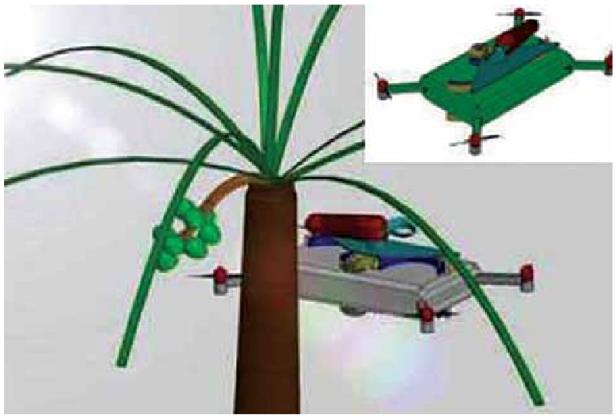
One of the important services that KVKs offers to farmers is proving quality seeds and planting materials to them free of cost or on a nominal charge. During the year, 1.76 lakh quintal seeds of improved varieties and hybrids various crops to

2.89 lakh farmers and 497.40 lakh quality planting materials of elite species of field and horticultural crops, medicinal and aromatic plants and forest species to 5.01 lakh farmers were provided. The bio-products such as bio-agents (998.59 q), bio-pesticides (1455.16 q), bio-fertilizers (23767.38 q), vermi-compost, mineral mixture etc., were produced and supplied benefiting 2.71 lakh farmers. Improved breeds of cow, sheep, goat, buffalo and breeding bull were produced and supplied to 56203 farmers. Different strains/ breeds/eggs of poultry birds to 44170 farmers and improved breeds of pigs to 729 farmers were also provided. The KVKs also enabled 105 farmers to establish small rabbit rearing units by providing 915 rabbits. A total of 289.24 lakh fish fingerlings were produced and supplied to 9586 farmers. For soil, plant and water health management, KVKs tested 3.10 lakh samples including 2.63 lakh soil samples, 8368 plant samples, 37956 water samples and 383 other samples like fertilizers, manures, food etc. benefiting 3.12 lakh farmers of 50914 villages. A total of 2.22 lakh Soil Health Cards were issued to farmers.

During 2021-22, 4.33 lakh farmers visited ATICs for obtaining solutions related to their agricultural problems and purchasing crucial farm inputs. In addition, 30.19 lakh farmers benefited from technological services provided by various ATICs. During the year, 4,340 entrepreneurial units were established benefiting 6,610 rural youth under ARYA. Under NICRA, 6477, 13931, 7187 demonstrations were conducted covering 5695.81, 6807.6 and 265.65 ha of area under NRM, Crop and Livestock modules, respectively.

Mera Gaon Mera Gaurav (MGMG) programme was implemented through 127 institutions including ICAR institutes and SAUs by 1,054 groups of 4,315 scientists and covered 3,680 villages. Altogether, 37982 field activities conducted and 27,958 advisories sent benefiting 5,05,303 farmers. Under Farmers 36,496 demonstrations and 2,649 extension programmes were organized. TSP KVKs conducted 4634 training attended by 121809 farmers. Under NATI programme, 16,681 nutri-gardens were established benefiting 30,310 farm families. KVKs also organized activities for promotion of nutrition garden, nutri-*thali*, value addition, biofortified crops, etc. Total 2,657 training programs benefiting 81,633 participants and 4,161 extension activities benefiting 1,37,674 participants on nutrition literacy were conducted. Total 6811 training conducted under SCSP which were attended by 118485 farmers. Seed-hubs were set-up at 95 KVKs for production of quality seeds of major pulse crops. During the year, 42,835.07 q seeds of pulses were produced and made available to farmers. For crop residue management, demonstrations on CRM machinery on >20,000 ha including 3000 demonstrations on decomposer technology was conducted. Total 3,778 IFS units were established on 88,406.19 ha. Total 5,894 IFS demonstrations and 9,512 trainings were conducted for 75,058 and 1,17,010 farmers respectively. Advisories on crop and livestock production/protection technologies in 15 different regional languages were circulated among farmers. Total 2,351 interventions to facilitate information about marketing of farm produce benefitting 5.42 lakh farmers were undertaken.

17. Research for Tribal and Hill Regions: For promotion of quality seeds of improved varieties in these disadvantaged areas,16.138 tones breeder seed of 46 varieties/ inbreds of 17 crops was produced and 13.121 t breeder seed supplied to seed producing agencies for further multiplication. Besides, 1,313 kg nucleus seed of 49 varieties of 17 crops and 655 kg Truthfully Labeled seed of 20 varieties of 13 crops were produced. Including the carry-over stock, about 402 kg TL seed was supplied to different stakeholders. VLQPM Hybrid maize



Fly Cocobot: A drone-based coconut harvester

VL *Gehun* 2028

released for cultivation in North Western Hill Zone and North Eastern Hill Region. VL *Dhan* 69 released for Uttarakhand, Sikkim and J&K. For Uttarakhand, Maize, VLQPM Hybrid 61 and VLQPM Hybrid 63; wheat, VL *Gehun* 2028 and VL *Gehun* 3010; rice, VL *Dhan* 210, VL *Dhan* 211 and VL *Dhan* 70; lentil, VL 150; and field pea, VL 64 were notified. A total eight micro watersheds comprising dairy-based land use, mixed forestry, silvi-pastoral land use, agro-pastoral system, agri-horti-silvi-pastoral, silvi-horticultural system, natural forest block and timber-based land-use system developed and evaluated on a long term basis in Meghalaya. The integration of crops and livestock resulted in maximum income (₹ 2,71,400) and employment generation (252 man-days excluding family labour). For jhum improvement, one agri-horti-silvi-pastoral system in 1.58 ha developed. The system produced 6,846 kg of rice equivalent yield with a net return of ₹ 62,961. Integrated Organic Farming System (IOFS) models were established at Tripura and Meghalaya. The Tripura model gave a net return of about ₹ 73,990 and employment of 67 days which is quite high compared to existing farming systems. About 70% of the nutrient requirement of the model was met from nutrient recycling within the model. The Meghalaya model recorded a total net return of ₹ 83,360 per year which is much higher than the region's farmer common practices of rice mono-cropping or improved practice of the rice-vegetables cropping system. Approximately 96% of the total N requirement, 87% of the total P_2O_5 requirement and 99% of the total K_2O requirement could be met within this model thus making it a self-sustainable one. Ten high yielding stress tolerant crop varieties were released for north eastern hill region. Fly Cocobot-a drone-based remotely controlled unmanned gender-friendly coconut harvesting and crown-clearing machine for safe harvesting of coconuts was developed. This device can be used in mixed cropping plantation of coconut and black pepper. The machine is conceptualized jointly by ICAR-CCARI and Goa University and have operational efficiency of 12-15 palms/hr.

18. IP, Organization and Management: During the period under report, 78 new Patent Applications were filed making total to 1,455 applications. Indian Patent Office (IPO) had published ICAR's 37 patent applications in this period and granted 47 patent applications, taking ICAR's cumulative number of granted patents to 455. In this process, 31 ICAR institutes were involved to protect their innovations. To protect the Plant Varieties, 23 varieties (19 extant and 4 new varieties) were filed at Plant Varieties and Farmers' Rights Authority (PPV&FRA). For applications filed earlier, 60 varieties (52 extant and 8 new) were granted registration certificates. The cumulative total for plant variety protection applications rose to 1,407. Total 650 formal Licensing Agreements were formed up with 442 public and private organizations and entrepreneurs involving 55 ICAR institutes. Eighteen ICAR institutions entered into 80 agreements for consultancy/contract research and services with 75 public and/or private organizations. To enhance the agri-business environment, 494 stakeholders were facilitated by 50 ABIs for their business incubation activities and motivated 42 entrepreneurs/startups to initiate their own business. These centres also organized 209 Entrepreneur Development Programmes (EDPs) and supported 366 Innovation/ technology/products.

The Rajbhasha saptah/pakhwara/mah was organized at ICAR Headquarters and its institutes. The RajbhashaUllas Pakhwara was organized during 16 to 29 September 2022 which was marked by inspiring messages of Hon'ble Minister of Agriculture and Farmers Welfare and the Minister of State for Agriculture and Farmers Welfare and appeal by Director General, ICAR to use Hindi the maximum in their official work. Under the Cash Award Scheme of Official Language, 10 personnel were given cash awards for doing their maximum work in Hindi during 2021-22. The Council also implements three more awards at its own -*Rajarshi Tandon Rajbhasha Purskar Yojana, Ganesh Shankar Vidyarthi Hindi Patrika Purskar Yojana and Dr Rajendra Prasad Puraskar Yojana*. As per the instructions/orders of Ministry of Home Affairs, 38 Institutes (one-third of total) were inspected for assessing the progress of Hindi and suggestions were given to rectify the shortcomings observed. This also includes inspections of Parliamentary Committee on Official Language. Besides, all Parliamentary Matters, Annual Reports, Parliamentary Committee, Annual General body Meetings of ICAR Society, and their proceedings were prepared bilingually.

The Technical Coordination Unit prepared monthly Cabinet Summary for Cabinet Secretary; organized 'Standing Committee' meeting for grant of financial assistance to scientific societies and academic for organizing seminars/symposiums/ conferences and publication of Journals; organized Director's Conference/prepared ATR and Agenda items; Coordinated and organized the ICAR Regional Committee Meetings; Collaborated with

Department of Science and Technology, Bureau of Indian Standards etc.; Dealt with the references received from Prime Minister's Office, President Secretariat etc.; Laying of ICAR Annual Report, Annual Accounts and Audited Report of ICAR in both the Houses of Parliament; acted as Nodal Point for e- Samiksha portal for DARE/ICAR and Releasing funds for Swachchta Action Plan (SAP); Quarterly Reports on SAP Portal. Various ICAR Awards for 15 different categories were given to 94 awardees, comprising of 71 scientists (including 7 women) and 11 farmers (including 2 women farmers).

19. Training and Capacity Building: Fifteen specialized online/offline training programmes, viz. Training Workshop for Vigilance Officers of ICAR Institutes; MDP on PME in Agricultural Research Projects, MDP for Effective Implementation of Training Functions; Good Agricultural Practices (GAPs) for Higher Productivity, Profitability and Resource-use Efficiency; Appropriate Sampling Techniques Including Sample Preparation and Preservation for Soil, Water, Plant and Air Samples for Various Analyses; Experimental Data Analysis; Cyber Security; Statistical Techniques for Agricultural Data Analysis; E-governance Application in ICAR; Pension and Retirement Benefits; Capacity Building Programme Towards a Secure and Resilient Workplace at ICAR; Accrual Accounting; Assets Management; Repair and Maintenance of Office, Residential Building including Guest Houses and Establishment Matters for UDCs and LDCs were organized by 8 Competent ICAR-Institutes. In these programmes, 794 employees of various categories as per programme participated. An online Training Programme on "Living Heartfulness: Heartfulness Practices for Well-being and Harmony" was organized by HRM Unit, ICAR HQs with the support of Heartfulness Institute, Telangana in which about 35Officers/ officials of ICAR HQs participated.

During the reporting period, 1467, 621, 507 and 239 scientists, technical, administrative including finance, and SSS were trained, respectively. Compared to 2013-14, ICAR-Institutes organized 19.4 and 640.0% more training programmes for technical and skilled support staff, respectively during 2021-22. The new Training Modules for all four categories of employees, i.e. Scientific, Technical, Administrative and SSS, designed, developed and organized from 2015-2020 based on TNA have been documented and published. ICAR also nominated 734 employees of various categories in training and capacity building programmes organized by various ICAR/non ICAR-Institutes, out of which 492 employees attended the training programmes.

20. Publications and Social Media: ICAR-DKMA encourages ICT-driven technology and create information dissemination systems to serve as agricultural knowledge repository. The Indian Journal of Agricultural Sciences (IJAgS) and Indian Journal of Animal Sciences (IJAnS) are multi-disciplinary journals, with the impact factor and H index 0.37 and 29 and 0.31 and 23, respectively. These journals have wide readership and subscription. A total of 3,500 submissions in IJAg S and 1,928 in IJAnS were received during 2022. Popular periodicals like *Indian Farming* and *Indian Horticulture* were brought out for outreach to the masses with special issues on Farmer FIRST Success Stories, Reimagining Rainfed Agro-ecosystems and International Year of Millets and Plantation Crops. Digital Object Identifier (DOI) allotment to the articles for both the research journals was introduced which will benefit the authors as well as journal immensely. To check the plagiarism, software iThenticate was subscribed. For facilitating publication of the books, e-book platform was developed. During the year, ten new titles were published under the books, Stingless Bees – An Unexplored Pollinator in India; Textbook of Ergonomics and Safety in Agriculture; Textbook on Forages; Ravine Land Management : Principles, Practices and Strategies; Textbook of Pet Animal Management; Textbook of Fundamentals of Agricultural and Animal Husbandry Extension; Textbook on Physical Chemistry and Mineralogy of soils; Textbook of Principles and Practices of Weed Management; Textbook of Environmental Agrometeorology; Sugarcane Crop Management Practices in India.

The Hindi journals *Kheti* (monthly) and *Phalphul* (bimonthly) are published to disseminate the latest technologies. These journals are circulated offline and online. During the year, six special issues of *Kheti, viz.* 'success stories of farmers', 'livestock', 'climate change and agriculture', '75th year of publication of Kheti', 'Nutrition' and 'Millets' were published. The two special issues of *Phalphul*, on Fruits, and vegetables were also published. To add the publication of the Hindi journals, e-patrika portal was developed. The gross revenue of approximately ₹ 62.0 lakhs was realized from sale of publications during the period. To disseminate information in real-time, the ICAR

Website is updated on a regular basis. Total 4,250 pages were updated and 51,89,432-page views from more than 200 countries recorded. ICAR Twitter Handle has more than 1,94,458 Followers. On an average, 3 tweets are posted every day and a total of 1,020 tweets were posted during the year.

21. Administration and Finance: During the year, following posts were filled up under the promotion quota: 6 Joint Secretary/Joint Director (Admin), 3 Joint Secretary (Finance)/Senior Comptroller, 8 Director/CAO (Senior Grade), 4 Director (F)/Comptroller, 1 Director (Official Language), 15 Deputy Secretary / CAO, 1 Deputy Director (Finance), 3 Joint Director (OL), 2 Senior Principal Private Secretary, 5 Under Secretary, 1 Senior Administrative Officer, 5 Senior Finance and Account Officer, 48 Principal Private Secretary, 6 Deputy Director (OL), 43 Administrative Officer, 17 Finance and Accounts Officer, 13 Section Officer, 11 Private Secretary and 22 Assistants at ICAR Headquarters. During the year, 10 eligible officers and Staff of ICAR were granted the benefits of financial up-gradation under the Modified Assured Career Progression scheme.The RE of DARE/ICAR for 2021-22 was ₹ 8,513.62 crores. An internal resource of ₹ 352.2 crores (including interest on Loans and Advances, income from Revolving Fund Schemes and interest on Short Term Deposits) was generated during the year 2021-22. The total BE for 2022-23 is ₹ 8,513.62 crores.

ICAR, for its services to nation and contribution towards furtherance of science, has won several accolades in the past, viz Global Gene Stewardship Award 2018 of the Borlaug Global Rust Initiative; International King Bhomibol Word Soil Day Award of FAO, 2020; and Digital India Awards 2020. ICAR is working concomitantly with other national and international organizations in the field of agriculture.

03

DARE INTERNATIONAL COOPERATION ACTIVITIES

IC-I Section

(Including NAAS and IAUA)

Major Activities

- About 3 cases of foreign deputation including short term and long term deputations were approved during 2022-23.
- About 12 cases of Cabinet note were processed during 2022-23.
- About 20 cases for grant of approval/NOC to various organizations for organizing International Conferences/Workshops, etc. in India were approved during 2022-23.
- Approval for 1 case of international consultancy project at various ICAR Institutes was granted during 2022-23.
- A number of cases related to grant of permission to foreign nationals for undergoing research work under various Post-Doctoral and Doctoral Fellowships were processed and approved.
- The details of the fund released to concerned SAU/ICAR Institute in respect of African students and Afghanistan Fellowship during October, 2021 to September, 2022 is given below.

S No.	Name of Fellowship Scheme(s)	Fund released during October, 2021 to September, 2022
1.	India-Afghan Fellowship Scheme	₹16,84,960/-
2.	India-Africa Forum Summit-III	₹ 28,66,267/-

- Applications of 9 Nepalese candidates have been received from Ministry of External Affairs for admission under India-Nepal Fund Scheme and process for their admission in various SAUs is under progress through Agricultural Education Division, ICAR.
- Grant-in-aid to the tune of ₹0.99 crore was released to National Academy of Agricultural Sciences, New Delhi.
- Grant-in-aid to the tune of ₹30.40 lakh was released to Indian Agricultural Universities Association, New Delhi.
- Ministry of Finance, D/o Expenditure vide O.M. No. 7(105)/EMC Cell/2020 (Part-III) dated 10 March, 2022 in the meeting held on 25 February, 2022 chaired by AS (PFS), Department of Expenditure directed for phase wise disintegration of IAUA and NAAS during period of 3 years and 4 years, respectively. Subsequently, phase-wise disengagement of Indian Agricultural Universities Association (IAUA) and National Academy of Agricultural Sciences (NAAS) and gradual reduction of Grant-in-aid has been carried out as per direction of the communication of DoE, MoF dated 10 March, 2022 in the following manner:

For NAAS

- 2022-23 - ₹ 93,00,000/
- 2023-24 - ₹ 62,00,000/
- 2024-25 - ₹ 31,00,000/
- 2025-26 onwards – Nil

For IAUA

- 2022-23 - ₹ 25,20,000/
- 2023-24 - ₹ 14,40,000/
- 2024-25 onwards - NIL

National Academy of Agricultural Sciences (NAAS)

The National Academy of Agricultural Sciences (NAAS), a national think-tank and platform for science-policy interface, leads in promoting excellence and convergence of agricultural research (science), education and extension for the growth of national economy with a vibrant farm sector. In pursuance of this mission, the Academy has been organizing agricultural science congresses, conferences, brainstorming sessions, consultations, round-table discussions and dialogues on important research and development related policy issues, for the benefit of the concerned stakeholders for promoting ecologically sustainable, economically vibrant and socially equitable agriculture. The Academy has played a significant role in providing vital and timely inputs on several critical policy issues for active consideration of the Government.

During the period, the Academy organised 15 brainstorming sessions, strategy workshops, experts' meet and expert consultations in virtual and/or hybrid mode, besides organising a number of lectures on contemporary issues on Indian agriculture. Publications were brought out based on the recommendations from these events with action points for policymakers, Central and State governments, institutions of higher learning, farmers and other stakeholders.

In pursuance of its mandate, the NAAS carried out activities during 2021-22 as described here:

I. Brainstorming sessions/strategy workshops/consultation meetings

- A Brainstorming session on WTO and Indian Agriculture was organized under the Convenorship of Dr P S Birthal, Dr Sachin Sharma and Prof Abhijit Das on 7 October, 2021, to generate feedback for policymakers to effectively manage challenges at the WTO.
- A Brainstorming session was organized on 'Secondary Agriculture: Challenges, Opportunities and Way Forward' on 21 October 2021 under the Convenorship of Dr S N Jha.
- A Brainstorming session on 'Agri-startups in India: Opportunities, Challenges and Way Forward' was organized under the Convenorship of Dr Ch Srinivasa Rao and Dr Ranjit Kumar on 5 November, 2021 to deliberate on different aspects of the agri-startup ecosystem and create an enabling environment.
- A Roundtable Discussion on the Global Hunger Index was organized with leaders and academicians in fields of nutrition, medical science, statistics and economics on 8 November, 2021 under the Convenorship of Dr Mahtab S Bamji, Dr P K Joshi and Dr Rajender Parsad. The objective of the discussion was to (i) critically examine the GHI report and present views on whether it is an appropriate measure of hunger, and (ii) propose the way forward on the 'Hunger Index'.
- A Strategy workshop on 'Waste to Wealth– Use of Food Industry Waste as Animal Feed and Beyond' was organized on 3 December, 2021 to explore opportunities to convert food waste into animal feed under the Convenorship of Dr N K S Gowda.
- A Brainstorming session on 'Road Map to Rehabilitate 26 million ha Degraded Lands by 2030' was organized under the Convenorships of Dr Ch Srinivasa Rao, Dr J C Katyal and Dr Anil K Singh on 9 December, 2021.
- The Academy organized a Brainstorming session on 'Entrepreneurship for Quality Fodder Production' on 17 December, 2021 under the Convenorship of Dr Ajoy Kumar Roy, Dr Amaresh Chandra and Dr D R Malaviya to identify potential areas for developing enterprises for quality fodder production and marketing.
- A Stakeholders consultation on 'Draft Regulation for Genetically Modified (GM) Food and Feed Imports and Detection of Unauthorized GM Food Events' was organized by the Academy on 10 January, 2022 under the Convenorship of Prof K C Bansal and Co-convenorship of Dr Gurinderjit Randhawa.
- A Strategic consultation on 'Preparedness for Prevention of Transboundary Infectious Diseases of Livestock and Poultry in South Asian Countries' was organized on 15 February, 2022 jointly with the International Livestock Research Institute (ILRI), the South Asian Association for Regional Cooperation (SAARC) and the Bangladesh Academy of Agriculture (BAAG) under the Convenorship of Dr U S Singh and Dr H Rahman.
- A Brainstorming Session on 'Food Fortification Issues and Way Forward' was organized on 11 March, 2022 under the Convenorship of Dr K Madhavan Nair to deliberate upon the issues emerging from the new recommendations on nutrient requirements and dietary allowances by the ICMR-NIN 2020, a nationwide study on the status of micronutrients (anaemia, iron, vitamin A and D, folic acid and vitamin B12, and iodine) among children aged between 1-19 and adolescents (CNNS 2019); and urban diet and nutrient survey (NNMB 2017).
- An Experts meet on 'Self-sufficiency in Edible Oil Production' was organized under the Convenorship of Dr Sanjeev Gupta on 28 March, 2022.
- A Brainstorming Session on 'Sustaining Pulses Revolution in India' was organized on 5 April, 2022 under the Convenorship of Dr Anjani Kumar. Participants included researchers, policymakers, representatives from the private sector, government organisations, civil societies, farmers groups and emerging agri-preneurs. The brainstorming session deliberated on various aspects to chalk-out strategies and action plan for accelerating and sustaining production of pulses and improving its consumption.
- A Brainstorming Session on 'Impact of Covid-19 on Livestock and Poultry Sector' was organized on 24 June, 2022 under the Convenorship of Dr R K Singh. Sector-specific presentations were made on the impact of Covid-19 on dairy, poultry, fisheries, feed and meat industries as well as on breeding and health. Specific policy inputs were suggested

for managing veterinary services, supply chain solutions, challenges in veterinary science education and role of extension services in mitigating the impact of the pandemic.

- A Brainstorming Session on 'Scaling up Innovative Agricultural Extension Models Sector' was organized on 12 September, 2022 under the Convenorship of Dr Ashok K Singh.
- A Brainstorming Session on 'Beyond Price Support and Subsidies' was organized on 30 September, 2022 under the Convenorship of Dr Pratap S Birthal.

Special Webinar: The Academy organized a special webinar on 'Transforming Agriculture in Asia' by Dr Takashi Yamano, Principal Economist, Asian Development Bank (ADB), Manila on 20 December' 2021.The webinar was based on the report prepared by the ADB to show how agriculture has minimized the impact of Covid-19.

National Science Day: The Academy celebrated National Science Day on 28 February 2022, with an online lecture by Prof. R. Ramakumar from the Tata Institute of Social Sciences, Mumbai.

International Women's Day: The Academy celebrated International Women's Day on 8 March 2022, by organizing an online panel discussion on 'R&D Innovations for Sustainable Agriculture in India'.

World Biodiversity Day: On 22 May 2022, the NAAS observed World Biodiversity Day by organising a discussion on Global Genebanks and Biodiversity Management for Sustainable Agriculture. Some of the eminent speakers were Dr Hugh Pritchard, Kew Botanic Garden, UK; Dr Ashok Kumar, Director (Acting), ICAR-NBPGR, New Delhi, Dr. Ashok K Singh, Director, ICAR-IARI, New Delhi; Mr Kent Nnadozie, Secretary of the International Treaty, FAO, Rome; Dr Murukarthick Jayakodi, Group Leader, Leibniz Institute of Plant Genetics and Crop Plant Research (IPK) Gatersleben, Germany; Prof. Rajeev Varshney, International Chair in Agriculture and Food Security, Food Futures Institute, Murdoch University, Australia. Over 350 delegates participated in this programme.

XV Agricultural Science Congress: The Academy organized the XV Agriculture Science Congress on the theme 'Energy and Agriculture: Challenges in 21st Century' jointly with the Banaras Hindu University, Varanasi, from 13-16 November, 2021. In view of the Covid-19 pandemic, the Congress was organized in a hybrid mode. It deliberated on the issues related to technologies, strategies and policies to make India energy-independent by 2047. More than 1,800 delegates (900 in-person including 300 farmers) participated including fellows of the academy, researchers, academicians, policymakers, students, farmers, leaders from the industry and representatives of the civil society organizations and exchanged their ideas on various themes and sub-themes of the Congress. A national-level elocution contest was also organized on the theme of the Congress for the students selected from all over the country. The Agri-expo organized during the Congress provided a platform to more than 50 public and private organizations for showcasing their technologies, products and services for the benefit of farmers.

II. Foundation Day Programme/Annual General Body Meeting

During 2021-22, the Foundation Day Programme/AGB Meeting was held on 4-5 June, 2022 at New Delhi. Besides usual AGB business session, following science-based activities were organized:

- Scientific presentations by newly elected fellows.
- The Presidential Address was delivered by Dr T Mohapatra, President, NAAS in 29th AGM. In his address, he drew attention to the fact that although India has made remarkable progress in food production, ensuring food and nutrition security, increasing agricultural exports, and improving agricultural sustainability remain important in the process of transformation of food system in view of the changing consumers' preferences and social aspects of food consumption.
- The Foundation Day Lecture: On the occasion of its Foundation Day on 5 June, 2022, the Academy organized in hybrid mode a lecture by Prof P Balaram, Former Director, Indian Institute of Science, Bengaluru. He spoke on 'Reflections on Science in the age of the Corona Virus' and presented an excellent account on the evolutionary history of corona virus and highlighted the interdependence of biology and chemistry. He explained how chemistry and biology together can reveal the unknown in the nature. He defined science as the study of nature. Citing the examples of the telescope

and the microscope in pursuing the science of cosmology and microbiology, respectively, he said that science is often driven by new technology than by new concepts. He cited the example of rDNA technology, which facilitated development of genetically modified crops. Prof Balaram highlighted that scientists should keep striving to unravel the mystery of nature and search nature-based solutions for human welfare through innovations in agricultural sciences. As we have learnt immensely from the corona virus pandemic, we should prepare ourselves for a better life in future through an integrated approach based on the basics of chemistry, physics and biology. He concluded by reminding us of the lessons that we must learn from the corona virus pandemic, and the that we should respect the nature.

III. NAAS regional chapters' activities

Twelve Regional Chapters of the Academy are actively functioning at Barapani, Bengaluru, Bhopal, Coimbatore, Cuttack, Hyderabad, Karnal, Kolkata, Lucknow, Ludhiana, Pune and Varanasi.

Notwithstanding the grave situation arising due to the Covid 19 pandemic, the Regional Chapters made commendable efforts to promote scientific activities for addressing regional issues. Barring a few, most of the activities were held on virtual platforms. During the period, Regional Chapters organised highly successful events focussing on students. The high school, graduate, and post graduate students were exposed to different facets of agriculture such as rural bio-entrepreneurship, opportunities in agriculture under *Atma Nirbhar Bharat* scheme, and other contemporary issues related to health, nutrition and environment.

IV. Publications

The crystallized views of the scientists emerging from the interactive sessions organized by the Academy are published as Policy/Status/Strategy Papers and Policy Briefs, which provide useful inputs to the policymakers, planners, educationists and decision-makers. Following policy documents were published for the period:

Policy/Status/Papers

- Policy Paper 99: New Agricultural Education Policy for Reshaping India
- Policy Paper 100: Strategies for Enhancing Soil Organic Carbon for Food Security and Climate Action
- Policy Paper 101: Big Data Analytics in Agriculture
- Policy Paper 102: WTO and Indian Agriculture: Issues, Concerns and Possible Solutions
- Policy Paper 103: Antimicrobial Resistance
- Policy Paper 104: One World One Health
- Policy Paper 105: Sugarcane-based Ethanol Production for Sustainable Fuel
- Ethanol Blending Programme
- Policy Paper 106: Utilization of Wastewaters in Urban and Peri-urban Agriculture
- Policy Paper 107: Certification of Quality Planting Material of Clonally Propagated Fruit Crops for Promoting Agricultural Diversification
- Policy Paper 108: Agri-startups in India: Opportunities, Challenges and Way Forward
- Policy Paper 109: Emergency Preparedness for Prevention of Transboundary Infectious Diseases in Indian Livestock and Poultry

Strategy Papers

- Strategy Paper 14: Innovations in Potato Seed Production
- Strategy Paper 15: Potential of Transgenic Poultry for Biopharming
- Strategy Paper 16: Need for Breeding Tomatoes Suitable for Processing
- Agricultural Research, the official Science Journal of the Academy (published by Springer India Pvt Ltd, Vol. 11, No. 1 and Vol. 12, No. 1 (quarterly).

V. Recognizing and promoting excellence of individual scientists in the field of agriculture

- **Fellowship/Associateship:** The Fellowship of the Academy embodies a wide spectrum of national and international scientists. Fellows including Pravasi and Foreign Fellows are elected annually in recognition of their distinguished achievements in the field of agriculture and allied sciences. During 2022,

34 new Fellows including two foreign Fellows and three Pravasi Fellows were elected and inducted into the Academy. The Academy also has a scheme of NAAS Associates for encouraging promising young scientists below the age of 40 years, to be associated with the Academy activities. During the year, 11 young scientists were selected as Associates of the Academy based on their academic excellence and scientific contributions as reflected by publications, and products, processes and technologies developed, etc.

- **Academy Awards:** The National Academy of Agricultural Sciences has instituted following Awards for recognizing significant contributions of senior, middle level and young scientists to promote agricultural research and recognize scientists for excellence in research in Agricultural and Allied Sciences including Environment and Nutrition. Memorial, Endowment and Recognition awards are presented biennially at the time of Agricultural Sciences Congress. Young Scientist Awards are given annually and are presented in the Annual General Body meeting of the Academy.

  (i) Memorial Awards (7)

  (ii) Recognition Awards (6)

  (iii) Young Scientists Awards (6)

  (iv) Endowment Awards (3)

  (v) Dr A B Joshi Memorial Lecture Award

During this year, the six Young Scientists' Awards for 2021 were presented on 5 June, 2022.

Indian Agricultural Universities Association (IAUA)

Indian Agricultural Universities Association (IAUA) was established on 10 November, 1967 (Registration no. 3498). There were only nine founder member of agricultural universities: PAU, Chandigarh (now Ludhiana); APAU, Hyderabad, (now ANGRAU, Guntur); JNKVV, Jabalpur; UPAU (now GBPUAT), Pantnagar; UAS, Bengaluru; KU, Kalyani (now BCKV, Mohanpur); OUAT, Bhubaneswar; UU (now MPUAT), Udaipur; and IARI, New Delhi. Presently, the IAUA has 71 member universities.

The main objective of the Association is to promote agricultural research, education and extension in the universities and the states, and thereby rural development in the country. It also acts as a bureau of information to facilitate communication, coordination and mutual consultation among agricultural universities. The Association also acts as a liaison between member universities and concerning government departments to facilitate communication and expedite the needed action in matters of importance.

A quarterly newsletter is being published by the Association since 2000, giving important news, events and achievements by member universities for the information of all the members and others stakeholders. An Annual Report is also being published documenting major activities of IAUA and member universities of the year.

The information on events and proceedings are published through the host universities and the recommendations are uploaded on IAUA website (www.iauaindia.org) and also circulated to all the Vice Chancellors of member universities and other main stakeholders.

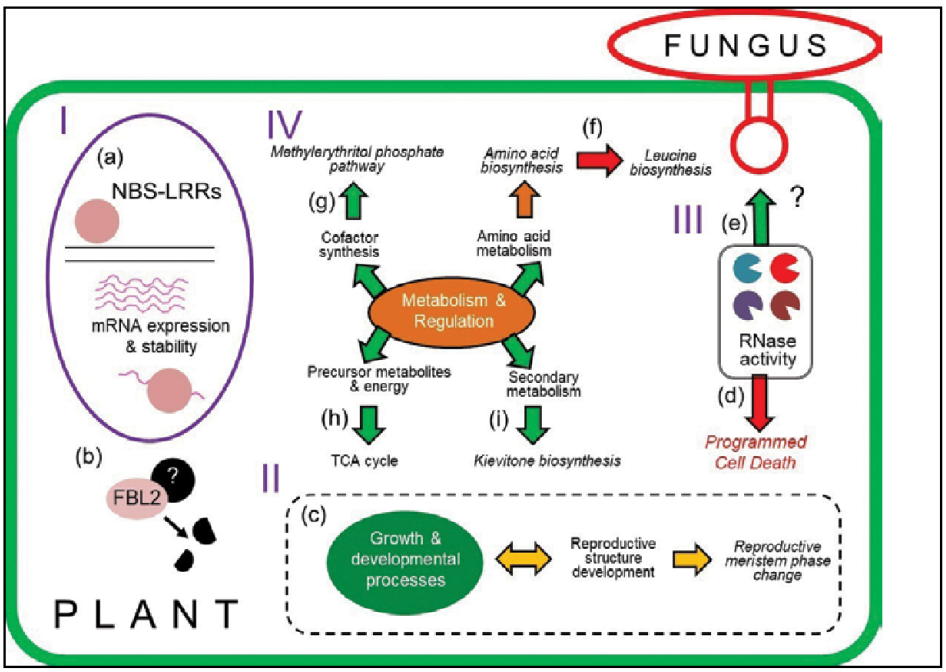
A brief description of important events organized by IAUA/member universities is given on the following pages:

45th Vice Chancellors' Convention: The 45th Vice Chancellors' Convention of Indian Agricultural Universities Association (IAUA) was organized on the theme 'Improving Standard, Sustainability and Societal Impact of Agricultural Universities' at Birsa Agricultural University (BAU), Ranchi on 20-21 December, 2021 in hybrid mode.

The Vice Chancellors of State Agricultural/ Horticultural/Animal Science Universities, Central Agricultural Universities and Deemed Universities of India attended the Convention (off-/on-line), shared their experience, knowledge, expertise, and gave an overview on how to improve standards and social impact of Agricultural Universities. The deliberations were made to align research and education in agricultural and allied disciplines in India in view of NEP (2020) during following four technical sessions conducted on the sub-themes selected for the Convention:

I. Achieving International Standard in Agricultural Education and Research in the Context of new National Education Policy, 2020.

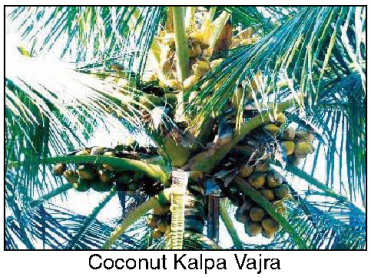
II. Strategies to Increase Agricultural Productivity



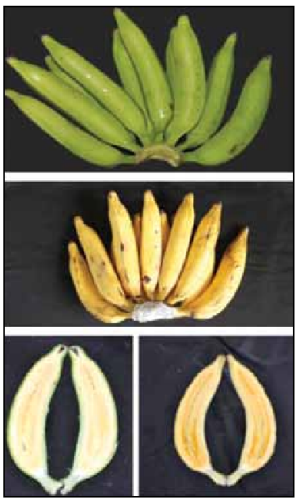
Schematic representation of the role of maize constitutive gene network in fungal resistance.

Improved varieties of various horticultural crops

Narendera Bael-11



Coconut Kalpa Vajra



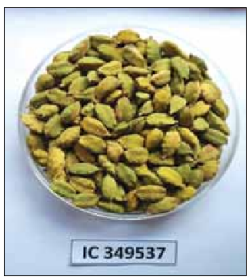
Fruits of Kaveri Kanchan (NCR 17)

Nethra Jumbo 1cashew hybrid

SreeKaveri Cassava

Potato MP / 09-45

tannia variety IGSGTN-1



Small cardamom IC 349537

genic-SSR markers for winged bean was developed from the publicly available RNA seq data sets and 58811 unigenes were assembled, and 4,107 perfect SSRs were identified. Effect of Zn deficiency was evaluated in BKS-41 (high seed zinc) and Sadabahar (low seed zinc). Higher shoot length, root length, longer root hair zone, high root hair density, higher relative chlorophyll content and dry weight were observed in BKS-41 as compared to Sadabahar under zinc deficient condition. The study to identify

regulatory genes associated with RFOs biosynthesis in peanut (*Arachis hypogaea*) suggested Raffinose Synthase (RS) for the differential accumulation of RFOs. four varieties of faba bean, i.e. *Swarna Suraksha*, *Swarna Safal*, *Swarna Gaurav* and *Pusa Sumeet* were evaluated as a natural source of L-Dopa. Higher amount of L-Dopa was found in immature leaf and flowers. A screening method was designed for amylose estimation in maize kernels. The proposed method is rapid and simple for screening of maize kernels with varied amylose amounts, and gets completed in 1 min. Meta-QTL analysis for fungal disease resistance in maize revealed 128 QTLs associated with resistance against 12 fungal diseases (SLB, NCLB, BLSB, GLS, HS, FSR, FER, GER, AER, PLS, CS, SDM) across the maize genome. Application for an Indian patent (Application No. 202211015547) on rapid differentiation of normal maize from Quality Protein Maize was filed. The developed method requires 5 minutes for differentiating normal maize from QPM, when a milled sample is provided. Genome editing for early flowering and seed size displayed increase in leaf size, stem length and seed weight in edited chickpea lines as compared to their normal control types. Full-length gene sequence of grasspea oxalyl-CoA synthetase and ODAP synthase, enzymes functional in OAP synthesis in grass pea, were identified and submitted to Genbank with accession No. MH469748 and MZ127288, respectively. Two QTLs/genomic region on chromosome 2 and 8 were mapped for Fusarium wilt resistance in pigeonpea.

CRISPR/Cas technology was utilized to edit the cytokinin oxidase (*OsCKX2)* gene of indica rice cultivar controlling the grain number in order to increase the yield of Samba Mahsuri. The genome-edited To lines showed 200 to 496 grains/panicle in comparison to ~150 grains/panicle in wild-type or non-edited Samba Mahsuri plants while T1 lines showed desired characters like strong culm and early maturity. To create novel variants for morphological, physiological, and biotic stress tolerance traits, induced mutations were created in the background of Samba Mahsuri (BPT 5204). The mutant lines showed enhanced tolerance to important biotic stresses (YSB, ShB and BLB). Multiple abiotic stress responsive genes were identified using transcriptomics in sugarcane. A chromosome-level reference genome assembly (2.93 Gb; 97.66% Coverage) of Indian Tea (*Camellia assamica* var. Masters cv. TV-1) genome was generated anchoring 99.4% of super-scaffold level assembly into 15 clusters or pseudomolecules by Hi-C data with the size of clusters ranging from 303.18 Mb to 119.95 Mb. A novel abiotic stress responsive gene LOC_Os06g10210 (*OsCHI2*) isolated from a drought tolerant rice cv. Nagina 22 (N22) which showed upregulation in response to drought stress was identified. miR156 site in *Ideal Plant Architecture 1* (*IPA1*) gene in rice variety, Swarna, was edited. Panicle architecture and spikelets/panicle improved significantly in edited lines. Presence of Protein Body 1 and 2 under different post-harvest processing conditions of grains of high protein rice CR Dhan 310 was identified. In order to identify the high resistant starch rice, 100 rice lines were analyzed which revealed ariation in the range of 0.28% to 2.94% with Gayatri rice line showing the highest resistant starch content of 2.94% over the years (2019 to 2022).

To screen large number of genotypes for vivipary, laboratory method was proved efficient considering the correlation with field observation data, outstanding genotypic difference and convenience of testing. Mutants of BPT 5204 with robust root system architecture, early seedling vigour index, and higher yield under limiting water conditions identified which are suitable for the dry direct seeding under aerobic system of rice cultivation. Genomes of rice restorer line KMR3 (salinity-sensitive) and its salinity tolerant introgression line IL50-13 were sequenced. Draft genome of yellow stem borer *Scirpophaga, incertulas* an agriculturally important pest with 46,057 genes and estimated size of 308 Mb was generated. During 2021-22, breeder seed production in field crops was 101617.5 quintals against the indent of 77260.1 quintals and total production of quality seed was 349596.6 quintals against the target of 312584.7 quintals. In addition, 234.5 lakh planting material and 5.4 lakh tissue culture plantlets were produced against the targets of 174.3 and 4.7 lakh, respectively.

In horticultural crops, 122 varieties were notified for cultivation under different agroclimatic conditions. These included 15 varieties of fruits, 1 of plantation crops, 97 of vegetables, 2 of tropical tubers and 7 of spices. The molecular linkage maps of two grape varieties (Carolina Black Rose and Thompson Seedless) were developed. Genome assembly of Indian pomegranate cv. Bhagawa was released. Varietal signature for genetic purity of spices were identified and identity of nutmeg varieties IISR Vishwashree, IISR Keralashree and Sindhushree was established. Marker free late blight resistant transgenic line KJ66 of potato was

identified. A total 1047 activation tagged lines were generated in potato cv. Kufri Jyoti and Kufri Chipsona 1 using activation tagging vector pSKI015. Targeted editing of potato genome was done to develop variety specific True Potato Seed (TPS). A total of 16 lines of potato with mutation within MiMe genes (StOSD, StREC8 and StSP011) were generated. Molecular identification and diversity of 25 *Pleurotus* mushrooms were investigated. Seven new hybrid strains of *Pleurotus* were developed by mating single spores from *Pleu rotusos treatus* (DMRP 30) and *Pleurotus florida* (DMRP 49). The biological efficiency was recorded maximum for hybrid P18102 (79.00%) in two flushes compared to parents and check on pasteurized wheat straw.

2. Livestock Improvement: The evidence of selection signatures in the datasets of 284 individuals of Tharparkar cattle along with 11 other indigenous and exotic cattle breeds were demonstrated. Significant candidate genes were identified related to various important traits such as ADRB2 in Tharparkar; HERC5, SCC25A48 in Gir; CA8 in Ongole and KIAI217 in Sahiwal for milk production; PARN in Holstein; ZBTB20 in Sahiwal; and APBB1 in Tharparkar for reproduction; SP110 in Brown Swiss; HSP90AB1 in Tharparkar and Red Sindhi for thermo-tolerance trait.

The influence of X-linked genes on the sperm functional parameters and field fertility rate in the cattle and Murrah buffalo bulls was studied. The sperm transcriptome studies revealed that the total number and the expression levels of X-linked genes in the mature sperm were very low in both species, and only 23.3% of these genes were commonly expressed between them. The X- linked genes related to embryonic organ development and reproduction were enriched in cattle and buffalo sperm, respectively. The expression levels of X-linked genes in cattle RPL10 and ZCCHC13, and buffalo AKAP4, TSPAN6, RPL10 and RPS4X were significantly correlated with sperm kinematics. Evidently, the expression level of RPL10 and RPS4X was significantly correlated with the field fertility rate in cattle and buffalo, respectively. Multivariate regression models and receiver operating curve analysis suggested that the expression levels of X-linked genes may be useful in predicting the bull fertility rate.

An egg yolk-free, ready to use, semen extender for cattle and buffalo with higher shelf-life (≥18 months, 4°C) for cryopreservation of buffalo semen was developed for the first time in India. The post-thaw progressive motility of cryopreserved buffalo sperm in the new egg-yolk free semen extender was significantly higher. A farm-to-fork block chain-based buffalo meat traceability system, BuffTrace, was developed for buffalo meat industry in collaboration with a private company. The system helps in collection of post-slaughter information and retrieval of the traceability information based on the label details.

CARI-Prabal

The complete mitochondrial genome sequences of 88 Indian sheep representing 22 breeds/ population were analyzed for the first time to get a comprehensive picture of the maternal diversity in the sheep genetic resources of India. The mitochondrial DNA sequence of all Indian sheep was observed to be 16617 bp long and contained 37 genes, including 13 protein coding genes, 2 rRNA genes, 22 tRNA genes, and a control region. Network Project on Sheep Improvement (NWPSI) and Mega Sheep Seed Project (MSSP) with major objective of improvement of indigenous sheep breeds were initiated.

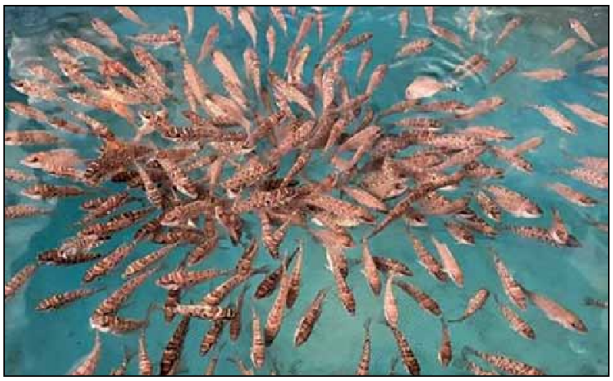
Concurrent transcriptome and methylome analysis of pig breeds (Mali and Hampshire) with varying muscularity was done to obtain insights into myogenesis. Muscle transcriptome identified 20226 mRNAs out of which 15170 were present across the samples. Developed economic and nutritionally balanced silage-based pig feed following standard procedure from vegetable wastes adding jaggery (gur) at the rate of 3 kg per 100 kg raw chaffed

vegetable waste for suitable anaerobic fermentation in silage bags. A total of 1,934 liquid boar semen doses were produced and supplied for artificial insemination in pigs at the farmers' field and organized farms.

Three climate resilient dual type hardy birds, CARI-Dhawal, CARI-Prabal and CARI-Saloni were developed for efficient egg and meat production. To overcome the antibiotic growth promoters used in poultry feed, CARI-HERBIGROW, a natural product was developed with the property of antioxidants, immune enhancer, stress reducer and helps chicken to improve overall production.CARI–HERBISTRESSMIN, a phytogenic feed additive was developed by CARI to reduce effect of heat stress and improve immunity of birds during hot and hot-humid summer. Alternatives for antibiotic growth promoters (AGPs) in feed and alternate protein meal and biofortified maize in poultry diet (black soldier fly (BSF) larva meal) were also developed.

Inhibin alpha gene editing by CRISPR/Cas in Nicobari indigenous chicken led to efficiency of production. The egg production up to 72 weeks of age increased by 203% from 261 eggs in edited birds as compared to 128 egg in control birds. Immunochromatography-based chicken detection kit (ICDK) was developed for the authentication of chicken. Genomic diversity was estimated in Arunachali yak population based on data generated using ddRAD sequencing. Three indices, viz. nucleotide diversity (0.041 in 200 bp windows), effective population size (Ne = 83) and runs of homozygosity (>90% were short and medium length) revealed that the genomic diversity in Arunachali yak breed as of now is optimum.

3. Fish Improvement: Successful natural spawning of green snapper, *Lethrinus nebulosus,* was achieved in recirculatory aquaculture system (RAS). It is a large tropical marine fish species that grows to 80 cm in length and 8.4 kg in weight. *Lethrinus nebulosus* were collected from wild and developed into functional broodstock in 10 t RAS system. Simple non-invasive breeding and culture protocols were developed for four indigenous ornamental fishes of the Western Ghat, viz. *Pethia setnai, Pethia nigripinnis, Dawkinsia tambraparniei* and *Dawkinsia arulius*. Similarly, breeding technique were standardized for two endangered species of genus *Dawkinsia*, viz. *Dawkinsia tambraparniei*, the Tambraparniei barb and *Dawkinsia arulius*, the Arulius barb. Two



Hatchery produced seeds of *Lethrinus nebulosus*

backyard recirculating aquaculture system (RAS) models of rearing tanks size 3 and 7 cubic metre with production capacity of 30 kg per m^3 were designed, fabricated and validated for small-scale farming of rainbow trout by the farmers of hill states to reduce the initial cost of investment.

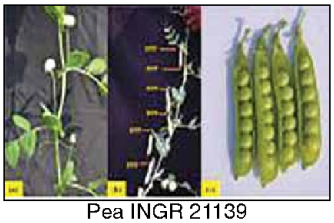
4. Genetic Resources: Total 890 accessions (450 cultivated and 440 wild) including unique landraces of cereals, pulses, oilseeds, vegetables and germplasms of wild edible fruits and wild relatives of the cultivated crops were collected through 18 explorations. Under National Gene bank, 5,152 accessions of orthodox seed species added for long-term storage resulting into the total of 4,62,923 accessions in its present base collection. In Cryogene bank, 404 accessions of seeds and pollen genomic resources of different crop species were cryopreserved, making the total collection of 12,480 accessions. Total of 41,557 accessions were imported from 37 countries and 14,641 entries from trails/nurseries from CG centres. Imported samples numbering 133,673 were processed for quarantine clearance. One plant quarantine database and two web-based applications were developed. ICAR-NBAIM, the nodal agency for developing DNA fingerprints of microbial cultures to be registered as biopesticides developed fingerprints of more than 487 samples for accurate identity. A total of 26 microbes were accessioned under safe deposition and 72 cultures were sold to academia and companies fetching ₹ 291600 revenue to the institute.

In horticulture, a total of 3,346 accessions were collected and 26 accessions showing unique traits were registered as novel genetic stock. Five genotypes of longan of fruit size (8.1 – 8.5g/fruit), an oilpalm cross progeny number 483 (599NATP × 33D) promising for more oil to bunch ratio (21.37%) and 175 fungal mushroom accessions were identified. A QR coded gene bank exclusively for wild genetic resources of banana established at

ICAR-NRC-Banana, Tiruchirappalli. This is the first of its kind in India for conservation of genetic diversity and identify resistant sources to various biotic and abiotic stresses in banana.

Germplasm accessions of horticultural crops showing unique traits


Banana 22060


Pea INGR 21139


Tomato INGR 21150


Radish INGR 21220


Chrysanthemum INGR 21108


Tuberose INGR 22056

In livestock, 10 new breeds of indigenous livestock species, Kathani cattle (Maharashtra), Sanchori cattle (Rajasthan) and Masilum cattle (Meghalaya); Purnathadi buffalo (Maharashtra); Sojat goat (Rajasthan), Karauli goat (Rajasthan) and Gujari goat (Rajasthan); Banda pig (Jharkhand), Manipuri Black pig (Manipur) and Wak Chambil (Meghalaya) were registered making total number of registered indigenous breeds to 212. A total of 44,860 semen doses of 17 native livestock breeds, including nine of cattle (Red Sindhi, Badri, Red Kandhari, Nimari, Deoni, Gaolao, Bhijarpuri, Ghumsari, Khariar) and 8 of goat (Ganjam, Jamnapari, Beetal, Berari, Osmanabadi, Sirohi, Sangamneri and Barbari) were cryopreserved. Also, 1,020 somatic cell vials of 7 native breeds--Purnea, Mewati, Hariana and Shweta Kapila of cattle, Konkan Kanyal of goat; Doom and Purnea of pig were added for cryopreservation. Presently,

Newly registered livestock breeds


Purnathadi buffalo


Sanchori cattle


Karauli goat


Banda pig

National Gene Bank has repository of 61 native breeds/populations of livestock and poultry in form of semen, and 28 in form of somatic cells. Under the Mission Zero Non-descript AnGR, 22 new populations of native livestock and poultry have been identified. These are being characterized in their respective breeding tracts.

In fisheries, 3 freshwater species *Amblycepsh molaii* from Kawlchaw river, Mizoram; *Pangasius icaria,* from Cauvery river, Karnataka; and *Tor sattalensis* from Sattal Lake, Uttarakhand and 5 marine fish/shrimp *Eptatretus wadgensis*,

Marine fish/shrimp species


Amblycepsh molaii sp. nov.

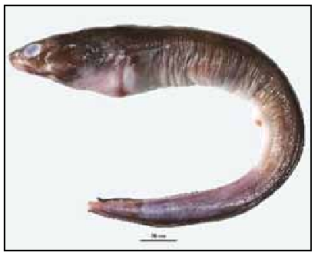

Pangasius icari


Tor sattalensis


Eptatretus wadgensis

Dussumieria modakandai sp. nov

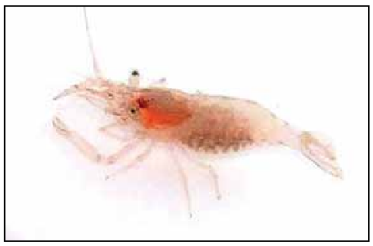
Ariosoma melanospilos



Ariosoma albimaculatum

Ariosoma indicum

Ariosoma maurostigma



Actinimenes koyas

Dussumeria modakandai, Ariosomaalbi maculatum, Ariosoma melanospilos and *Actinimene skoyas* were discovered. Canary top wrasse, *Halichoeres leucoxanthus,* previously distributed in Maldives, Myanmar, Chrismas Island (Australia), Thailand and Western Indonesia was found for the first time in Indian waters. For the first time, recorded catch of marine/deep sea fish species like *Aluterus monoceros, Antennarius indicus, Ariomma indica, Diodom hystrix, Labotes surinamensis, Nemipterus randalli, Priacanthus prolixus, Seriolina nigrofasciata,* in Hooghly- Matlah estuary. Indian oil sardine's whole genome assembly is 1.077 GB (31.86 Mb scaffold N50) in size with repeated content of 22.84%. The sequences were deposited in NCBI, GeneBank. The cell lines from rainbow trout heart and snow trout muscles were developed, authenticated and deposited in ICAR-NBFGR National Repository of Fish Cell Lines.

5. Crop Management: Application of consortium of methane utilizing bacteria (MUB) formulation comprising of *Methylobacterium oryzae* MNL7 and *Paenibacillus polymyxa* MaAL 70 through seedling root dip technology and as spray reduced methane emission by 5 to 25% in flooded rice. Rise in temperature by 1.7^{0}C with elevated CO_2 showed an increase in grain yield across two wheat varieties. Elevated CO_2 (ECO_2) with elevated O_3 (EO_3) alleviated the negative effect of ozone on grain yield. Durum and bread wheat were exposed to leaf compost (LC) and vermicompost (VC) enriched with polyvinyl chloride (PVC) and poly propylene (PP). The microplastics in the farm inputs altered the nutrient availability and uptake. Satellite based crop health indices were developed for whole of India. The spatial layer of active fire points of rice residue burning (October-December) was uploaded on ICAR KRISHI Geoportal on daily basis. Near real time crop condition monitoring was developed using google earth engine platform and moderate resolution satellite data.

Real time soil moisture-based irrigation scheduling of green pea revealed water saving of 44-50% against surface irrigation practice. Conservation practice, permanent beds with residue recorded highest grain yield of *kharif* crops followed by zero tillage and CT. Sugarcane based Integrated farming system developed by ICAR-IISR fetched additional income of ₹ 2,65,902.5/ha in autumn planted sugarcane and ₹ 2,63,020/ha in spring planted sugarcane. The wireless smart trap developed for real time pest monitoring in cotton showed a weekly mean trap catch of 19.8 (*P. gossypiella)*, 6.18 (*S. litura*), 0.19 (*H. armigera*) and 0.08 (*E. vittella*) during 2021-22.

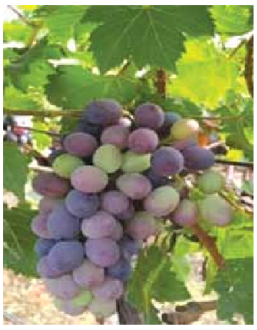
Four mVOCs formulations evaluated @ 5 ppm concentration on the attraction of 4 sucking pests -whiteflies, jassids, aphids, and thrips in cotton using yellow sticky traps (YST) trapped 232%, 1517%, 709%, and 237% higher whiteflies, jassids, aphids, and thrips, respectively as compared to the control. Insect bioassay (*in vitro*) conducted to study the efficacy of the native strain of the *M. rileyi* on FAW indicated M. *rileyi* as potential microbial agent for management of the fall armyworm in sorghum. The survey conducted to understand the infestation and distribution of common bruchid species in legumes, indicated 5 bruchid species infesting pulses, 3 of which were *Callosobruchus*. Among *Callosobruchus* species, *C. analis* was distributed on 50% of the samples and locations, followed by *C. maculatus* and *C. chinensis*.

The formulations based on two Trichoderma species having excellent quality to protect the rice

CICR Wireless Smart Trap

Untreated control

Bio Pulse + Sulphur



Eco-pesticide + Sulphur

Effect of microbial technologies on disease incidence in grape

plant against soil and seed-borne diseases and excellent growth promotion capability developed and tested at farmers' fields. They were highly effective in maize, finger millet, niger and rice. Entomopathogenic nematode (EPN) biopesticide formulation technology was commercialized to 5 companies with a license fee of ₹10 lakhs. Efficacy of fungicide against rice bakanae disease was tested. Spraying of propiconazole @ 2 ml l of water at 15 DAT resulted in the lowest incidence of bakanae disease and higher yield of rice.

Soil application of mycorrhizal consortium @ 20 kg along with 500 kg of compost/ha at the time of sugarcane planting proved an effective bio-control of parasitic weed *Striga* spp. in sugarcane. A multi-residue analysis method was developed for simultaneous determination of 30 herbicides in agricultural commodities using LC-MS/MS. Similarly, a multi-residue analysis method using TLC with the detection limit of <0.01 µg/g was also developed for determination of herbicide combination products namely, pretilachlor + pyrazosulfuron, cyhalofop-p-butyl + penoxsulam and traifmaone + ethoxysulfuron. A user friendly multi-lingual mobile app named 'Herb Cal' for application of herbicides was developed. After entering the herbicide information such as crop, area, dose and herbicide formulation to be used, the app automatically calculates the amount of herbicide and quantity of water to be taken for spray. Biological control of alien invasive weed *Salvinia molesta* in a 20 ha *Salvinia* infested pond in village Padua of Katni district was achieved by releasing 2000 adult weevils of a host specific insect *Cyrtobagous saliviniae*. With the increase of bioagent population 50, 80 and 100% control of *S. molesta* was achieved by 8, 11 and 18 months, respectively.

In grapes, microbe-based technologies, Eco-pesticide, Bio-Pulse, UBSTH-501 and Bio-Care 24 were evaluated against *Erysiphe necator* grape powdery mildew and integrated these technologies with a safer fungicide (sulfur). The percent disease index (PDI) reduced significantly in grape leaves treated with Eco-Pesticide®/sulfur (22.37) followed by Bio-Pulse®/sulfur (22.62) and Bio-Care 24®/sulfur (24.62). An efficient technology for multiplication of clonal rootstock of apple through cutting under greenhouse conditions using soilless rooting medium was standardized. Field application of Nanoparticles of iron and zinc showed a significant increase in leaf Fe and Zn content after 14 and 28 days of application over conventional fertilizers. The performance of Crimson Seedless, Manjari Kishmish and Manjari Medika grapevines grafted on Dogridge and 110R was found superior over other rootstocks. A microbial consortium CISHD ecomposer has potential to accelerate the composting rate. DRIS indices and critical leaf nutrient concentrations were developed for oil palm plantations. Coconut-based Integrated Farming System (CBIFS) realized a net return of ₹ 6,53,853/ha.

Application of customized fertilizers in sweet potato was best for higher tuber yield (22.74 t/ha) compared to present POP (19.67 t/ha). Low cost technology for the paddy straw mushroom cultivation was developed. Vertical farming was standardized for growing important high value flower crops by utilization of 11 feet vertical space of the polyhouse. Nutritional and chemical finger prints of popular turmeric varieties were developed. The effects of nanoZnO (nZnO) on the compositional and functional responses of bacterial communities in soils were examined using high throughput sequencing. Microbial consortia for enhancing the growth and yield of cumin and coriander was identified. Organic nutrient management practices for Sarpagandha were developed. New insect- pests in banana (Fall armyworm, *Spodoptera frugiperda;* Bondar's nesting whitefly, *Paraleyrodes bondari* and bagworm, *Manatha albipes* were identified. Litchi stink bug (*Tessaratoma javanica*) and

the Flower webber were recorded as emerging insect pest attaining major pest status of litchi. An algorithm based on object detection approach was developed for surveillance of rhinoceros beetle infestation using unmanned aerial vehicle (UAV or drone).

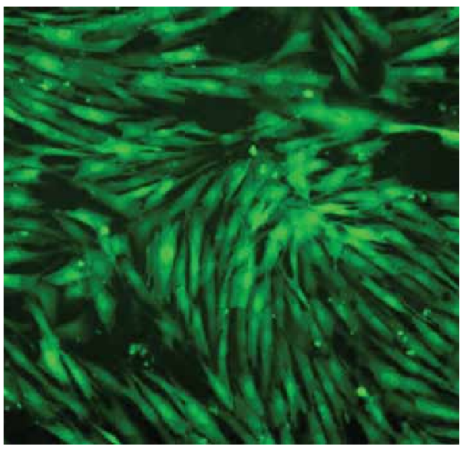
An entomopathogenic fungus isolated from infected *H. theivora* was identified as *M. anisopliae* TMBMA1 and found effective in mirid management in cocoa. Competitive regulation and biological control of rugose spiralling whitefly by the Bondar's nesting whitefly (BNW) during 2021 was observed. Incidence of Fusarium wilt disease, tropical race 4 (Foc TR4) in banana in West Bengal was identified. Citrus microbiome was utilized in rejuvenating Khasi Mandarin plants affected by important citrus diseases. Etiology of emerging diseases in plantation crops was established. A rapid and novel mycelium inoculation technique for inducing *Ganoderma lucidum* infection in coconut and arecanut seedlings was developed. A native plant growth promoting isolate of *Trichoderma asperellum* (isolate AT172) having antagonistic activity against arecanut basal stem rot pathogen *G. lucidum* was identified and characterized.

The cashew leaf blight disease caused by *Neopestalotiopsi sclavispora* was identified for the first time in cashew. RPA-lateral flow assay (RPA-LFA) method was standardized for the on-site detection of the piper yellow mottle virus infecting black pepper. Singleplex and duplex recombinase polymerase amplification (RPA) assays were optimized for specific and sensitive detection of *Pythium* spp. and *Ralstonia pseudosolanacearum* from ginger rhizomes. Marker free late blight resistant transgenic line KJ66 was identified. Prototype of a remote operated unmanned ground (UGV) vehicle was designed and developed for spraying of agrochemicals on potato crop. Sodium alginate-based bead formulation of fungal mycelia and conidia for long term storage of fungal cultures were developed.

6. Livestock Management: Thirteen healthy buffalo calves (seven males and six females) were produced from semen of two cloned bulls. This technology will lead to future sustainable milk production in the country. Prototype of intra-vaginal wireless sensor device was developed for remote monitoring of calving process in dairy cows. This could help in predicting the calving time in cattle. NADRESv2, a dynamic geographic information and remote sensing-enabled expert system maintained by ICAR-NIVEDI was updated in the NADRES database, and a total of 5655 predictions for major livestock diseases were communicated to State Animal Husbandry Departments and Department of Animal Husbandry and Dairying (DAHD), GoI, in the form of risk maps, bulletins, and post-prediction maps for necessary preparedness. Nation-wide sampling plans for sero-surveillance and sero-monitoring of foot and mouth disease (FMD), brucellosis, *Peste des Petits Ruminants* (PPR) and classical swine fever (CSF) for each state/UTs of the country were formulated and provided to DAHD, GoI, for strengthening the surveillance system. Screening of serum samples (32,257) for important livestock diseases from different animal species submitted to various NADEN units and State Animal Husbandry Departments was carried out. The sero-diagnostic services were provided for infectious bovine rhinotracheitis (IBR), trypanosomiasis and pasteurellosis with 28.9%, 49% and 4.5% positivity, respectively in ruminants. Brucella post-vaccination sero-monitoring is one of the major activities to evaluate the impact of the control program. Towards this, a total of 14,611 sera collected from different states were screened, of which, 64.45% were positive for anti- brucella antibodies.

Under FMD sero-surveillance, 98,185 bovine serum samples from around the country were analyzed and an overallsero-positivity in 16.6% of the tested samples was reported. The state FMD centers were provided with three main test kits (3AB3 indirect DIVA ELISA for 1,75,583 samples, Solid Phase Competitive ELISA (SPCE) for 1,56,778 samples, and Sandwich ELISA for 3893 samples. Clinical samples (2824) were analyzed for serotype identification in 378 FMD outbreaks. During 2021, all three FMD virus serotypes were documented, with serotype O leading the outbreak scenario followed by serotype A. Overall, the disease incidences have increased compared to previous year. A total of 113 FMD virus isolates (102 O, 10 A and 1 Asia 1) revived in BHK-21 cell system were added to the National Repository of FMD Virus maintained at International Centre for FMD, Bhubaneswar and Mukteswar Laboratory. PPR Ab Check kit for the detection of PPR Virus nucleocapsid protein antibodies in the serum samples and PPR Ag Check kit for the detection of PPR virus in Clinical specimens of sheep and goats; Recombinant nucleocapsid protein based indirect ELISA kit for detection of Anti SARS CoV-antibodies in canines (CAN-CoV-2 iELISA

kit) and Multi recombinant proteins based ELISA Kit for diagnosis of Trypanosoma evansi infection in animals; TaqMan-probe-based realtime RT-PCR assays (RT-qPCR) for pan-serotype detection of FMDV; Recombinase polymerase assay for detection of African swine fever virus in pigs; Multiplex PCR to differentiate Mycobacterium tuberculosis complex species; Rapid colorimetric assay for detection of the extended spectrum β-lactamase producing bacteria; Lateral flow assays (LFAs) for detection of CD virus antigen and antibody were developed. Among the vaccines, Ancovax for SARS-CoV2 infection; LSD vaccine named Lumpi-ProVacInd against LSD; Inactivated Low Pathogenic Avian Influenza (H9N2) vaccine for chickens; Thermostable serotype O vaccine for FMD were developed. Mesenchymal stem cells (MSCs) with or without egg shell membrane, bioactive collagen gel, collagen powder, platelet rich plasma, and MSC laden Nano-scaffolds of hydroxyapatite and multiwalled carbon nanotubes were evaluated for skin wound, bone and nerve healing in animal models, and showed promising results. p38 mitogen activated protein kinase inhibition suppresses buffalopox virus (BPXV) protein synthesis by targeting p38-MNK1-eIF4E signaling pathway. The P60-SB239063 virus exhibited significant resistance to SB239063 as compared to the P60-Control virus. This is a rare evidence, wherein a virus was shown to bypass the dependency on a critical cellular factor under selective pressure of a drug. An online database management system named MHC Database was created (http://www.mhcdbms.in/) to allow easy access and use of immune polymorphism data. This system also allows user to upload as well as download the indigenous Ovar MHC allelic database for sheep breeds in FASTA format. CRISPR/CAS9 mediated knock-in of human Erythropoietin gene in the goat fibroblast cells was done and the transgenic goat fetal fibroblast cells expressed hEPO gene fused with green fluorescent protein (GFP) gene. ICAR-NRCE, Hisar is actively involved in glanders surveillance, providing diagnostic support, capacity building of state diagnostic laboratories/ RDDLs. For rapid and efficient execution of surveillance activities, Hcp1 ELISA kit developed by NRCE is being used for glanders diagnosis. A total of 1737 equine serum samples from 8 states were tested for equine infectious anemia (EIA), equine influenza (EI), Equine Herpes Virus-1 (EHV-1), Japanese Encephalitis/ West Nile Virus (JEV/ WNV), *Trypanosoma evansi* (Trypanosomiases), piroplasmosis Salmonella, *Abortus equi* and brucellosis. Highest sero-prevalence was observed for equine piroplasmosis (38.40%) followed by EHV-1 (7.80%), JE/WNV (7.40%), and *Trypanosoma evansi* (2.15%). Stallion seminal plasma proteins were profiled and the proteins and pathways associated with sperm motility were identified. Purification, molecular characterization and ligand binding properties of the major donkey seminal plasma protein (DSP-1) isolated from donkey (*Equus hemionus*) seminal plasma was done. Transgenic chickens were produced through sperm mediated gene transfer (SMGT) method with an efficiency of 5.4%. In the transgenic birds, human interferon alpha 2b gene was introduced at the germ line stage in the chicken genome. The transgenic hens laid 132 eggs with an average content of 30-40 mg of interferon alpha 2b protein in each egg. Characterization of colostrum of native cattle and yak of high-altitude region of Leh-Ladakh was done in comparison to Sahiwal (SAC). Samples from LSD suspected outbreaks in 20 States/UTs of the country were tested to identify laboratory confirmed cases of LSDV infection for undertaking prevention and control measures against LSD in India. A total 2456 bovine (cattle



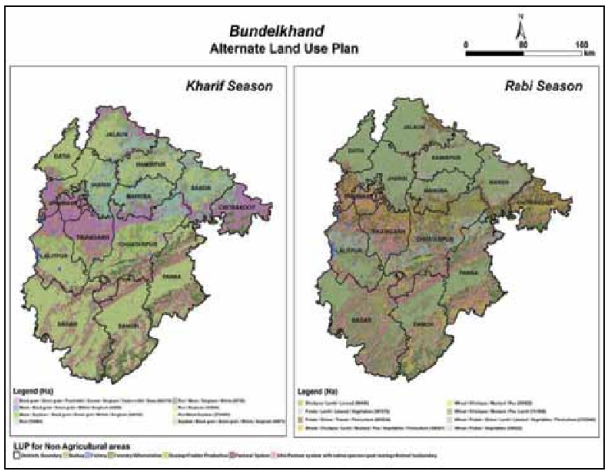
Transgenic goat fetal fibroblast cells expressing hEPO gene fused with green fluorescent protein (GFP) gene

MCRV infected *S. serrata* displaying grey colour shell discolouration

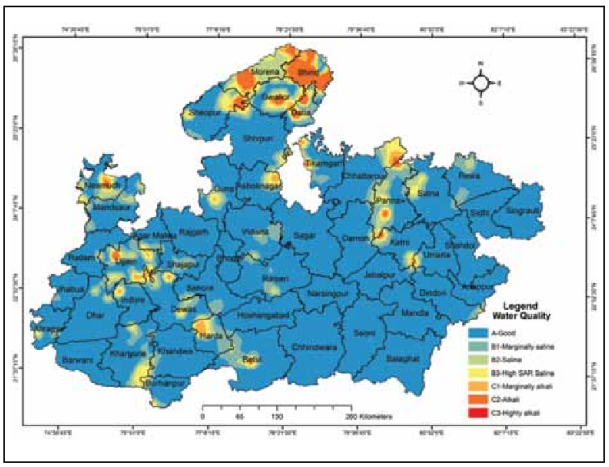
and buffalo) samples were tested, of which, 1156 cattle samples from 19 States/UTs tested positive for LSDV. First whole genome analysis of Indian African swine fever viruses revealed potential genetic determinants to differentiate closely related ASFV circulating in Asia. Global alignment of the complete genome sequences showed nucleotide identity of 99.96% amongst the two Indian isolates (IND/AS/SD-02/2020 and IND/AR/SD-61/2020). The results showed the importance of the 14 ORFs in understanding the evolution of ASFV in Asian countries and their divergence from prototype ASFV Georgia/2007. Whole Genome Sequencing of 12 Bovine coronaviruses isolated from cow (3) and buffalo (9) nasal and faecal samples collected in 2020-21 revealed two different subgroups: subgroup GIa having 9 viruses cluster from across the world and GIb subgroup having 3 other viruses cluster which has majorly the isolates of France in 2017. A food-grade meat decontaminant spray was developed by using the extracts of Ashwagandha roots and Guava leaf spray which could reduce the microbial load many folds in retail fresh chicken. Phytochemicals (thymol and cinnamaldehyde) conjugated silver nanoparticles (AgNPs) were tested for their efficacy against Enteroaggregative *Escherichia coli* (EAEC) and non-typhoidal Salmonella. Assays revealed the antimicrobial activity of the encapsulated compounds (EAgC and EAgT) and appeared to be safe.

7. Fisheries Management: A web-GIS application for location-specific riverine fisheries management was developed. It provides an interactive and user-friendly interface which contains environmental data of 300 sampling stations covering 20 major rivers of India. The portal's database and customized reports will facilitate various researchers, planners and policymakers to make judicious planning/strategies for the betterment of fisheries resources. Mud crab, *Scylla serrata,* is an economically important crustacean species which is also being cultured. Mud Crab Reo Virus (MCRV) is an emerging viral pathogen in mud crab culture. On RT-PCR screening, MCRV were detected in gills and hepatopancreatic tissues. Herpes viralha ematopoietic necrosis disease (HVHND) is caused by CyHV-2, which causes severe mortality in goldfish. A rapid and sensitive RPA (Recombinase Polymerase Amplification) assay, coupled with lateral flow dipsticks (LFD) was developed by designing specialized RPA primer, LFA primers and probes. The RPA-LFD assay developed presents a simple, rapid and sensitive method for point-of-care diagnosis of CyHV-2, especially under resource limited conditions. A Coliphage cocktail for controlling antimicrobial resistant (AMR) *E. coli,* containing 10 coliphages, selected based on their broad host range, varied location and their ability to lyse AMR *E. coli* was developed. The Coliphage cocktail has a phage titer of ~10^{12} to 10^{14} pfu/ml and can be used for the control of *E. coli* and AMR *E. coli* on food contact surfaces. The Coliphage cocktail can be stored under chilled conditions (<4ºC) condition for a minimum period of 3 months.

8. Soil and Water Productivity: Micro level



Proposed alternate land use plan for Bundelkhand



Groundwater quality map of Madhya Pradesh for irrigation

agricultural land-use planning, soil and water conservation, water harvesting, storage and groundwater recharge, improvement in water productivity and nutrients use efficiency, integrated nutrient management, resource conservation technologies, chemical free agriculture, integrated farming system, waste-water use, dryland, hill and coastal agriculture, weed management, precision agriculture, climate resilient agriculture, abiotic stress management was given special thrust. The land resource inventory (1:10,000 scale) for Bundelkhand region prepared for sustainable land use, spectral signature library of the soils of India for quick and inexpensive acquisition of surface soil properties, potential crop planning zones of Telangana, and land suitability analysis for turmeric in Kerala under projected climate change scenarios were accomplished. The groundwater quality map of M.P. for irrigation and groundwater recharge plan for Korba and Janjgir-Champa districts in the upper Mahanadi Basin developed. ICAR-CSSRI and NTPC joint study on efficiency of flue gas desulfurization gypsum (FGDG) revealed 8-11% decline in saline soil pH after one year of FGDG surface application (0-15 cm depth) and neutralization of soil alkalinity improved paddy yield by ~40%. A Solar Irrigation Pump Sizing Tool (SIPS) was developed for large scale adoption by farmers and support the PM-KUSUM initiatives. To promote organic farming, packages for 5 cropping systems for Gujarat, Rajasthan and Uttarakhand were developed. ICAR-NIASM developed beta version of the Abiotic Stress Information system (ASIS) consisting of modules on Atmospheric and Soil Stress information for generating query based geo-spatial maps. The new salt tolerant varieties in rice (CSR 76) and mustard (CS 61 and CS 62) were developed.

9. Mechanization and Energy Management: A tractor operated side trencher was developed to make trench up to 300 mm depth. The effective field capacity and field efficiency of the trencher were 0.2 ha/h and 71%, respectively when operated to dig a trench of 300 mm deep in 3 m wide vineyard at 2.0 km/h forward speed. The cost of operation of tractor operated side trencher is about ₹ 560/hr. It economizes the cost of operation, labour and time by 72, 94 and 80%, respectively as compared to manual digging of trench with hand tools. The tractor operated FYM applicator of 1 tonne capacity was developed for placing FYM near the plant. The cost of operation of tractor operated FYM applicator is about ₹ 645/hr which saves labour, time and cost of operation by 98, 80 and 88%, respectively as compared to manual method. Manual operations of raised bed forming, drip lateral and plastic mulch laying, and planting seeds in a plastic mulch requires about 29 man-days/ha. A tractor operated drip lateral and plastic mulch layer-cum-planter was developed to perform raised bed formation, drip lateral and plastic mulch layingetcin single pass of the tractor. The total cost of equipment is ₹3,00,000 with operational cost of ₹1,500/hr. The payback period of equipment is 1.9 years. A self-propelled walk-behind maize harvester for snapping the maize cobs from the maize plants and simultaneously cutting the plants has been developed. The effective field capacity of the harvester is 0.2 ha/hr and the cost of operation of the maize harvester is ₹ 2,850/ha. The saving in cost of operation, time and labour are 25, 96 and 91%, respectively compared to manual harvesting. A remote-controlled electronic system was developed for ride-on rice transplanter to reduce human drudgery. It can be remotely operated at a distance of 200 m. The field capacity of remote-controlled ride-on rice transplanter is 0.24 ha/hr. To ease the digging of garlic, a tractor operated harvester was developed which can harvest garlic crop planted on raised beds. The harvesting efficiency of the harvester is 97% and bulb damage is <0.5%. A small tractor-mounted hydraulic pruner for orchards was developed with the pruning capacity of 120 plants/hr. The cost and operating cost of the pruner is ₹ 4,50,000 and ₹ 4,910/ha, respectively. ICAR-CIAE had developed a low-cost SPAD meter 2.0. It measures SPAD values for crops such as rice, wheat, maize, etc. with leaves up to 1 mm thickness. The SPAD values, measured with the device, can be used to generate recommendations for top-dressing of nitrogen fertilizer dose. A small tractor operated boom sprayer was developed for orchard crops. The cost of the spraying system is ₹ 30,000. The discharge rate of boom sprayer is 608 l/hr at 0.3 MPa pressure. The application rate and turning time of the spraying system was 475 l/ha and 12 s, respectively. A power tiller operated groundnut digger was developed with field capacity of 0.07-0.11 ha/h and digging efficiency of 97.6%. A tractor operated potato digger developed which performs three operations, viz. digging of potato tubers (two rows), separation of potatoes from soil and collection of potatoes in the collection unit. The average field capacity and output capacity are 0.12 ha/hr, 2700 kg/hr for sandy loam soil and 0.11 ha/hr, 2685 kg/hr for loamy soil, respectively. A digital flume with the Internet of Things (IoT) connectivity