ICAR Research Complex for Eastern Region, Patna

Major Achievements during last 12 years

A. Summary Achievements

- For greening rice-fallow areas, standardized and disseminated resource conservation-based cropping system, involving short-duration and drought-tolerant rice varieties followed by zero-till chickpea, lentil, mustard or safflower across 1,000 acres. Due to concerted efforts, the rice fallow area in the eastern region decreased by approximately 15 lakh ha compared to 2015–16.

- Integrated farming system models (one & two acre) developed for irrigated, rainfed, hill & plateau region generating net annual income of Rs. 1.86–2.68 lakhs, respectively, and disseminated them in about 300 farmers' field through ATARI and Line Department.

- Technology for sustainable intensification of the rice-wheat cropping system comprising, Rice (medium duration)-Zero-till Wheat-Zero-till Mung bean have been developed and disseminated over 10,000 acres. This intervention resulted in ~20% increase in system productivity, 30% rise in net income and 10% reduction in greenhouse gas emissions.

- Developed resource conservation technology (raised bed + drip-fertigation + poly-mulching) based vegetable system with water productivity and income of 5.70 kg/m^3 and 2–3 lakh/acre, respectively. The technology has been disseminated across more than 15,000 acres in the Chhotanagpur Plateau region.

- Developed ecofriendly solar irrigation pump sizing tool (Adapted by MNRE under PM-KUSUM), eco-friendly solar water pumping system, solar-powered rice thresher, insect trap and fish vending cart.

- Developed 14 climate-resilient and high-yielding rice varieties, 01 chickpea variety, 25 vegetable varieties and 03 fruit varieties for the eastern India covering more than 4 lakh ha in eastern region.

- Under the Climate-Resilient Agriculture Programme (Government of Bihar), climate-smart interventions demonstrated in 10 villages of Gaya Ji and Buxar covering ~12,000 acres involving 15,000 farmers. These interventions enhanced farmers' income by 25–30%.

- Six indigenous breeds-Purnea cattle and Maithili duck from Bihar, and Medini cattle, Palamu goat, Mala chicken and Kodo duck from Jharkhand registered with ICAR-NBAGR.

- A region-specific mineral mixture, "Swarna Min," developed, leading to improved animal health and a 10–15% increase in milk production.

- Under TSP and SCSP flagship programme-Participatory Research Application for Yield and Sustainability (PRAYAS) and '*Kaushal Se Kisan Samriddhi'*-over 18,000 farmers across 18 districts in seven eastern states benefited, achieving a 20–25% increase in income.

- The Farmer Producer Organization (FPO)-based technology dissemination model developed by the institute enhanced farmers' income by 17%.

- Institute developed 25 technologies (ICAR Certified), signed 64 MoUs, created 21 agri-entrepreneurs, 21 incubates registered under ABI and organized numerous capacity development programs, directly benefitting more than 5 lakh farmers.

B. Detail Achievements

Crop Research

- **Integrated Farming Systems (IFS):** Developed Integrated Farming System (IFS) model for different ecologies based on crop, livestock, fish and vegetable-based IFS models for eastern India, increasing farmers' income by 2.0–4.5 times (₹1.86–2.68 lakh), soil organic carbon by 16.0–28.5%, employment generation by 52–235 man-days, and water productivity by 28–44 % over the rice–wheat system; These IFS models have been transferred to Govt. of Bihar and till date these models have been replicated in more than 300 farmer fields of Patna, Vaishali, Nalanda, East and West Champaran, Bhagalpur, Buxar etc. districts.

  Similarly, for rainfed hill and plateau ecosystems designed, field-tested, and validated location-specific 1-acre Integrated Farming System (IFS) models tailored for to sustain a 4-person family (2 adults} + 2kids). The system integrates a dairy unit, fruits, cereals, pulses, vegetables, oilseeds, and fodder with field-bund border plantations (*Tephrosia*, pigeon pea, Napier grass, *Bakain*). Backed by intensive internal nutrient recycling (vermicompost, FYM, and crop biomass), the model doubled soil organic carbon from 0.31% to 0.64% over a 12-year period, recorded a carbon sequestration rate of 0.18 Mg/acre/year, maintained an output/input energy efficiency ratio of 1.3, generated 130–140 man-days of annual employment, achieved an REY 4 times higher than conventional rice-fallow monocropping.
- **Crop Diversification Frameworks for rainfed uplands:** Developed alternative pulses vegetables and millet crops diversification systems for direct-sown rainfed uplands to transition from subsistence to commercial farming. A highly specialized direct-sown *Rice* + *Legume* intercropping setup combining 6 rows of upland rice with 6 rows of rust-resistant *Swarna Vasundhara* vegetable soybean achieved a breakthrough Rice Equivalent Yield (REY) of 6.09 t/ha, vastly optimizing land use over conventional rainfed rice monocropping.
- **Crop Diversification Frameworks for irrigated plains EIGP:** Crop diversification programme was conducted in 500 acres in the farmers' fields in East and West Champaran Districts of Bihar where rice crop was diversified with maize, soybean, ragi, bajra and pigeon pea due to which system productivity enhanced by 45–67 % and water productivity by 43–72 % over the base crop rice. With the learning of diversification programme, in Kharif 2025, about 350 ha more rice fields have been diversified with Maize, Ragi and Bajra by own.
- **Sustainable Intensification Technology for Rice–Wheat System:** Developed RCT-based rice–ZT wheat–ZT greengram system achieving 11% higher net returns, ~25% higher energy productivity, 46% higher soil organic carbon, and 8–10% lower global warming potential; demonstrated over ~10,000 acres under the CRA programme.
- **Technology for Productive Utilization of Rice Fallow Lands:** Technological options for greening rice fallow areas (~11.65 m ha) through crop intensification involving short duration drought tolerant Rice (110-115 days, e.g. Swarna Shreya/Lalit) under DSR followed by chickpea, lentil, Rapeseed-mustard and safflower under Zero tillage and residue retention systems, enhanced system productivity & net returns by ~50% & 15%, respectively, demonstrated across ~1000 acres

in Bihar, Jharkhand and Chhattisgarh. Package of practices developed & shared with State govt. /stakeholders. Due to concerted efforts, the rice fallow area in the eastern region decreased by approximately 15 lakh ha compared to 2015–16.

- **Millet-based Climate Resilient Cropping System for Eastern India**: Evaluation of ten millet-based diverse cropping systems identified maize cob–pigeon pea (ZT) (22.3 t/ha) followed by sorghum fodder-mustard (ZT)–urd bean (ZT) (18.5 t/ha) systems for their adoption in Eastern India. These systems reduced input cost by 43-69% and enhanced income by two times & popularized under CRAP with Govt of Bihar.
- **Weed management in CA based system**: The conservation agriculture (CA)-based zero-till direct-seeded rice–zero-till wheat–zero-till greengram (ZTDSR-ZTW-ZTG) integrated with efficient herbicides [pyrazosulfuron-ethyl fb cyhalofop-butyl + penoxsulam in rice, clodinafop-propargyl + metsulfuron-methyl in wheat, and pendimethalin fb imazethapyr in greengram] achieved 78–93% weed control efficiency, 5.9% higher rice grain equivalent yield, and 15.2% higher net returns than conventional tillage practice. This CA-based practice also increased soil organic carbon by 35.9% (0–7.5 cm), improved water productivity by 23%, and reduced global warming potential by 33.5%, indicating strong potential for sustainable crop intensification in the EIGP.
- **Soil biology under long term CA system:** The conservation agriculture (CA)-based zero-till direct-seeded rice–zero-till wheat–zero-till green gram (ZTDSR–ZTW–ZTG) system supported a bacteria-dominated soil microbiome (92–96%) with greater microbial diversity and community heterogeneity than the conventional tillage system. Alpha and beta diversity analyses confirmed distinct microbial community structures under CA. This practice enhanced soil biological quality and promoted a more stable soil microbiome, supporting long-term agroecosystem sustainability in the EIGP.
- **Valuation of Ecosystem Services:** Assessment of Ecosystem services (ES) provided by different rice establishment methods indicated that ZTDSR provides the highest ES value at approximately US$ 9583 ha^{-1} yr^{-1}, about 9.3% higher than conventional RPTR. Regulation and maintenance services (e.g., temperature regulation, carbon flow, and nutrient cycling) contribute ~79.4% of the total ES value, while provisioning and cultural services contribute 20.3% and 0.3%, respectively.
- **Resilient Nutri-Cereal Based Farming System Technology:** A climate-resilient crop diversification technology was developed to enhance productivity and sustainability of rainfed farming systems in Eastern India through the inclusion of nutri-cereals such as Bajra (pearl millet) and Ragi (finger millet). Under rainfed conditions, sowing up to mid-July was found to be effective in improving system performance and resilience. Further intensification through Bajra/Ragi–chickpea cropping systems significantly enhanced system productivity (8.8–10.4 t/ha) compared to sole maize cultivation.
- **Site-Specific Nitrogen Management Technology for Rice-Maize Cropping System:** A nutrient management technology developed to optimize nitrogen application for enhanced productivity, nitrogen use efficiency, grain quality, and profitability in rice–maize systems. The technology recommends economically optimum nitrogen doses of 165 kg N ha^{-1} for rice and 167 kg N ha^{-1} for

maize, ensuring higher yields while minimizing nutrient losses and environmental impacts. It also utilizes crop response indicators such as chlorophyll content and grain nitrogen concentration for efficient nutrient management, making it suitable for sustainable intensification of rice–maize production systems.

- **Soil Organic Carbon Improvement through Agroforestry Technology:** A field study in Vaishali district, Bihar, demonstrated an agroforestry-based technology for enhancing soil organic carbon (SOC), carbon sequestration, and microbial activity. Among different systems evaluated, poplar-based agroforestry showed the highest performance, with total organic carbon ranging up to 6.64 Mg C ha^{-1} and carbon stocks reaching 41.43 Mg C ha^{-1} (0–45 cm soil depth). It also recorded the highest soil microbial biomass carbon (219.36 μg g^{-1}) and basal respiration, indicating improved soil biological activity.
- **Climate-Resilient High-Yielding Crop Varieties for Diverse Agro-Ecologies:** A suite of climate-resilient, high-yielding crop varieties was developed to enhance productivity and nutritional security across diverse agro-ecological regions of India. Fourteen rice varieties, namely Swarna Shreya, Swarna Shakti Dhan, Swarna Samriddhi Dhan, Swarna Unnat Dhan, Swarna Sukha Dhan, Swarna Shusk Dhan, Swarna Purvi Dhan 1,2,3,4,5, Swarna Mohan Dhan), were released with yield potential ranging from 4.0–6.0 t/ha, suitable for aerobic, irrigated, rainfed upland, midland, and shallow lowland conditions across Bihar, Jharkhand, Odisha, West Bengal, Uttar Pradesh, Chhattisgarh, Madhya Pradesh, Rajasthan, Haryana, Maharashtra, and Gujarat. In addition, chickpea variety Swarna Lakshami (DBGC-3) was developed with a yield potential of 1.7 t/ha and protein content exceeding 20%, suitable for cultivation in Uttar Pradesh, Bihar, Jharkhand, West Bengal, and Assam. In addition, two bakla (broad bean) varieties-Swarna Gaurav and Swarna Suraksha and one makhana variety, Swarna Vaidehi, have also been developed.
- **Plant Growth-Promoting Microbial Technology Based on Beneficial Bacteria**: Whole-genome analysis of S10P2 (*Pseudomonas anuradhapurensis*) and B14P1 (*Enterobacter hormaechei*) revealed key genetic traits associated with plant growth promotion, abiotic stress tolerance, and bioremediation. The identified functional attributes indicate their potential as next-generation microbial resources for enhancing crop productivity, improving resilience to environmental stresses, and supporting sustainable agricultural and environmental management practices.
- **Sowing-Time Based Management Technology for False Smut in Rice**: A climate-smart crop management technology was developed for minimizing false smut incidence in rice. Evaluation of six rice genotypes under six sowing dates showed that disease severity was higher in late-sown crops, particularly in Moudhamini and Swarna Samridhi. Timely sowing reduced disease incidence by ensuring flowering under minimum temperatures above 25°C, while lower temperatures combined with high relative humidity favored disease development. The technology recommends early sowing as an effective and economical strategy to reduce false smut severity and improve rice productivity.
- **Phyllody Disease Detection Technology**: A molecular diagnostic technology was developed for the characterization and identification of phytoplasma associated with phyllody disease in chickpea

and lentil in eastern India. Through molecular analysis, the causal organism was identified as Candidatus Phytoplasma asteris-related strain (16SrI-B). The study also established periwinkle as an important offseason reservoir host, contributing to the survival and spread of the pathogen. This technology provides a reliable tool for early diagnosis, disease surveillance, epidemiological studies, and the development of effective disease management strategies in pulse crops.

- **Climate-Resilient Digital Weather Advisory Technology (WAAS Framework)**
  A climate-resilient digital advisory framework was developed and implemented across Patna and Buxar districts of Bihar to strengthen weather-based agricultural decision support. The system involved diagnosis of key farmer needs, deployment of local "Mausam Mitras," and dissemination of vernacular advisory literature. Bi-directional WhatsApp groups enabled real-time interaction between farmers and a multidisciplinary expert team, providing field-specific advisories based on IMD Patna weather forecasts.
- **Coalmine Affected Area Ecological Rehabilitation:** Designed and established a sustainable Agri-Horti-Silvi-Pastural agroforestry rehabilitation model on highly degraded, acidic soils within the Phusri coal mine-affected area (Mandu, Ramgarh). The model integrates vital fruit species (*Guava, Lemon, Mango, Pomegranate, Bael, Jackfruit*) and multipurpose trees (*Bakain, Bael, Teak, Mahogany, Arjun, Shisam, Bamboo, Tephrosia*) supported by water harvesting systems like *doba*, full/half-moon terraces, and contour trenches, achieving an annual carbon sequestration of 0.27 Mg C/ha, a green biomass yield of 6.28 q/ha/year, an annual net income of ₹68,000/ha, and increasing domestic fruit and vegetable consumption by 58.30%.
- **Basin Enrichment:** Standardized a high-efficiency basin enrichment technology utilizing *Tephrosia candida* (Bhoomi Sudha) biomass mulching as an alley crop. Due to a rapid decomposition half-life of <6 months and steady nutrient release, this practice significantly improves soil health indices (SMBC, total organic carbon, DHA) and boosts leaf nitrogen, phosphorus, and zinc concentrations, translating into a 40.25% increase in commercial fruit yields for mango and guava orchards. The technology has been certified by ICAR and officially adopted for state-wide scaling by the Government of Jharkhand under the Birsa Munda Bagwani Yojana (MGNREGA).
- **Evaluation of natural Farming:** Three years results (2022-25) on Natural farming in Rice-wheat-mung bean system in Patna indicated that rice & wheat productivity under NF were 25-30 & 30-35% less than conventional farming. Whereas, summer mungbean productivity was the highest under NF. While, Rice & wheat crop lodged under conventional system during heavy wind/off-season rain, the rice crop under NF was not affected. Further, the rice productivity (4.3t/ha) under NF in 3rd year was ~ 12% higher compared to its first year (3.8 t/ha). In addition, soil organic carbon (SOC) content was marginally higher under NF (0.60%) compared to CF (0.58%), reflecting gradual improvement in soil health. Further, evaluation of 60 rice and 27 wheat genotypes during 2023-25 (2 years) under NF indicated yield range of 1.76 to 4.31 t/ha & 1.35 to 3.19 t/ha, respectively.

- **Impact of elevated temperature on crop yields:** A climate change study in Bihar projects temperature increases of 0.68–0.79°C by 2030 and 1.59–2.21°C by 2050 under RCP4.5 and RCP8.5, which could cause rice yields in Patna to decline 5.5–14.4% and wheat up to 28.2% by 2050, while potato yields may decline moderately in Patna and Samastipur, with minimal impact in Sabour.
- **Nano-fertilizer:** Field evaluation in rice and wheat demonstrated that 50% conventional DAP combined with seed treatment using nano-DAP (5 ml kg^{-1} seed) and two foliar sprays of nano-DAP (4 ml L^{-1}), or 75% conventional DAP with nano-DAP seed treatment and one foliar spray, maintained grain yields at par with 100% RDF. These results highlight the potential of nano-fertilizers to reduce fertilizer use, improve nutrient-use efficiency, lower input costs, and support sustainable nutrient management.
- **Designed integrated Micro (250m^2) and Nano (150m^2) farming models** An integrated farming model comprising horticulture, nutrigardens, fodder production, backyard poultry, goat rearing, mushroom cultivation, and organic waste recycling was developed to enhance productivity and sustainability of smallholder farms. The model generated annual net returns of Rs. 45,466 and Rs. 19,150, respectively.
- **Seed Production Programme:** The institute undertakes seed and planting material production, annually generating over 40–50 tonnes of quality seed of rice, wheat, and pulses.

Horticulture Research

- **Genetic Resource Expansion & Germplasm Collection:** Expanded institutional genetic resources by collecting, multiplying, characterizing, and establishing 256 diverse wild edible and tuber crop germplasms within the field gene bank. The current field collection spans *Dioscorea spp. (56), Ipomoea batatas (12), Maranta arundinacea (3), Colocasia spp. (112), Amorphophallus spp. (47), Alocasia spp. (7), Manihot spp. (7), Xanthosoma spp. (5) and Cucumis melo var. agrestis (7)* across surveys in Jharkhand, Chhattisgarh, Nagaland, Odisha, and West Bengal.
- **Insect Molecular Characterization & Genomics:** Achieved the molecular characterization of the mango hopper (*Amritodus atkinsoni*) based on mitochondrial cytochrome oxidase I (COXI), securing formal NCBI GenBank accession numbers KC513458 to KC513474.
- **Mango Canopy Management Agro-techniques:** Standardized an effective canopy architectural layout shifting to the center opening of mango trees in the month of August to significantly minimize regional mango hopper infestations.
- **Pest Resistance Breeding Screening:** Screened 100 mango genotypes and successfully identified four specific varieties (*Mulgoa Hill, Himayuddin, Sammar Bahist Chausa*, and *Lat Sinduria*) with proven resistance to shoot gall psylla.

- **RGB Imaging and Machine Learning-Based Technology for Rapid Assessment of Yellow Mosaic Disease:** A high-throughput phenotyping technology was developed using RGB imaging and machine learning for rapid assessment of yellow mosaic disease (YMD) severity in yard-long

bean. Field evaluation of 143 genotypes revealed that 34 out of 45 RGB image indices were significantly associated with disease severity. Among these, RCC and ExR exhibited the strongest positive correlations (r = 0.87), while GRD showed the highest negative correlation (r = -0.88). Advanced machine learning algorithms, including Random Forest (RF), Cubist, XGBoost, KNN, and GBM, demonstrated high predictive accuracy ($R^2 > 0.88$) in validation datasets.

- **Precision Fertigation & Field Geometry Protocols:** Developed growth-stage-linked precision fertigation patterns and field geometry protocols for vegetables, achieving a peak tomato yield of 983.4 q/ha with a water use efficiency of 41.3 kg/m³ under optimized configurations. Established the superiority of the ridge-and-furrow planting method combined with plastic mulch for cauliflower, raising seasonal yields to 35.79 t/ha.
- **Post-Harvest Food Processing & Value Addition:** Standardized commercial-grade post-harvest processing, dehydration, and preservation protocols for regional crops. This includes an off-season culinary protocol for matured whole drumstick pods (hot water blanching followed by 55–60°C drying) alongside value-added jackfruit processes for products like Osmo-Dried Jackfruit Bulbs.
- **Horticultural Seed Priming Technologies:** Standardized specialized on-farm seed priming protocols for solanaceous and cucurbitaceous vegetables. Pre-soaking *Swarna Yamini* bitter gourd seeds with 500 ppm Ethrel or 1% KNO3 for 18 hours at 25–30°C successfully breaks seed dormancy and drives field emergence up to 93.8%.
- **Peach Fruit Fly Reference Genomics:** Sequenced and mapped the complete 15,935 bp circular mitochondrial genome of the peach fruit fly (*Bactrocera zonata*) to establish foundational molecular genetic markers for regional population genetics and stress resilience monitoring.
- **Tomato Hybrid Seed Production Economics:** Validated the commercial micro-economics of hybrid tomato seed production at the progressive farm level, documenting high-remunerative seed yields (up to 190 kg/ha), peak net incomes of ₹12.3 lakh/ha, and an optimal benefit-cost ratio of 2.36.
- **Plant Growth Regulator Crop Priming:** Documented significant field yield advancements in marketable solanaceous crops by combining seed priming with GA_3 (200 ppm) and Ethrel (200 ppm), boosting peak yields to 45.2 t/ha and 44.1 t/ha respectively, against 38.9 t/ha for untreated seeds.
- **Crop Residue Field Decomposition Baselines:** Established standard residue decay kinetics and tissue half-lives using the litter-bag technique, mapping total dry-matter loss timelines for surface-placed straw (complete decomposition in 9 months for maize and 10 months for paddy) and subsurface roots.
- **Consolidated Multi-Tier Cropping Systems:** Standardized long-term multi-tier canopy systems to maximize land productivity, nutritional security, and climate resilience. This includes an Agroforestry-Based Multi-Tier System that combines top-story Timber (*Mahogany* at 10 x 20 m), middle-story Fruit (*Mango cv. Amrapali* at 10x 20 m), filler crops (*Pomegranate cv. Bhagwa, Peach cv. Florda Prince*, or *Aonla cv. NA-7* at 5x10 m), and annual crops (*Rice, Finger Millet,*

Niger) to provide a mahogany timber girth annual increment of 47.32%, a system REY 225% higher than conventional monocropping, and a net income of ₹1.0 lakh/ha after the 8th year.

- **Fruit Based Multi-Tier Cropping System:** A Fruit-Based Multi-Tier System where main fruit trees (*Mango, Litchi*, or *Aonla* at 10x10 m, 100 plants/ha) are intercropped with fillers (*Guava, Lemon*, or *Custard Apple* at 5x5 m, 300 plants/ha) and annuals, generating a cumulative initial 10-year net profit of ₹6.4 lakh for mango systems (₹1.90 lakh/ha annually after the 10^{th} year) and ₹8.8 lakh for litchi systems (₹2.90 lakh/ha annually after the 10th year), which has been adopted under the Birsa Harit Gram Yojana (MGNREGA) to reach 1.67 lakh families across 1.45 lakh acres.
- **Fruit Tree Carbon Sequestration Profiling:** Quantified the long-term carbon sequestration and biomass loading profiles of major regional fruit species planted at a standard 5x 5 m spacing (400 trees/ha), establishing that total dry biomass scales up to 10.5 Mg/ha for a 10-year-old mango system and up to 13.36 Mg/ha for a companion guava system.
- **Environment-Safe Orchard Spray Modules:** Developed eco-friendly, pollinator-safe chemical spray modules for litchi orchards. The protocols standardize effective insecticidal molecules against sucking pests-such as ***Fertigation Patterns*** *50% EC* (1.5 ml/L) + *Thiacloprid 21.7% SC* (0.5 ml/L) or *Imidacloprid 17.8% SL* (0.3 ml/L)-and seed/fruit borers-utilizing *Flubendiamide 39.35 SC* (0.3 ml/L) or *Emamectin benzoate 5 SG* (0.5 g/L)-timed precisely around pollinator dynamics to shield insect populations.
- **Vegetable Soybean Variety:** Developed *Swarna Vasundhara*, an elite rust-resistant vegetable soybean variety tailored for processing and recommended for Jharkhand and Bihar. It achieves a fresh pod yield of 15–20 t/ha, a 50% to 55% recovery rate of shelled bright green beans, a maturity window of 75–80 days, and a net income of ₹2.7 lakh/ha. Standardized value-added community processing pathways for soy derivative foods like tofu retailed at ₹300/kg, soy curd, chhena, gulab jamun, and ice cream, scaling the variety's adoption across 17 states.
- **State Variety Release Committee Notifications (2026):** Eight high-yielding crop varieties developed by the center were officially identified for state-wide release and notification by the State Variety Release Committee in May 2026, expanding the institutional portfolio with seven specialized vegetable selections: *Swarna Ratan* cherry tomato (42.1 t/ha), *Swarna Praphulya* wilt-resistant chilli (20.7 t/ha), *Swarna Atulya* yellow-maturing capsicum (42.5 t/ha), *Swarna Yamini* early bitter gourd (20.2 t/ha), *Swarna Nidhi* off-season dolichos bean (18.75 t/ha), *Swarna Sugandha* aromatic vegetable soybean (13.32 t/ha), and *Swarna Suparna* multicut green amaranth (20.92 t/ha). Further, *Swarna Vishist,* an early-maturing bush-type lablab bean variety, was developed for Bihar, exhibiting 17–18 t/ha yield potential, 11.76% higher yield than 'Arka Sambhram', along with 23.74% protein, 460 mg/100 g phosphorus content, and a dwarf, non-staking growth habit. Three fruit varieties Litchi-*Swarna Madhu,* Bael-*Swarna Vasudha and* Mulberry-*Swarna Rasrani*
- **Landscape-Scale Technology Adoption Impact:** Achieved massive regional landscape impact by embedding institute mango-based technology interventions across 1.5 lakh hectares via corporate

integration with MGNREGA, while completing 26 intensive capacity-building mushroom modules to train 1,240 rural farmers over the last 5 years.

Intellectual Property & Brand Asset Protection: Filed for formal intellectual property brand protection with the Controller General of Patents, Designs and Trade Marks, securing the official federal trademark for the institute's primary high-performing seed and variety line name: **'SWARNA'**.

Land and Water Management

- **Consolidated Drip Irrigation & Water Management:** Engineered high-efficiency plastic-mulched raised bed production protocols paired with drip irrigation, driving chickpea seed yields up to 2.5 t/ha, and standardized a growth-stage-linked Modified Drip Fertigation Framework (DIM) with bicolor polythene mulch for commercial vegetable cultivation. Under optimized patterns, the framework significantly improved nutrient use efficiency from 30% to 85%, generating a net profit of ₹2.5–3.0 lakh/acre and delivering peak rabi yields of 80.9 t/ha for tomato, 14.4 t/ha for chilli, and 31.3 t/ha for broccoli, outperforming conventional furrow irrigation methods by up to 111%.
- **Solar-Powered Irrigation Command Architecture:** Standardized a collective resource management and engineering framework using 3hp solar irrigation pumps across smallholder farming groups, expanding the irrigated command area to 1.0–1.5 ha per unit and successfully boosting regional cropping intensity from 120% to 250%.
- **A water-smart farming model:** A water-smart farming model combining raised–sunken bed (RSB)-based diversified cropping, aquaculture, horticulture, and poultry substantially enhanced water productivity, land productivity, and overall system resilience. The modified RSB-based diversified cropping system enhanced land productivity of approximately 195–233 q ha^{-1} and water productivity of 11.0–14.4 kg m^{-3}, representing 3.5–4.5-fold and 20–25-fold improvements over rice monocropping, respectively, and 2–2.5-fold and 9–12-fold gains over the conventional rice–wheat system. Integrated aquaculture further strengthened system performance, producing 0.84 kg m^{-2} of fish with a fish water productivity of 0.56 kg m^{-3}, while composite fish culture demonstrated species-specific growth, with grass carp attaining the highest weight. The pond-integrated poultry component also improved productivity, with ducks exhibiting higher body weight (up to 1.3 kg) and enhanced egg production compared with conventional rearing. Overall, the integration of complementary enterprises optimized resource use, increased productivity per unit of water, and promoted climate-resilient and sustainable farming.
- **Lysimeter Technology Development:** Indigenously designed and built a low-cost, non-weighing sub-surface lysimeter technology to replace expensive commercial alternatives (~₹10 lakh) with an affordable unit costing just ₹10,000. Sized at 4 × 3 × 1 m and lined with 500-micron black polythene, it enables precise regional leaching water-nutrient balance studies,

quantifying applied fertilizer leaching losses under standard practices (ranging up to 24.4% N and 25.1% K in paddy) and validating that Integrated Nutrient Management (INM) practices (50% inorganic + 50% organic) save 4% to 10% of applied N and K across major field crops.

- **Irrigation Water Pricing:** Studies conducted at the Nalanda Corridor Project site and the Paliganj distributary aimed to determine the cost of irrigation water for various crops, including rice, wheat, and moong. The research used the Residual Value Method to estimate water prices, providing critical economic data for irrigation management. For the Nalanda Corridor, the estimated irrigation water prices were ₹12.96/m³ for rice, ₹29.59/m³ for wheat, and ₹9.02/m³ for moong. In contrast, prices in the Paliganj distributary ranged from ₹4.73/m³ to ₹6.24/m³ for rice and wheat, depending on water applied. These findings are essential for developing water pricing policies and improving water-use efficiency in irrigation systems.
- **GIS-based Water Harvesting Planning Framework:** A GIS-based Water Harvesting Planning Framework was developed for Nalanda district, Bihar, by integrating Remote Sensing (RS), GIS, and multivariate decision-making techniques. Watershed prioritization using the Weighted Sum Approach identified about 56.3% of the area as very high priority and 30.5% as moderate priority for water harvesting interventions. Based on the analysis, suitable structures such as farm ponds, check dams, tanks, ahar-pyne systems, bunding, and conservation ditches were recommended. The framework supports groundwater recharge, runoff reduction, and efficient water conservation planning. It serves as a robust decision-support tool for policymakers and watershed managers for sustainable water resource management
- **Drought Susceptibility Assessment Framework**: A Conceptual Framework for Identifying Drought-Susceptible Zones was developed for the Sakri River Basin to support drought monitoring, early warning, and climate-resilient resource management. The framework integrates long-term hydro-meteorological analysis, drought indices (SPI, SPEI, and EDI), and geomorphometric watershed prioritization. Analysis of 30 years of climate data revealed monsoon-dominated rainfall and rising temperatures, indicating increased agricultural drought risk. Assessment of eleven sub-watersheds identified 46.82–56.56% of the basin as highly vulnerable to drought and erosion. The framework provides a scientific basis for watershed prioritization, irrigation planning, climate adaptation, and sustainable resource management in Eastern India.
- **Machine learning module for ET:** A comprehensive database on actual crop evapotranspiration (AETc), water balance, and crop coefficients (Kc) for transplanted puddled rice was developed using a low-cost non-weighing paddy lysimeter in the Middle Indo-Gangetic Plains. The estimated Kc values closely matched FAO recommendations, while water balance analysis identified percolation and evapotranspiration as the major water loss components. Among six machine learning models evaluated for AETc prediction, the ANN model showed the highest accuracy (R^2 = 0.99), demonstrating that integrating low-cost lysimeter data with machine learning offers a reliable, cost-effective, and scalable approach for real-time evapotranspiration estimation and precision irrigation scheduling.

- **Solar-Powered Farm Mechanization Inventions:** Designed, fabricated, and filed official patents with the Indian Patent Office (IPO) for two novel, solar-assisted hardware solutions built for remote, off-grid regions:
  i. Solar operated hold-on type paddy thresher powered by a 975 Wp panel array with an operating capacity of 85–90 kg/hr, delivering a 98.0% threshing efficiency and 98.5% cleaning efficiency using 2 operators (Patent Application: 202311038252),
  ii. Hybrid Solar Light-Pheromone Trap which is a lightweight, portable crop protection trap fitted with a 30W (12V) solar panel, 12V (15 Ah) battery, and automatic dusk-to-dawn trip sensors running a daily 8-hour cycle (Patent Application: 202311034975).
- **Solar Water Pumping Sizing Software:**
  i. Designed and developed standalone decision-support computer software applications to ensure precision optimization of solar pump installations. This features the Solar Irrigation Pump Sizing (SIPS) Tool engineered to prevent negligent under sizing and capital-wasteful oversizing by mapping cropping patterns, water sources, irrigation methods, and local topography (officially integrated into the Ministry of New and Renewable Energy's PM-KUSUM Component-B scheme)
  ii. Solar Water Pumping V1.0 tool developed with dual-language support (English & Nepali) to provide full Bill of Quantities (BoQ) and hardware sizing reports (formally adopted by the Alternative Energy Promotion Centre, AEPC, Government of Nepal, for its nationwide pumping programs).
- **Micro-Scale Rainwater Harvesting Infrastructure:** Developed a low-cost rainwater harvesting technology utilizing plastic-lined *doba* structures to overcome dry-season restrictions in hill and plateau regions. Sized at 3x 1.5x 1.0 m with a holding capacity of 4,500 liters, a single unit built for ₹1,800 retains harvested water until mid-June to supply critical life-saving irrigation to 10 establishing orchard trees, with over 2,000 units demonstrated across Jharkhand, leading to its formal adoption in NABARD's flagship multi-state 'wadi' project.
- **Predictive Forestry Biomass Mathematical Modeling:** Successfully fitted and validated a 10-parameter predictive Richard's Model (R^2 up to 0.973) using tree collar diameter as an independent variable to mathematically map and estimate above- and below-ground carbon sequestration dynamics in *Litchi chinensis* plantations across a 2-to-10-year age gradient.
- **Land Reclamation through Agroforestry Technology:** A resilient agroforestry technology was developed for sustainable utilization of waterlogged areas through the establishment of a multi-species tree-based system comprising Arjun, Mahogany, Kadamb, and Jamun. Performance evaluation identified Kadamb as the most suitable species, exhibiting superior growth (4.2 m height and 9.6 cm collar diameter) and the highest carbon sequestration potential (0.71 t ha^{-1} yr^{-1}) within two years. The system also supported productive intercropping with lentil (9.2 q/ha), moong (8.5 q/ha), and paddy (37.5 q/ha), demonstrating minimal tree-crop competition during the establishment phase.

- **Peripatetic fish vending cart**: An innovative solar-powered mobile fish vending unit designed to enhance mobility, hygiene, storage, and marketing efficiency. It features a 250-L live fish tank with solar aeration, a 100-L insulated storage box for frozen fish, a hygienic cutting platform, tool storage, and waste disposal units. The cart improves market access, expands customer reach, and increases income opportunities for fish vendors. Suitable for coastal and inland fish-producing regions, it offers strong commercialization potential for fish vendors, farmer groups, NGOs, and development agencies.
- **Eco-Friendly Plantable Seedling Pot:** A biodegradable and sustainable alternative to plastic nursery pots, developed from rice straw, natural binders, and water. The pot decomposes within 3–5 months after planting, enriches the soil, reduces transplant shock, and promotes healthy root growth through improved aeration and drainage. It offers an eco-friendly solution to plastic pollution and crop residue burning, with strong commercialization potential for nurseries, agri-entrepreneurs, and agro-based industries across India.
- **Farm Machinery Hiring Calculator:** The web-based application developed is a digital decision-support tool designed to help farmers estimate optimal rental charges for agricultural machinery. This user-friendly tool supports transparent and economically viable farm machinery hiring, benefiting both machinery owners and users. It promotes efficient machinery utilization, improves access to farm mechanization services, and helps reduce operational costs for small and marginal farmers. The technology has strong potential for adoption by custom hiring centres, farmer groups, entrepreneurs, and agricultural service providers across India.
- **Solar Photovoltaic System for Groundwater Pumping:** The Solar Photovoltaic System for Groundwater Pumping developed by institute represents the first successful solar-powered groundwater pumping system in Eastern India. The system comprises a 3060 Wp crystalline silicon solar array coupled with a 3 HP submersible pump capable of extracting up to 170 m^3 of groundwater per day under peak solar conditions. Water is stored in a 117 m^3 storage tank and redistributed through a 2 HP DC pump for irrigation purposes. Performance evaluation demonstrated a hydraulic efficiency of 71%, ensuring reliable water supply even during periods of reduced solar radiation. The technology promotes efficient groundwater utilization, reduces dependence on conventional energy sources, enhances irrigation reliability, and supports improved crop productivity and water-use efficiency.
- **Solar Photovoltaic Aerator for Fish Pond:** A spray-type Solar Photovoltaic Aerator was developed and tested by ICAR-RCER to improve dissolved oxygen levels in fish ponds using renewable energy. The system consists of a 900 Wp solar photovoltaic panel and a 1 HP DC surface pump that sprays oxygen-deficient pond water into the atmosphere, facilitating aeration and vertical water mixing. The aerator effectively disrupts thermal stratification and improves oxygen distribution throughout the pond. Field evaluation in a fish pond at Patna showed an increase in dissolved oxygen levels by 20–22% at 0.5 m depth and 40–50% at 1.0 m depth compared to untreated ponds. The technology offers an environmentally friendly and cost-effective solution for improving water quality, fish health, and aquaculture productivity.

- **Solar Photovoltaic System for Animal Shed Cleaning:** A Solar Photovoltaic Watering System was designed and installed for animal shed cleaning and water supply in livestock units. The system utilizes a 900 Wp solar panel connected to a 1 HP DC motor pump that lifts water from a nearby pond and supplies it to animal sheds within a radius of approximately 50 m. Operating between 8:00 AM and 2:30 PM, the system delivers water at a discharge rate of 5,000–6,000 liters per hour while maintaining adequate pressure. By utilizing renewable energy resources, the system reduces operational costs and provides a reliable source of water for livestock management, sanitation, and cleaning operations, thereby improving hygiene and overall farm management efficiency.
- **Solar Submersible Pumps in Eastern India:** A extensive studies to quantify the groundwater abstraction capacity of solar submersible pumps ranging from 1 HP to 3 HP under Eastern Indian conditions. These pumps were found particularly suitable for small and marginal farmers with operational holdings of up to 2 hectares and groundwater depths generally less than 10 m. The study demonstrated that solar tracking systems increased water extraction by 19–23% compared to fixed solar arrays. The technology facilitates sustainable irrigation, reduces dependence on diesel and grid electricity, and encourages farmers to diversify towards high-value crops such as vegetables and fruits. The findings provide valuable guidance for the wider adoption of solar irrigation technologies in the region.
- **Manual Mechanical Weeder for Row Crops:** A novel manual mechanical weeder was designed and developed specifically for small and marginal farmers based on the anthropometric characteristics of agricultural workers in Eastern India. The implement provides an affordable and efficient alternative to traditional hand weeding methods. Field evaluation in maize demonstrated a weeding efficiency of approximately 85% with a field capacity of 0.012 ha h^{-1}. The equipment reduces labor drudgery, improves operational efficiency, and lowers weeding costs. With an estimated manufacturing cost of ₹1,200–1,400, the weeder offers considerable potential for local production and widespread adoption among resource-poor farmers.
- **Hand-Operated Makhana Grader:** A hand-operated Makhana Grader was developed to improve the efficiency and uniformity of makhana seed grading. The machine consists of a circular grading drum fitted with cylindrical bars and is capable of sorting makhana seeds into five standard size categories: 14 mm, 12 mm, 9 mm, 7 mm, and below 7 mm diameter. The grader achieves an output capacity of 550–600 kg per hour, significantly reducing labor requirements and improving grading accuracy compared to manual methods. This technology supports value addition, quality improvement, and market competitiveness in the makhana industry, particularly in Bihar where makhana cultivation is a major livelihood activity.
- **Stirrup Hoe:** The Stirrup Hoe was designed and fabricated as a low-cost implement for intercultural operations and weed management. The tool consists of a spring steel blade, a mild steel housing frame, and an MS hollow pipe handle. Designed for operation in a standing posture using a push-pull action, it minimizes worker fatigue and allows faster field operations compared to traditional khurpi-based weeding. The stirrup hoe has a field capacity of 0.0182 ha h^{-1} and can be

manufactured at a cost of approximately ₹800. Its ergonomic design, affordability, and operational efficiency make it a suitable mechanization option for smallholder farmers seeking labor-saving technologies for weed control.

- **Modified Non-weighing Paddy Lysimeter** was developed as a low-cost alternative to conventional weighing lysimeters and eddy covariance systems for estimating crop evapotranspiration (ETc), crop coefficient (K_c), and soil water balance in transplanted rice. The system comprises three cylindrical drums to measure evapotranspiration, percolation, and runoff losses under field conditions. It is easy to install, requires minimal manpower, and is well suited for data-scarce and resource-limited regions. The estimated stage-wise Kc values closely matched FAO recommendations, with deviations of less than 5%. The technology provides a reliable and affordable tool for irrigation planning, crop water requirement assessment, and water resource management in rice-growing areas.
- **Establishment of Farm Machinery Resource Centre at ICAR RCER, Patna**
  The Farm Machinery Resource Center (FMRC) was established at ICAR Patna and inaugurated on June 28, 2016, by the Hon'ble Union Minister of Agriculture, Shri Radha Mohan Singh (Fig. 27). The FMRC aims to enhance agricultural productivity and sustainability by promoting farm machinery development. Its primary focus is providing support, training, research, and resources to improve farming efficiency and operations.
- **Precision Agri-Drone Spraying Demonstrations:** Standardized and executed a high-tech drone application framework under the Agri-Drone project, completing 259 precision agro-chemical fluid demonstrations over 23 villages across 10 districts in Jharkhand and Chhattisgarh, directly benefiting 259 families and holding mass awareness programs for over 2,300 farmers.

Livestock and Fishery Management

- **Registration of six indigenous livestock and poultry germplasms** (Purnea Cattle, Maithili Duck, Jharkhandi Cattle, Palamu Goat, Kodo Duck, and Mala Chicken) contributed to the conservation, characterization, and documentation of animal genetic resources. Several additional germplasms are currently under evaluation for registration.
- **Generated complete mitochondrial genome maps of seven duck germplasms of eastern India** and deposited them in NCBI, providing valuable genetic resources for phylogenetic studies, conservation, and scientific breeding programmes.
- **Under the ICAR-AICRP on Goat Improvement, five Black Bengal goat clusters were established in Bihar**, resulting in the registration of 31,678 goats belonging to 2,044 farmers since 2018. A total of 7,377 non-descript goats were upgraded using superior Black Bengal bucks, while 9,560 goats were vaccinated, 11,558 treated/dewormed, and 686 farmers were trained in scientific goat farming.
- **Investigated genetic and non-genetic determinants of prolificacy in goats**, identifying parity, body weight, and photoperiodic buck effect as important factors associated with higher litter size. The study documented high prolificacy in Black Bengal goats, standardized transvaginal Doppler

ultrasonography for reproductive monitoring, and established vaginal microbiota profiling protocols with 11 bacterial isolates deposited in NCBI.

- **Deficiencies of major and trace minerals in soil, water, feed, fodder, and animal serum** were identified as key factors affecting productivity and reproductive performance in cattle. Based on surveys across 18 districts of Bihar and Jharkhand, an Area-Specific Mineral Mixture ('Swarna Min') was developed, which increased milk yield by 14.1–20%.
- **Standardized a round-the-year fodder production system** using annual cereal and legume fodders, producing about 49 t/ha of quality green fodder sufficient to meet the feeding requirements of 16 adult cattle for 150 days.
- **Assessed the potential of diara land farming for sustainable food production** in the Ganga and Gandak river basins of Bihar and characterized weed diversity, identifying Kush grass, *Cynodon*, and *Fimbristylis aestivalis* as dominant species.
- **Indigenous Livestock Characterization:** Completed comprehensive phenotypic characterization and established formal breed descriptors for regional poultry lines (Mala, Rangawa, and Charka), alongside securing NBAGR registrations for hardy regional livestock lines including Medini cattle (characterized as an elite draught animal working 7–8 hours/day), Palamu goats (hardy grazing lines), Mala chickens, and Kodo ducks.
- **Alternative Livestock Feed Formulations:** Developed low-cost alternative livestock rations by substituting traditional maize feed with boiled sweet potatoes up to 60% in crossbred (T x D) pig diets to optimize daily weight gains (up to 65.2 kg). Standardized a livestock management best practice by supplementing piglet feed with 15% spent-mahua (*Madhuca longifolia*) waste, significantly improving dry matter consumption, body weight, and body size.
- **Investigated livestock diseases and developed diagnostic capabilities**, including estimation of tick-borne disease prevalence (34.25%), standardization of diagnostic methods for major infectious agents, processing of over 600 biological samples, and treatment/vaccination support for approximately 7,000 animals.
- **Characterized the prevalence, phylogenetic diversity, and antimicrobial resistance profiles of bacterial isolates** from livestock and poultry, identifying multidrug-resistant and ESBL-producing *E. coli* carrying multiple antimicrobial resistance genes.
- **Established a biofloc-based seed rearing system for** *Pangasianodon hypophthalmus*, achieving the highest biomass production (24.82 kg) at a stocking density of 250 fry/m^3. Fish reared in the biofloc system exhibited improved haemoglobin (Hb) and red blood cell (RBC) levels, indicating better health status. Mineral analysis showed higher concentrations of iron (Fe), zinc (Zn), and copper (Cu) in biofloc-reared fish compared to those raised under natural conditions at similar stocking densities. The study demonstrated that biofloc technology is an efficient and sustainable approach for raising Pangasius seeds and producing quality fingerlings.
- **Screened fish samples from 90 fish farms and 54 hatcheries across Bihar for KHV and SVCV**, with no positive cases detected, and conducted fish disease management awareness programmes benefiting 556 farmers and entrepreneurs.

- **Developed fish-based integrated farming models:** Developed and replicated 06 numbers of fish-based integrated farming models (cattle-fish, buffalo-fish, goat-fish, poultry–fish, pig-fish, and duck-fish integration) for water surplus ecologies of Eastern India. The highest fish production was achieved with cattle-fish integration (4.50 t/ha) followed by pig-fish integration (3.60 t/ha) whereas production from traditional practice (<1.0t/ ha) is very less.
- **Standardized induced breeding protocols** for Magur, *Labeo gonius*, *Labeo bata*, and Kawai, enhancing fish productivity and seed production in water-surplus ecologies of Eastern India.
- **Breeding techniques for magur, *Labeo gonius*, *Labeo bata*, and Kawai** were standardized. WOVA-FH hormone can be used for induced magur (1.0 ml / kg of body weight in female) and *Labeo gonius* (@ 0.6-0.8 ml/ kg body weight, for females) with better fertilization and survival rate. Breeding of Bata can be induced breed using Ovaprim® @ 0.3ml for female
- **Conducted environmental and One Health studies**, including assessment of microplastic pollution in the Ganga, Sone, and Punpun rivers and evaluation of arsenic and fluoride contamination in groundwater, feed, fodder, and animal samples from Bihar.
- **Developed makhana cultivation technology and a makhana-based integrated farming system**, increasing net income by ₹15,930 and ₹35,560 per acre, respectively, over traditional practices.

Socio Economics and Extension

- **FPO-based technology delivery model**: Developed and validated an FPO-based technology delivery and institutional extension model**,** which significantly improved technology adoption, collective marketing, and farmer bargaining power. The impact study revealed the model itself has impacted 18–27% enhancement in farm income, improved access to quality inputs, advisory services, and market linkages, increased institutional participation and entrepreneurial orientation among smallholders.
- **Climate Resilient Model Villages developed:** Under the Climate Resilient Agriculture initiative, the institute successfully developed 10 Climate Resilient Model Villages in vulnerable agro-ecological regions. More than 1000 farmers adopted climate-smart agricultural technologies**,** including resilient cropping systems, integrated farming approaches, water conservation, and weather-based advisories. ystem productivity increased from 85 q/ha to 122 q/ha.
- **Makhana Value Chain Analysis in Bihar**: Conducted a comprehensive Makhana Value Chain Analysis in Bihar**,** identifying critical bottlenecks in production, processing, marketing, and export competitiveness.
- **Policy framework for flood-prone areas**: A pioneering policy-oriented framework developed for the identification of flood-prone regions as potential Fruit Hubs in Bihar**.**
- **Nutri-garden model**: Developed a Nutri-garden model to address anemia and hypovitaminosis in eastern India, providing substantial proportions of ICMR-RDA including Iron (60.7%), Calcium (52.2%), and Vitamin A & C (100%). Riboflavin: 41.6%.
- **Voluntary Carbon Credits (VCC) for Smallholder Agriculture:** A farmer segmentation framework was developed to design farmer-centric VCC programs for smallholders. The study

identified three adoption segments with distinct preferences for incentives, training, and mechanisation support. Training and technical assistance were the most valued features, while delayed payments were consistently rejected due to liquidity constraints. The framework provides actionable guidance for implementing India's Indian Carbon Market (ICM) and offers a replicable model for designing VCC programs to enhance smallholder participation across diverse regions.

- **Climate Resilient Agriculture Program (CRAP) with Govt of Bihar:** Drought, heat stress, flood, fertility depletion, low water use efficiency, low income of small and marginal farmers etc are major challenges in eastern India. To address these issues ICAR-RCER, Patna implemented Climate Resilient Agriculture Programme funded by the Government of Bihar in Gaya and Buxar districts since Rabi 2019-2026. Five villages have been adopted in each district in Gaya and Buxar. Under the program climate resilient technologies like direct seeded rice, multiple stress tolerant rice varieties, laser land levelling, zero tillage in rabi crops (wheat, lentil, chickpea), raised bed production of maize and potato, crop diversification with millets, the introduction of mungbean in rice-wheat cropping system, intercropping of maize and potato, integrated nutrient management etc were conducted at the farmer's field. Annually, 2936 acres covering about 3000 farmers were undertaken under the CRAP. Zero tillage production of rabi crops especially wheat is identified as the most accepted CRA intervention with a nearly 100% acceptance rate. The total number of capacity-building events organized was 160 with about 8100 beneficiaries.
- **Participatory Research Application for Year-Round Income and Agricultural Sustainability (PRAYAS): A process model for empowering weaker sections:** The PRAYAS model is a participatory, science-based development framework implemented across 16 villages in seven eastern states—Assam, Bihar, Jharkhand, Odisha, West Bengal, Chhattisgarh, and eastern Uttar Pradesh—to empower SC and ST farmers. It follows a phased approach including baseline assessment, problem prioritization using multi-criteria methods, strategic intervention design integrating traditional knowledge with modern science, collaborative implementation with ICAR institutes, KVKs and NGOs, capacity building, and continuous monitoring. The model focuses on income enhancement, sustainability, and human resource development through climate-resilient technologies, water conservation, skill development, and market linkages. Reaching over 12,000 tribal farmers (2023-25) and 8000 (2025-26), PRAYAS has increased farm income by about 20% while strengthening climate resilience and sustainable livelihoods, and holds strong potential for replication through consultancy-based development projects.
- **Socio-Economic Scaling Methodology:** Developed a multi-dimensional Socio-Economic Status (SES) metric scale using the M-K-J-B-D multidimensional scaling method, condensing 181 initial parameters into 10 key structural factors (including Income, Housing, Health, Occupation, Organizational membership, and Women participation) and 19 sub-items tested across 492 households. Applied across Bihar and Jharkhand, the scale established that the majority of regional farmers belong to the "Lower middle class" score range of 30–47.
- **Farmer Producer Organization (FPO) Inception:** Formulated, registered, and business-strengthened regional FPOs providing strong marketing linkages, highlighted by the Greenery

Agrotech Producer Company Limited (Itki, Ranchi) under NASF, which encompasses over 350 farmers, specializes in advanced vegetable processing/packaging, and generates a commercial turnover exceeding ₹1 crore with nearly 100 employees, supported by the Khunti Krishak and Ramgarh Kisan Producer Companies.

- **Mega Outreach & Technology Deployment Portfolios:** Scaled regional technology deployment via major multi-center outreach channels, benefiting 4,644 families across 5 modules under the Farmer FIRST project (driving base incomes from ₹0.93 lakh/ha up to ₹2.8 lakh/ha in horticulture and identifying mushroom production as the most profitable enterprise), while reaching 556 families under the Tribal Sub Plan (enhancing incomes by ₹1.3 lakh/year and increasing mango productivity by 20% to 35%) and supporting 118 families through dedicated SCSP crop-livestock-mushroom interventions.
- **Education**: The institute is also involved in the education mandate in carrying out academic activities of B.Sc., M. Tech, and Ph.D. students as a part of the IARI Mega University under the concept of the Sun-Satellite-Planet model since 2023. Currently, the institute has enrolled students, including 38 B. Sc (Hons.) Agriculture students and 2 M.Tech (SWC&E) and 3 Ph.D. (SWC&E), and 3 Ph.D. (Agronomy).

Implementation of NEH Component: ICAR RCER, Patna

Institute operationalized four-pillar framework: institutional engagement, two-way knowledge exchange, skill development, and demonstrations. A landmark Technology and Knowledge Sharing Workshop at Patna brought together over 100 stakeholders from ICAR-RC NEH, CAU, ATARIs, and KVKs to priorities state-specific technological needs. Capacity-building programmes covered IFS, horticulture skill development, FPO strengthening, and livestock-fish integration training etc. Customised IFS models established in Ri-Bhoi (Meghalaya), Dhalai (Tripura), Longleng (Nagaland), Imphal (Manipur), and Kolasib (Mizoram), generating net profits of ₹1.80–2.87 lakh per hectare. Special programme focusing on tribal women in Tamenglong, Manipur was conducted. Critical inputs, including climate-resilient seeds, ducklings, micronutrients, solar-powered tools, and budding/grafting kits, directly empowered over 750 farmers through 12 initiatives across different states of NEH Region including nearly 2,000 additional stakeholders through indirect knowledge sharing. State-specific interventions included flood-tolerant rice-fish IFS (Assam, Manipur), nutri-gardens (Sikkim, Mizoram, Tripura), and goat-crop models (Meghalaya), with strong emphasis on women's SHGs, FPOs, organic practices, and market linkages.

Viksit Krishi Sankalp Abhiyan (VKSA-2025)

Under the Viksit Krishi Sankalp Abhiyan (VKSA), the ICAR-Research Complex for Eastern Region served as the nodal agency for Bihar and Jharkhand, mobilizing 103 teams in Bihar and 57 in Jharkhand. In collaboration with ICAR-Agricultural Technology Application Research Institute, KVKs, SAUs, and State Departments, the campaign reached nearly 9 lakh farmers. ICAR-RCER alone deployed 32 teams (about 100 scientists/technical staff) who directly interacted with around 2 lakh farmers, addressing field problems, disseminating ICAR technologies, promoting government schemes, and identifying researchable issues. Under the Viksit Bharat Programme (2023–24), 380 villages were covered through KVKs in Buxar (Bihar) and Ramgarh (Jharkhand).

- **Other Significant Achievements:** The Institute developed 25 ICAR-certified technologies, signed 61 technology transfer and commercialization MoUs, created 20 agri-entrepreneurs, and organized numerous capacity development programmes, directly benefiting more than 5 lakh farmers. The MoUs facilitated the commercialization of key technologies, including grafted tomato plants, multi-tier cropping systems for rainfed uplands, mixed para-pheromone fruit fly traps, and standardized planting material production protocols for peach ('Florda Prince'), bael ('Swarna Vasudha'), and litchi ('Swarna Madhu'). Registered and supported 18 active commercial incubates through the center's Agri-Business Incubation Centre, establishing MoAs for ventures including nursery production, mushroom cultivation, ITK based medicinal products, hybrid seed production, polyhouse medicinal plant nurseries, amino acid fertilizers extracted from human hair, and value-added herbal tea blends.

B. Training

Training Details	2014-15	2015-16	2016-17	2017-18	2018-19	2019	2020	2021	2022	2023	2024	2025
<1week	158	69	106	147	133	81	141	157	152	130	252	220
1-2 week	10	14	15	0	8	4	7	8	16	14	6	8
>2week	0	0	1	1	3	1	2	0	6	2	1	0
Total	**168**	**83**	**122**	**148**	**144**	**86**	**150**	**165**	**174**	**146**	**259**	**228**
No. of farmers	4362	2158	3172	3848	3744	2236	3906	4995	5282	4471	7827	8805

C. Research Publications

Publications	2013-14	2014-15	2015-16	2016-17	2017-18	2018-19	2019	2020	2021	2022	2023	2024	2025
Research Papers	84	105	95	128	122	125	92	135	113	118	94	92	114
Books	5	1	5	3	2	5	5	2	2	9	-	2	14
Book Chapter	9	8	13	35	28	40	37	47	26	32	24	13	39
Bulletins	7	8	26	10	2	3	3	14	7	10	2	6	14
Training Manuals	2	3	0	2	1		6	1	0	2	-	-	*
Popular Article	31	28	20	19	33	21	28	82	68	62	53	31	32
Policy Paper	0	1	1	2		1	1	2	-	-	-	-	1

RCER Technologies Certified by ICAR

Certified Technologies in the year 2023-24

1. Solar Irrigation Pump Sizing Tool
2. IFS for different ecologies
3. Multitier cropping system for rain fed uplands
4. Sustainable intensification of rice-wheat cropping system
5. Carbon stock quantification models for important fruit trees
6. Modified drip fertigation technology for vegetable production
7. Design and Development of Solar operated hold on type paddy thresher
8. Seed based technology delivery model through FPO
9. Policy measures for Tenant farmers of Bihar
10. Socioeconomic status scale for farmers of Bihar and Jharkhand
11. Identification of CCL8 and CXCL10 as early pregnancy biomarker in buffaloes
12. Serological diagnosis (Indirect ELISA) of Theileria annulate using recombinant spm2 antigen

Certified Technologies in the year 2024-25

13. Improved agro-techniques for enhancing the productivity of millets in eastern India
14. Innovative millet-based climate-resilient cropping systems for eastern India
15. Technology for sustainable intensification of rice-fallow in Eastern India
16. Climate resilient agriculture practice in rice fallow ecosystems of the East India Plateau
17. Low-cost non-weighing Lysimeter for assessing nutrient leaching loss
18. Modified drip fertigated mulched planting system for commercial cultivation of vegetables in the East India Plateau
19. Agroforestry models for rehabilitation of coal mine affected areas in the Eastern plateau & hill region
20. Tephrosia biomass mulching technology for improving soil health and productivity of a fruit orchard
21. Climate Resilient Model Village Developed at Gaya and Buxar districts of Bihar
22. Strengthening the export potential of farmer producer organizations (FPO) through One District One Product (ODOP): A Conceptual Model
23. Nutrigarden Model Addressing Anemia and Hypovitaminosis Challenges of Eastern India
24. Flood-prone areas identified as fruit hubs in Bihar: A policy framework
25. Model for structural and functional analysis of the Makhana value chain model.