



National Agricultural Science Fund (NASF): Fostering advancement in basic and strategic research in agriculture

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ABSTRACT

The National Agricultural Science Fund (NASF) of the Indian Council of Agricultural Research has played a crucial role in strengthening basic, strategic and translational research in agriculture and allied sectors in India. The scheme supported 282 research projects involving 282 lead centers and 531 cooperating centers across the country with a cumulative funding of ₹688.01 crores. The performance and impact of NASF, analysed using quantitative data on project submissions, approvals, institutional participation, regional distribution, gender representation and research outputs, revealed that NASF-funded projects have generated around 950 publications in peer-reviewed high-impact journals along with several patents and the development and commercialisation of innovative technologies such as diagnostics, vaccines, nano and biotechnological solutions and climate-resilient agricultural interventions. NASF has contributed significantly to advancing scientific excellence, technology development and translational research to strengthen the National Agricultural Research System (NARS). The scheme has fostered multi-institutional and interdisciplinary collaborations to address national priorities and emerging challenges in agriculture. It has substantially enhanced research infrastructure, human resource capacity and scientific collaboration across institutions, to address immediate and long-term agricultural challenges related to productivity, sustainability and climate resilience. NASF fosters high-quality, collaborative agricultural research with significant implications for food security, farmer welfare and science-based policy formulation in India.

Keywords: Agricultural research, ICAR, Innovative technologies, Multi-institutional, National Agricultural Research System

Universities/colleges and research institutes are known to be the driving force of knowledge and creativity. The research and innovations generated by these organisations accelerate scientific vigour through the tangible and intangible assets contributing to country's prosperity. India has about 1,168 universities, 45,473 colleges and 12,002 stand-alone institutes which have been established and managed through the union government, state governments or private organisations (Anonymous 2022).

The Government of India supports scientific research and development through various schemes and programmes. According to the Research and Development (R&D) statistics, the Gross Domestic Expenditure on R&D (GERD) was 0.64% of the GDP during 2022–23. This is notably lower than the R&D spending in many developed nations, where the expenditure typically exceeds 2% of Gross Domestic Product (GDP). The GERD is primarily driven

by government sectors, including the Central Government (43.7%), State Governments (6.7%), Higher Education Institutions (8.8%) and Public Sector Industries (4.4%) with the Private Sector contributing 36.4% during the 2020–21 period (Anonymous 2023). During the year 2020–21, the Defence Research and Development Organisation (DRDO) accounted for the largest share of R&D expenditure of 30.7%, among the 12 major governmental scientific agencies. It was followed by the Department of Space (DOS) with 18.4%, Indian Council of Agricultural Research (ICAR) with 12.4%, Department of Atomic Energy (DAE) with 11.4%, Council of Scientific and Industrial Research (CSIR) with 8.2%, Department of Science and Technology (DST) with 6.8%, Department of Biotechnology (DBT) with 4.4%, Indian Council of Medical Research (ICMR) with 3.1%, Ministry of Electronics and Information Technology (MeitY) with 2.2%, Ministry of Education (MoE) with 1.5%, Ministry of Environment, Forest and Climate Change (MoEFCC) with 0.8%, and Ministry of New and Renewable Energy (MNRE) with 0.1% (Anonymous 2023).

According to the R&D statistics for 2022–23, India is emerging as a prominent player in the global science and

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technology landscape, ranking 3rd in terms of scientific publication output. India's share in global research publications has steadily increased from 3.1% in 2010 to 5.1% in 2020 (Science & Engineering Indicators 2022). During 2022–23, a total of 82,811 patents were filed in India, with Indian residents contributing 43,301 patents (52.29%). India ranked 6th globally in terms of resident patent filings. The Indian Institutes of Technology (IITs) emerged as the leading contributors with 803 patents while the Council of Scientific and Industrial Research (CSIR) ranked 4th with 231 patents in the category of Scientific and Research Organisations (IPI 2023). During this period, ICAR published 5,921 research papers in scientific journals and filed 78 patents and 31 varieties (19 extant and 12 new varieties) reported by the Protection of Plant Varieties and Farmers' Rights Authority (PPV& FRA) (Gerard *et al.* 2021, ICAR 2023).

The Government of India through DST supports fund in many innovative schemes such as Nano Science and Technology (NS&T), National Geospatial Programme (NGP), Cognitive Science Research Initiative (CSRI), Innovation and Technology Development programme through S&T Entrepreneurship Development (S&TED), Technology Development and Transfer (TD&T) etc., Institutional capacity building programme such as Fund for Improvement of Science & Technology Infrastructure (FIST), Promotion of University Research & Scientific Excellence (PURSE), Sophisticated Analytical Instrument Facilities (SAIF) etc., Human capacity building programmes such as Innovation in Science Pursuit for Inspired Research (INSPIRE) Scheme, Women in Science & Engineering (WISE-KIRAN) scheme exclusively for women. etc. (<https://dst.gov.in>, Madhu *et al.* 2015, Agarwal and Kaur 2023). These schemes promote research, technology transfer, encourage public private partnerships and entrepreneurship (Kaur *et al.* 2023). Similarly, DBT implements multiple schemes supporting the research and development in the biotechnology, biowealth, biosafety and related areas (<http://dbtindia.gov.in>).

Reflecting this national-level commitment to R&D expenditure, the agricultural sector also receives focused support to strengthen research, technology development and innovation. ICAR has been at the forefront, developing technologies to enhance agricultural production through varietal improvement, crop protection and horticultural innovations while also focusing on livestock, poultry and fisheries production and health to address national priorities and market demand (Srinivas 2018). ICAR is spearheading with 113 research institutes, 63 SAUs (State Agricultural Universities), 04 Deemed to be Universities, 03 CAUs (Central Agricultural Universities) and 04 Central Universities with agricultural faculty spread across the country, as one of the largest National Agricultural Research and Education Systems (NARES) in the world.

Despite these national-level initiatives, India's Gross Domestic Expenditure on Research and Development (GERD) remains relatively low compared to global

benchmarks. Recognising the need to strengthen research capacity in agriculture to address immediate, long-term and anticipatory agricultural challenges, ICAR established a fund named 'National Fund for Basic, Strategic and Frontier Application Research in Agriculture' (NFBSFARA) which was later renamed as National Agricultural Science Fund (NASF) to support basic, strategic and frontier research, enabling collaborative efforts across institutions to address national priorities, technological gaps and emerging challenges in the sector (Gerard *et al.* 2024).

NASF supports research exclusively in agriculture and allied sectors. In contrast, other funding agencies such as DBT, DST, CSIR, etc. contribute to India's wider scientific and innovation ecosystem across diverse disciplines. In these agencies, comparatively limited funding is allocated to agricultural research. NASF adopts innovative approaches such as multi-institutional consortia, collaborative funding mechanisms and also supports traditional knowledge-oriented research such as SUTRA (Scientific Utilisation through Research Augmentation-Prime Products from Indigenous Cows)-based thematic projects. It supports high-risk, high-impact research, encourages interdisciplinary collaboration and promotes the use of advanced technologies to address emerging challenges in agriculture and allied sectors. NASF strategically addresses the key R&D challenges in Indian agriculture such as climate variability, emerging pests and diseases, low productivity, resource degradation and limited technological adoption by awarding projects in these areas. The scheme also aims to bridge critical gaps in translational research and facilitate the validation and promotion of farmers innovations through a participatory approach. The agricultural scientists get the research funding from various funding agencies but the NASF has been a unique choice due to its emphasis on multi-institutional partnerships. NASF supports Sustainable Developmental Goal (SDG) 1, 2, 3, 6, 9, 12, 13 and 15 by addressing the agriculture-related national priorities of India like food security, climate resilience, sustainable agricultural growth and farmer welfare through targeted research in crop improvement, livestock development, natural resource management, climate resilience, biotechnology, nutritional quality improvement and sustainable agricultural systems.

The article aims to analyse the progress of the NASF scheme for promotion of basic and strategic research in agriculture and allied areas. It is based on data available with NASF, annual reports of ICAR and project reports submitted by Principal Investigators (PIs) during the period 2012–23. The selection criteria included projects funded exclusively through a competitive mode. The variables analysed in this study include project themes, participating institutions, states involved, gender of PIs and the number of publications arising from these projects. The analysis conducted is quantitative and descriptive in nature. Descriptive statistics such as counts and percentages were used to summarise the data, along with trend analysis to observe patterns over time. A trend analysis was conducted considering the factors such as thematic areas, states, institutions and

gender to assess the impact of NASF, using quantitatively available data on proposal submissions and approvals and the data based on the information on research achievements submitted to NASF by the PIs of NASF funded projects. The figures in the article have been adopted and modified from Gerard *et al.* (2024) along with showcasing of the success of few projects.

Indicators of the impact of the scheme: In the NASF scheme the projects are awarded under the two modes viz., Competitive and Sponsored Modes. The selection of the projects under competitive mode is a three/four-stage process. Pre-proposals for projects in the identified strategic areas in prescribed formats are called through open call. The submission process is entirely electronic through web base platform. The pre-proposals recommended by the expert committees are developed into full proposals in prescribed formats and examined by experts. The proposals having multi-institutional collaboration are preferred. The data of the projects have been compiled from the web platform and the secretariat of NASF (Gerard *et al.* 2024).

In the present paper, the projects approved under competitive modes were analysed. NASF has effectively implemented 282 projects involving about 282 Lead Centres and 531 Cooperating Centres located all over the country during the years 2012–23. A total of 282 projects have been awarded with a total budget of ₹688.01 crores during the last 10 years, on an average, more than 65 projects are running on year over year basis (Fig. 1). Most of these projects have been multi-institutional having research partnerships. These scientific collaborations have helped the scientists with increased visibility and led to sharing of acquired expertise between the participating teams (Suryanarayanan *et al.* 2020).

The scheme facilitates submission of proposals under different strategic areas namely biotechnology, genomics and allele mining in plants, animals and fisheries (BGAM), Abiotic and biotic stresses and quality traits in plants, animals and fisheries (ABSQT), Precision agriculture and management of natural resources and application of sensors in crops, animals and fisheries (PA), Farm mechanisation and energy (FME), Nanotechnology in agriculture (NA), Metabolomics in agriculture (MA) and Social Science and policy research in agriculture (SSP) (Fig. 2). The quantum of funding from ICAR has also reduced substantially in Xth call (26.08 crores) compared to IXth call (73.28 crores). This is likely to affect

the scheme of NASF and the support provided for innovative research projects.

Participating organisations and institute-wise trend analysis: The NASF scheme has been effectively implemented through 813 Implementing centres located across the country involving about 282 Lead centres and 531 Cooperating centres (Fig. 3).

The pluralistic nature of NASF was reflected due to the involvement of a diverse range of institutions and agencies from the public sector, private sector and civil society organisations. Their level of participation varied across the various themes according to the priority thrust areas identified under each theme. The scheme involved about 60% of project implementing institutions in ICAR, 14% in SAUs and 1% in CAUs apart from other organisations. This collaborative research has spearheaded many novel research ideas in the agriculture sector as already proven in other scientific sectors (Sharma *et al.* 2019, Suryanarayanan *et al.* 2020) (Fig. 4).

State-wise analysis: The state-wise distribution of the projects showed that Delhi (20%), Uttar Pradesh (14.7%) and Haryana (9.8%) received the largest number of projects as lead centres. This indicates that northern region has the highest no. of lead centres. Nine projects are being

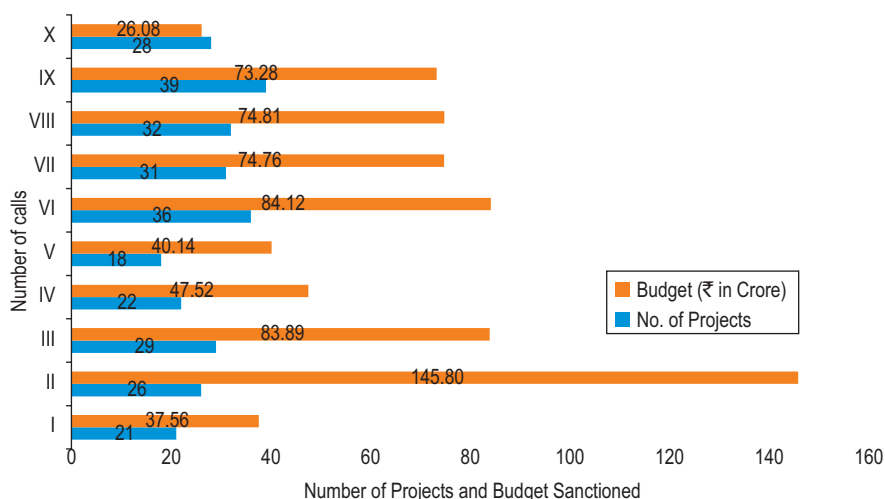


Fig. 1 Call-wise number of projects and budget sanctioned. Call I (2006), II (2011), III (2012), IV (2013), V (2014), VI (2015), VII (2016), VIII (2017), IX (2019), X (2024).

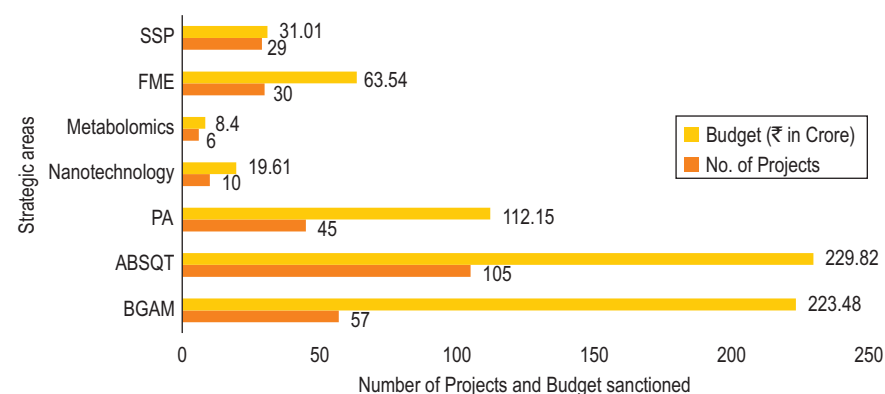


Fig. 2 Projects funded under different strategic areas and budget sanctioned.

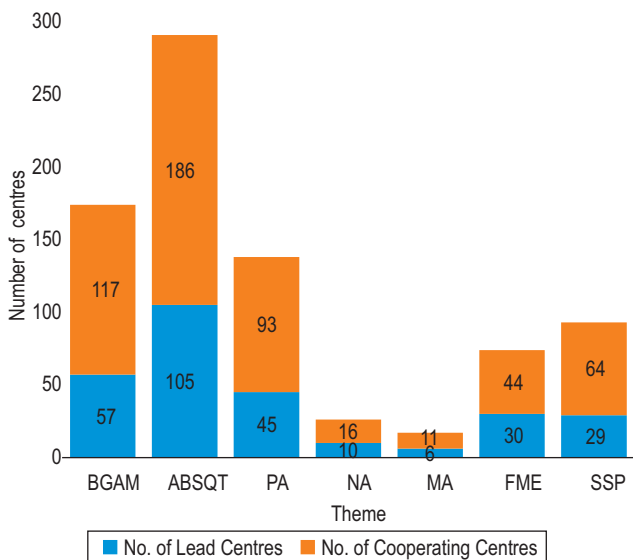


Fig. 3 Participation of Lead Centres and Cooperating Centres under different themes.

BGAM, Biotechnology, genomics and allele mining in plants, animals and fisheries; ABSQT, Abiotic and biotic stresses and quality traits in plants, animals and fisheries; PA, Precision agriculture; NA, Nanotechnology in agriculture; MA, Metabolomics in agriculture; FME, Farm mechanisation and energy; SSP, Social Science and policy research in agriculture.

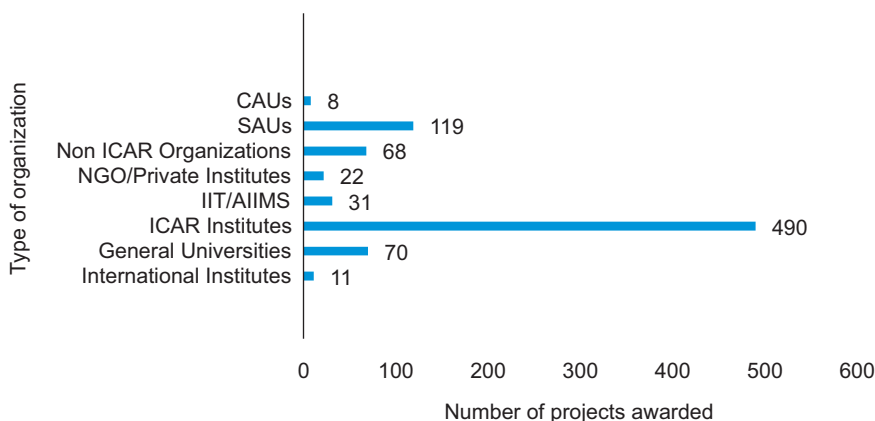


Fig. 4 Participating organisations in NASF.

CAU, Central agricultural universities; SAU, State agricultural universities; NGO, Non-governmental organisation; NASF, National Agricultural Science Fund.

implemented in north-eastern region (Fig. 5). The higher number of the projects in the northern region could be attributed due to the ICAR deemed universities such as Indian Agricultural Research Institute (IARI), National Dairy Research Institute (NDRI) and Indian Veterinary Research Institute (IVRI). These trends indicate that there is a need for enhanced communication and awareness of NASF scheme in SAUs and other institutions across the country (Kamiya *et al.* 2023). The regional imbalance in NASF projects is primarily influenced by institutional concentration in particular states, infrastructure and human resource disparities, regional agricultural priorities and

variations in research proposal capacity. Addressing these gaps requires focused capacity building, awareness programs and targeted support for underrepresented regions to ensure equitable participation in agricultural research funding.

Human resource analysis: This scheme provides a platform to evaluate and encourage the emerging talent pool in the country, fostering greater inclusion of institutions in the nation's scientific advancement, thereby creating both direct and indirect employment opportunities. Besides supporting the projects, creating infrastructure for advanced research, generating technologies, products, capacity building through training and skill development of scientists, a large number of human resource i.e. around 1,200 SRF/RAs/YPs/others have benefitted and received knowledge and developed skill base in different areas of agriculture and allied sectors. In addition, large number of skilled/semi-skilled workers get employment in the projects.

Gender-wise analysis: Under NASF, equal opportunities are given to both genders for award of projects. Among the implemented total projects of 282 the gender distribution among the PIs/CCPIs indicates a skewed distribution of only 7% projects to women researchers while a majority of 93% projects are being implemented by men researchers (Fig. 6). This could be attributed to fact that the more proposals are being submitted by men researchers. A lower proportion of projects led by women Principal Investigators (PIs) compared

to men may be due to higher teaching or administrative responsibilities, limited mentorship, reduced awareness of funding opportunities and institutional constraints and collaborative networks. These factors contribute to the under-representation of women in NASF-funded projects and highlight the need for targeted interventions to support gender equity in agricultural research. Further, it highlights the issues/challenges the women agricultural scientists face to leverage the opportunities offered by the government funding initiatives. Concerted efforts are needed to raise awareness to promote the scheme among women researchers.

Year-wise publications' analysis:

NASF projects have led to the publication of about 950 research papers in peer-reviewed journals, with the majority appearing in journals having a National Academy of Agricultural Sciences (NAAS) score rating above 6.0 (Fig. 7). The number of publications has increased from 37 in 2013–14 to 55 in 2023–24 and the NAAS rating has risen from 140 to 370, reflecting a significant improvement in the number and quality of publications over the past decade. Moreover, a significant number of patents and technologies have also been developed through NASF projects. Various technologies have also been commercialised like SARS-CoV-2 nucleic acid detection LFA kit, SARS-CoV-2

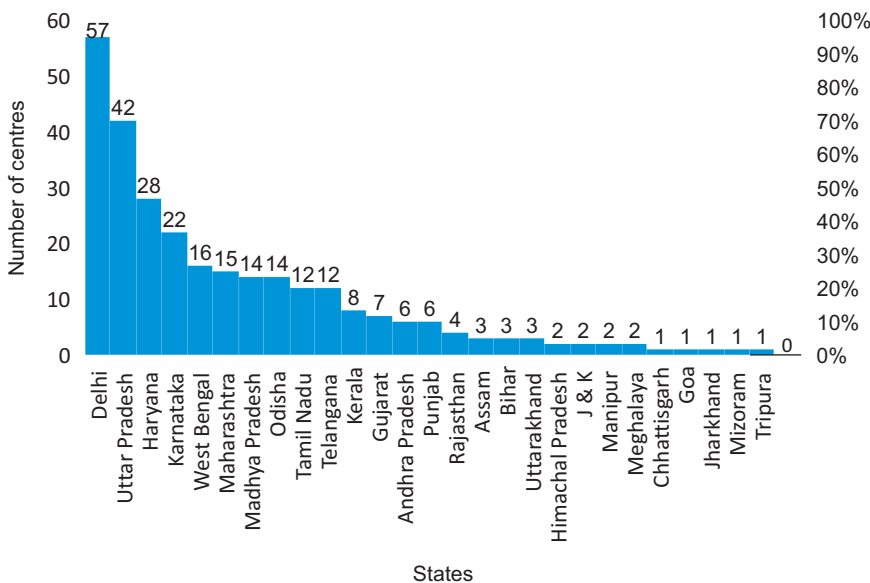


Fig. 5 State-wise spread of project implementing lead centres.

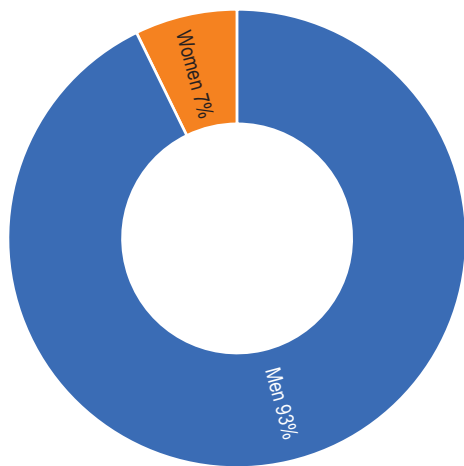


Fig. 6 Gender-wise distribution (%) of Principal Investigators/Co-Principal Investigators.

Antibody detection ELISA Kit, Covid-19 Blocking ELISA kit, Bivalent marker vaccine against bovine herpesvirus-1 and *Brucella*, Phyto-acaricides for controlling resistant cattle ticks, encapsulated nanoparticle conjugated phytochemicals

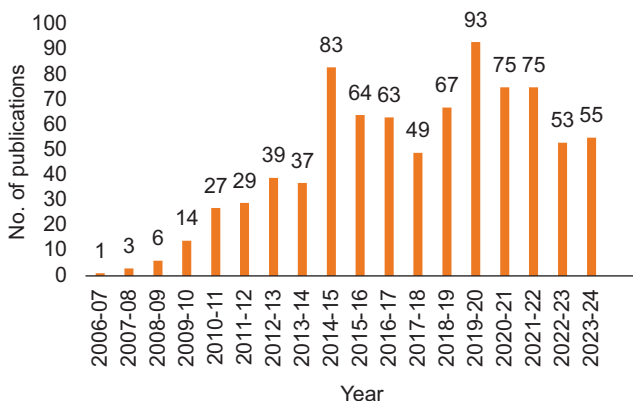


Fig. 7 Year-wise number of publications from the NASF projects (NAAS score rating 6.0 and above).

100% to combat antimicrobial resistance in poultry and Nano Chitosan encapsulated green technology to combat antimicrobial resistance in poultry. The process of technology commercialisation follows the ICAR guidelines (Singh *et al.* 2022).

Many of the NASF projects have been successful and contributed in novel research findings, advancement in knowledge, trained human source and creation of state-of-the-art infrastructure development. Achievements of some of these projects have been highlighted.

Development of state-of-the-art phenomics infrastructure: The Nanaji Deshmukh Plant Phenomics Facility, established at ICAR-IARI, New Delhi, aims to advance research on moisture

deficit, low temperature stress tolerance and nitrogen use efficiency in rice and wheat. It is a state-of-the-art, automated, high-throughput phenotyping system, which integrates advanced climate-controlled greenhouses and a mechanised plant handling system. This system supports precise, non-destructive phenotypic analysis of up to 1,200 plants, utilising cutting-edge imaging platforms such as IR Thermal, Chlorophyll Fluorescence and VNIR Hyperspectral sensors. The facility led to several patented technologies like the multi-modal sensor-based biomass measurement system and the WirePheno protocol for root phenotyping. It has a significant impact, leading to over 30 peer-reviewed publications, the development of innovative methodologies for plant trait evaluation and the training of over 100 students through new specialised courses. The facility has become a global hub for plant phenomics, attracting international delegates and hosting training programs that have benefited researchers and students worldwide.

Genetic improvement of rice through genome editing using CRISPR-Cas9: The consortium project on RNA-guided genome editing in rice aims to enhance yield, nitrogen and water use efficiency and tolerance to major abiotic and biotic stresses in elite rice varieties under the changing climate scenario. It aimed for development and deployment of precise CRISPR-Cas9/Cpf1 genome-editing tools for targeted modification of stress and yield-related genes in mega rice varieties such as MTU1010, Swarna, Samba Mahsuri and ASD16. The efforts led to the development of the world’s first genome-edited rice varieties, DRR Dhan 100 (Kamala), a genome-edited Samba Mahsuri with ~35% higher grain yield, stronger culm, early maturity and improved photosynthetic efficiency and Pusa Rice DST1, a drought and salt-tolerant MTU1010 derivative with significantly enhanced yield while retaining grain quality (Anonymous 2024). The release of two genome-edited varieties by Union Minister for Agriculture and Farmers’ Welfare, Shri Shivraj Singh Chouhan on 4 May

2025, demonstrated the successful translation of genome-editing research into farmer-ready cultivars and marked a major milestone in India's agricultural biotechnology by strengthening climate resilience, productivity and national food security.

Metabolite-based non-invasive SMART sensor for non-destructive detection of apple scab disease: The project on apple scab aimed to enable early, non-invasive detection of *Venturia inaequalis* infection to reduce reliance on repeated fungicide applications and mitigate associated environmental and health risks. The major innovation was the integration of comparative metabolomics with sensor engineering to identify scab-resistance-associated metabolites and to develop a metal-oxide and nanomaterial based semiconductor sensor capable of detecting disease-specific volatile organic compounds (VOCs) emitted during early, asymptomatic stages of infection. It led to successful development of a real-time diagnostic sensor that demonstrated high accuracy in predicting scab infection in susceptible apple cultivars under greenhouse conditions. The research has a potential to enable timely, localised disease management, substantially reducing fungicide use and production costs while offering a low-cost, farmer-friendly technology for large-scale adoption in apple orchards, with ongoing field validation strengthening its translational value for the horticulture industry (Demiwal *et al.* 2024a; 2024b).

Solar powered prime mover with multi-tool attachments for small farm holdings: Solar-powered farm mechanisation aimed in developing an affordable, energy-efficient prime mover to enhance operational efficiency, reduce drudgery and improve access to mechanisation for small and marginal farmers. The main innovation was the design and development of a solar-powered prime mover integrated with an optional *in situ* solar charging cart and multiple interchangeable tool attachments for core farm operations such as sowing, spraying and weeding. A multifunctional solar charging cart was developed, which not only recharges the battery pack but also powers DC and AC farm equipment up to 2 hp capacity, enabling its use for allied operations including chaff cutting, mini-dhall milling, milking and groundnut stripping. Large-scale field demonstrations to the farmers during the Agri Expo at Vijayamangalam, Tamil Nadu, highlighted its potential to lower operational costs, reduce dependence on fossil fuels and manual labour and support sustainable, climate-smart mechanisation for small farm holdings.

Development of animal cloning technology: The efforts on animal cloning aimed to overcome the acute shortage of elite breeding buffalo bulls in India by enabling large-scale multiplication of genetically superior animals beyond the limitations of conventional progeny-testing programmes. Successful application and optimisation of somatic cell nuclear transfer technology for buffalo cloning was achieved, including improved embryo production, recipient synchronisation and neonatal management protocols, which enhanced cloning efficiency from less than 1% to 6–8%. It led to successful cloning of 13 calves from six elite

breeding bulls and one superior female buffalo, production of multiple clones from top-ranked bulls (including re-cloning), establishment of a somatic cell bio-bank of elite buffaloes and validation of normal fertility and semen quality of cloned bulls, resulting in the production of over 25,000 freezable semen doses. The significant impact is reflected in the birth of more than 75 progeny from cloned-bull semen, initiation of semen donation by the next generation and the strong potential for large-scale genetic upgradation, wherein each cloned bull is projected to generate ~1.5 lakh semen doses capable of producing up to 7.5 lakh genetically superior buffaloes, thereby substantially enhancing milk productivity, farmer income and national livestock genetic resources (Selokar *et al.* 2019, Yadav *et al.* 2020, Dua *et al.* 2021, Yadav *et al.* 2023).

Identification of unique signatures of selective sweeps in indigenous dairy cattle breeds: The SUTRA-based project on indigenous dairy cattle breeds aimed to safeguard India's indigenous cattle diversity by identifying genomic signatures of selection that underlie economically important traits and can inform conservation, grading and breed improvement strategies. High-resolution genomic tools, including Bovine BeadChip genotyping and ddRAD-based genotyping-by-sequencing, were used to systematically detect selective sweep signatures in major indigenous dairy cattle breeds. It led to the development of a well-curated and diversified genomic repository comprising Red Sindhi, Rathi, Tharparkar and other indigenous cattle populations, along with the identification of 40 genes under selection associated with morphometric, production and fitness-related traits across breeds such as Kankrej, Tharparkar, Nelore, Sahiwal and Gir, including breed-specific candidate genes influencing body conformation and productivity. The efforts have generated actionable genomic knowledge and resources that support informed breeding decisions, long-term conservation of native germplasm and genetic improvement of indigenous cattle, thereby helping counter genetic dilution from unplanned crossbreeding while sustaining productivity, reproductive efficiency and phenotypic diversity in Indian cattle populations (Rajawat *et al.* 2022, Nayak *et al.* 2025).

Encapsulated nanoparticles combating antimicrobial resistance in poultry: The project aimed in developing safe, effective and non-antibiotic alternatives to combat multidrug-resistant (MDR) pathogens in poultry, thereby addressing the growing challenge of antimicrobial resistance while ensuring food safety and productivity. The nanoparticle-conjugated, microencapsulated phytochemicals (EAgC and EAgT) were designed for targeted intestinal delivery, enhanced bioavailability and prolonged bioactivity, with controlled release (>80%) at alkaline pH. It led to the demonstration of strong antibacterial activity, improved survival rates, minimal toxicity across *in-vitro* systems and *in vivo* models (*Galleria mellonella*, mice and broiler poultry), improved feed conversion ratio and absence of detectable residues in poultry meat. The work has a potential to significantly reduce antibiotic usage in poultry production, lower the risk of resistance development, improve production

efficiency and enhance consumer safety, with successful commercialisation of the technology to an industry partner, highlighting its readiness for large-scale adoption and contribution to sustainable, AMR-resilient poultry farming systems (Abishad *et al.* 2023, Arya *et al.* 2023).

Development of diagnostic kits in veterinary sciences

Development of diagnostic kits for detection of covid-19 infection in animals: The efforts to develop diagnostics for Coronavirus infections aimed in strengthening surveillance and rapid detection of SARS-CoV-2 infections in animals to support public health, epidemiological monitoring and wildlife disease management. Rapid, sensitive and point-of-care diagnostic platforms were developed, including an RPA–CRISPR-based lateral flow assay (LFA) kit for nucleic acid detection and multiple ELISA-based serological assays for antibody detection across diverse animal species. The ‘SARS-CoV-2 Nucleic Acid Detection LFA Kit’, which was developed is capable of delivering results within one hour using minimal laboratory infrastructure and species-adaptable ELISA kits, indirect and blocking formats successfully validated for detecting SARS-CoV-2 antibodies in companion animals and wildlife, including lions and tigers. The significant impact of the kit is evidenced by the successful field application of the blocking ELISA during the 2021 outbreak in captive wild felids, generation of five peer-reviewed publications and one Indian patent and the establishment of robust diagnostic tools that enhance animal health surveillance, zoonotic disease preparedness and One Health-based pandemic response frameworks (Kaushik *et al.* 2022, Kumar *et al.* 2023).

Early detection bovine pregnancy diagnosis kits: The work on early and accurate diagnosis of pregnancy in dairy animals aimed to enable early, accurate and farm-level diagnosis of pregnancy in cattle and buffaloes to improve reproductive efficiency and economic sustainability of dairy farming. Identification and molecular characterisation of pregnancy-associated protein biomarkers was done, especially PAG-7 as the most abundantly expressed isoform in buffalo, followed by PAG-18 and PAG-2 and their translation into India’s first cow-side pregnancy detection technologies. It led to cloning and recombinant expression of PAG isoforms, development of monoclonal antibodies against predicted immunogenic epitopes and successful creation of ELISA and lateral flow-based point-of-care kits, including the PAG-based LFA and the metabolite-based Preg-D kit, specifically designed for bovine species. There was significant reduction of calving intervals and unnecessary maintenance costs by enabling early identification of pregnant and non-pregnant animals, resulting in estimated savings of ~₹4,000 per animal per reproductive cycle, alongside improved herd productivity, enhanced reproductive management and dissemination of knowledge through seven high-quality peer-reviewed publications (Rawat *et al.* 2016).

Design and development of Sagar Harita FV: The project on Green Fishing Systems for Tropical Seas aimed in

reducing fuel consumption and carbon emissions in India’s mechanised marine fisheries through the development of a standardised, energy-efficient fishing vessel suitable for tropical seas. The design and construction of *FV Sagar Harita*, a 19.75 m multipurpose ‘green’ combination fishing vessel that integrates optimised hull and machinery design, renewable energy through onboard solar panels and advanced navigational, fishing and fuel-monitoring technologies was achieved, while fully complying with Indian Register of Shipping standards. A versatile platform capable of trawling, gillnetting and long-lining, equipped with trawl telemetry and real-time fuel monitoring systems was created for improved operational efficiency. The initiative demonstrated a ~15.5% reduction in fuel consumption compared to conventional trawlers of similar size, adoption of the vessel design by the Ministry of Fisheries as a national model and its role in guiding the development of energy-efficient commercial fishing vessels, thereby contributing to reduced operational costs, lower carbon footprint and enhanced sustainability of India’s marine capture fisheries (Sherief *et al.* 2015).

Development of captive breeding of Hilsa, Tenulosa ilisha: The initiative on *Tenulosa ilisha* aimed in developing captive breeding, seed production and culture protocols to establish sustainable hilsa stocks, reduce dependence on wild broodstock and support conservation and aquaculture-based production of this economically and nutritionally important species. Standardized artificial breeding protocols were developed using wild-caught broodfish with fertilisation rates of 90–95% and hatching rates of 70–89%, advanced larval, fry and fingerling rearing techniques with live feed and functional diets achieving survival rates of 81–99% and the creation of a portable battery-operated anesthetic delivery device to minimise handling stress. Successful breeding was achieved using cryopreserved milt and recirculatory aquaculture systems (RAS) optimised for broodstock and grow-out culture. The work demonstrated the feasibility of pond-based Hilsa aquaculture, providing robust culture and broodstock management protocols, enabling long-term conservation through aquaculture interventions and contributing to technology transfer and intellectual property generation with two patents granted, thereby laying the foundation for sustainable Hilsa production and ecological management of wild populations (De *et al.* 2020, Suresh *et al.* 2021).

Development of biosensors for detection of fish pathogenic bacteria and hazardous metalloids in water bodies: The initiative on developing rapid, sensitive and cost-effective biosensor-based tools for the detection of fish pathogenic bacteria and hazardous metalloids in aquaculture and water environments was undertaken, to enhance food safety, disease management and environmental monitoring. The designing of nanoparticle-based colorimetric sensors for arsenic detection using α -FeOOH nanoparticles (detection limit 5 ppb), development of an aptamer-based sensor for detecting *Aeromonas veronii* and creation of a hand-held nano-biosensing device, IMAGinE, employing gold

nanoparticles and aptamers for ultra-trace detection of hexavalent chromium (Cr^{6+}) was achieved. Complementing the device, a mobile application, 'Cr-Detector', was developed for real-time analyte detection. Highly sensitive, precise and portable detection capabilities were achieved (LOD 0.0037 ppm; LOQ 0.0112 ppm for Cr^{6+}), enabling timely intervention in aquaculture systems, minimising health risks from contaminated water and fish and providing a scalable platform for on-site monitoring of environmental pollutants and fish pathogens (Dei *et al.* 2024a, 2024b).

Smart Aquaculture Model (SAM) for sustainable shrimp aquaculture: The development of Smart Aquaculture Model (SAM) aimed in enhancing the sustainability and efficiency of shrimp farming in India by leveraging information and communication technology (ICT) and data analytics for real-time farm management and decision-making. CIBA Shrimp Krishi App was developed, which is an interactive, multilingual mobile application integrating three expert systems for shrimp feed management, water quality management and disease management. It enabled the farmers to input daily farm observations, receive pond-wise advisories on shrimp survival, biomass, feed conversion ratio, water quality and costs, store and retrieve crop data for long-term decision-making and interact with experts through a query-response system. It achieved widespread adoption among Indian shrimp farmers, enabling informed, data-driven management decisions, improving farm productivity and sustainability and creating a platform for real-time monitoring and extension of customised technical advisories, thereby reducing risks and enhancing profitability in shrimp aquaculture.

Funding support can play a significant role in fostering and strengthening the R&D ecosystem. In the last ten years, NASF has received a good response from researchers across the country as evident from the large number of the proposals received. The projects have contributed about 950 research papers in peer-reviewed journals, demonstrating a marked improvement in both the quantity and quality of publications, as reflected by the increase in overall NAAS ratings from 140–370 in the past decade. Global state-of-the-art research facilities created through NASF support are an asset and will pave the way for the new path breaking research in the future. The projects have facilitated the development and commercialisation of several innovative products and diagnostics, vaccines and numerous patents. New research methodologies have been developed leading to many new varieties in crop. A large number of scientists from various institutions have worked in multidisciplinary areas through multi-institutional projects. They have developed and sharpened their knowledge and skills in frontier areas of science and also availed overseas training in cutting edge areas.

NASF has significantly strengthened India's agricultural research ecosystem by advancing cutting-edge science, from genomics and molecular breeding to precision and climate-smart agriculture. It has delivered climate-resilient and

high-yielding crop and livestock technologies, eco-friendly pest and nutrient management solutions and innovations that enhance productivity while reducing post-harvest losses. Technologies like gene edited rice with stress tolerance and higher yield, Sagar Harita fishing vessel supports fishermen by promoting sustainable coastal and marine resource use through improved fisheries technologies and resilient livelihood solutions. These interventions have contributed to higher farmer incomes, improved nutrition security and expanded livelihood opportunities across rural communities. NASF has also promoted sustainable resource use by improving soil health and water-use efficiency. NASF has empowered rural communities, women and youth through training and agri-entrepreneurship. NASF has built research capacity and generated evidence that impacts national policies related to food safety, climate resilience and sustainable agricultural development through strong multi-institutional collaborations within the NARS.

NASF envisages enhanced regional outreach, digital agriculture, climate-smart innovations and greater integration of AI/ML-based solutions. NASF envisions partnering with Anusandhan National Research Foundation (ANRF) through MoUs under Research, Development and Innovation (RDI) schemes to strengthen farm-to-fork technologies and accelerate integrated, innovation-driven agri-food system transformation. NASF-supported innovations may be translated into deployable technologies such as diagnostics, vaccines and sensor-based tools and their commercialisation pathways through public-private partnerships, start-ups and technology transfer units within ICAR. Institutes may showcase their technologies in industrial meets and feature them on the Agri-Innovate platform to enable wider industry visibility and foster greater collaboration. There is need for enhanced collaborations of ICAR institutes with other science and technology-based institutes/universities for better output and wider partnerships. The indicators show that the funding support has been concentrated to the northern region and needs to be extended to other regions of the country. Agriculture is a state subject and require many localised solutions to the problems, many states are lagging behind in agricultural research output. Such SAUs must get covered in the scheme to strengthen their regional agricultural ecosystem. The indicators also emphasise the need for institutes to raise awareness, inspire, mentor, support and provide guidance to female researchers, encouraging them to submit their research ideas for funding, especially when the ratio of female students in SAUs is now more than 50%. It is also seen that the quantum of funding to projects have been significantly reduced, this may lead to an adverse effect on the development of innovative technologies in future. The scheme encourages the researchers to submit projects having initial leads in their research which can be taken forward to provide solutions for agriculture and allied sectors. Therefore, it is important to design an oversight mechanism for generating awareness and communicating to institutes and universities in agriculture as well as basic sciences/engineering in the remote areas of the country

leading wider participation of the researchers.

NASF has been successful in fostering the basic, strategic and translational research in agriculture and allied areas in the country. The existing infrastructure of NARS has been strengthened through the funding support and resulted in creation of state-of-the-art infrastructure in phenomics, design of fishing vessels, contribution of novel research in grain improvement of crops, climate resistant crop varieties, cloning of animal technology, many veterinary vaccines and diagnostic tools, etc. All these activities not only upgraded the knowledge and skills of scientists but also enabled them to build professional contact with other scientific institutions working in their areas of interest. To enrich the knowledge capacity building of quality human resources has also been achieved. New schemes like mission-mode research on oilseeds and pulses and smart functional foods, enhanced monitoring systems, balanced regional and gender representation etc. can also be introduced. This will ensure a continuous exchange of knowledge and ideas, fostering collaborative efforts among various stakeholders in basic, strategic and frontier application research to address agricultural challenges leading to commercialisation of technologies and promotion of entrepreneurship while contributing to the formulation of science policy in agriculture.

REFERENCES

- Abishad P, Jayashankar M, Namratha K, Srinath B S, Kurkure N V, Barbuddhe S B, Rawool D B, Vergis J and Byrappa K. 2023. Synthesis of ZIF-8(Fe) functionalised with citral as potent antimicrobial candidate against multi-drug resistant enteroaggregative *Escherichia coli* and non-typhoidal *Salmonella* spp. *Russian Journal of Bioorganic Chemistry* **49**: 360–66.
- Agarwal M and Kaur P. 2023. Impact of selected schemes of SERB empowering Indian women in R&D spectrum. *ACS Omega* **8**(15): 15354–63.
- Anonymous. 2022. *All India Survey on Higher Education Report, 2021-22*. Ministry of Education, Department of Higher Education, New Delhi. <https://aishe.gov.in/aishe/home>
- Anonymous. 2023. *Research and Development Statistics at a Glance, 2022-23*. Department of Science and Technology, Ministry of Science and Technology. <https://dst.gov.in>
- Anonymous. 2024. *ICAR Launched India's First-Ever Genome-Edited Rice Varieties*. Indian Council of Agricultural Research, New Delhi. https://iari.res.in/files/Latest-News/ICAR_Genome_Edited_Rice_04052025.pdf
- Arya P R, Abishad P, Unni V, Ram V P, Polumahanti N, Yasur J, John L, Karthikeyan A, Nambiar P, Juliet S, Vinod V K, Vergis J, Kurkure N V, Barbuddhe S B, Byrappa K and Rawool D B. 2023. Facile synthesis of silver- zinc oxide nanocomposites using *Curcuma longa* extract and its *in vitro* antimicrobial activity against multi-drug resistant non-typhoidal *Salmonella* spp. *Inorganic Chemistry Communications* **148**: 110356.
- Dei J, Bhattacharyya S, Ghosh K, Sarkar S, Pal S, Mukherjee S, Sarkar D J, Ghosh A, Bandyopadhyay R, Das B K and Behera B K. 2024a. Development of field portable potentiostat using electrochemical aptasensing technology for detection of Cr (VI) in aquatic environment. *Current Research in Biotechnology* **7**: 100193.
- Dei J, Mondal S, Biswas A, Sarkar D J, Bhattacharyya S, Pal S, Mukherjee S, Sarkar S, Ghosh A, Bansal V and Bandyopadhyay R. 2024b. Cr-Detector: A simple chemosensing system for onsite Cr (VI) detection in water. *PLoS One* **19**(1): e0295687.
- De D, Shyne Anand P S, Mukherjee S, Kumar P, Dayal J S, Raja R A, Bera A, Suresh V R and Vijayan K K. 2020. Broodstock development and captive maturation of hilsa (*Tenualosa ilisha*) in a brackishwater pond-based system. *Journal of Fish Biology* **97**(3): 720–33.
- Department of Biotechnology. *DBT India*. <http://dbtindia.gov.in>
- Demiwal P, Mir J I and Sircar D. 2024a. A non-invasive method for phenotyping scab-tolerant apple plants using volatile organic compounds. *Physiologia Plantarum* **176**(3): e14377.
- Demiwal P, Tayade S, Yadav S R and Sircar D. 2024b. A metabolomics perspective on root-derived plant immunity and phytohormone interaction. *Physiologia Plantarum* **176**(1): e14150.
- Dua S, Bajwa K K, Prashar A, Bansal S, Beniwal M, Kumar P, Pinetha M, Selokar N L, Yadav P S and Kumar D. 2021. Empowering of reproductive health of farm animals through genome editing technology. *Journal of Reproductive Healthcare and Medicine* **2**(4): 1–8. https://doi.org/10.25259/JRHM_17_2020
- Gerard M, Kumar A, Kumar A and Kumar J. 2024. *Glimpses of National Agricultural Science Fund (2006-2023)*. Indian Council of Agricultural Research, New Delhi.
- Gerard M, Gupta M, Srinivas K and Sastry R K. 2021. An insight of IP management practices in the agricultural research system. *The Indian Journal of Agricultural Sciences* **91**(4): 563–67.
- ICAR. 2023. *Annual Report, 2022-23*. Indian Council of Agricultural Research, New Delhi.
- IPI. 2023. *Annual Report, 2022-23*. Intellectual Property India.
- Kamiya A, Nandy A, Singh P and Singh V K. 2023. Mapping the research output from Indian states, 2019. *Current Science* **124**(11): 1245–55.
- Kaur P J, Agarwal M and Gupta A. 2023. SERB-SURE scheme in India: Early indicators and recommendations. *Current Science* **125**(9): 1335–45.
- Kaushik R, Kumar N, Zhang K Y, Srivastava P, Bhatia S and Malik Y S. 2022. A novel structure-based approach for identification of vertebrate susceptibility to SARS-CoV-2: Implications for future surveillance programmes. *Environmental Research* **212**(Pt C): 113303.
- Kumar N, Kaushik R, Zhang K Y, Uversky V N, Sahu U, Sood R and Bhatia S. 2023. A novel consensus-based computational pipeline for screening of antibody therapeutics for efficacy against SARS-CoV-2 variants of concern including Omicron variant. *Proteins* **91**(6): 798–806. <https://doi.org/10.1002/prot.26467>
- Madhu K P, Madhu G and Jha V. 2015. Innovations in attracting the young to the pursuit of science. *Current Science* **108**(2): 243–48.
- Nayak S S, Panigrahi M and Dutt T. 2025. Genome wide insights into selection signatures for transcription factor binding sites in cattle ROH regions. *Mammalian Genome* **36**: 541–56.
- National Science Foundation. 2022. *Science and Engineering Indicators, 2022*. NSF database.
- Rajawat D, Panigrahi M, Kumar H, Nayak S S, Parida S, Bhushan B, Gaur G K, Dutt T and Mishra B P. 2022. Identification of important genomic footprints using eight different selection signature statistics in domestic cattle breeds. *Gene* **816**: 146165.
- Rawat P, Bathla S, Baithalu R, Yadav M L, Kumar S, Ali S A,

- Tiwari A, Lotfan M, Naru J, Jena M and Behere P. 2016. Identification of potential protein biomarkers for early detection of pregnancy in cow urine using 2D DIGE and label free quantitation. *Clinical Proteomics* **13**: 15.
- Selokar N L, Sharma P, Saini M, Sheoran S, Rajendran R, Kumar D, Sharma R K, Motiani R K, Kumar P, Jerome A and Khanna S. 2019. Successful cloning of a superior buffalo bull. *Scientific Reports* **9**(1): 11366. <https://doi.org/10.1038/s41598-019-47909-8>
- Sharma A K, Dwivedee B P, Soni S, Kapoor D N and Patil V. 2019. Scientometric analysis of biotechnology research output in India during 2008–17. *Library Philosophy and Practice (e-journal)* **2983**. <https://digitalcommons.unl.edu/libphilprac/2983>
- Sherief P M, Joseph R, Thomas S N and Edwin L. 2015. Design and general features of Ray gillnets used in Kanayakumari Coast. *International Journal of Engineering Trends and Technology* **25**(1): 150–55.
- Singh V, Gerard M, Datt S and Srinivas K. 2022. *Licensing of Innovative Technologies @Indian Council of Agricultural Research (ICAR)*. Indian Council of Agricultural Research, New Delhi.
- Srinivas K, Gerard M, Singh V, Gupta M, Soam S K, Arunachalam A, Datt S, Saxena S and Rao Srinivasa Ch. 2018. *Agri-startups: Reflection of ICAR Technologies in Market (AgRIM)*. Indian Council of Agricultural Research, New Delhi.
- Suresh V R, Mandhir S K, Sajina A M, Manna R K, Mukherjee J, Banik S K, Maity T, Samanta R, Raman R K, Jayaraman J and Behera B K. 2021. Reproductive potential and stock status of the anadromous shad, *Tenualosa ilisha* (Hamilton, 1822): Implications for managing its declining fisheries in northern Bay of Bengal bordering India. *Regional Studies in Marine Science* **44**: 101753.
- Suryanarayanan T S, Ravishankar J P and Muruganandam V. 2020. Scientific research: A collaborative endeavor is unrivalled. *Current Science* **119**(11): 1689–95.
- Yadav P S, Kumar D, Saini M, Sharma R K, Dua S, Selokar N L, Bansal S, Punetha M, Gupta A, Kumar R and Kumar P. 2023. Evaluation of postnatal growth, hematology, telomere length and semen attributes of multiple clones and re-clone of superior buffalo breeding bulls. *Theriogenology* **213**: 24–33.
- Yadav P S, Selokar N L, Kumar D, Sharma R K, Kumar P, Kumar R, Saini M and Dua S. 2020. ICAR-CIRB produces seven clones of a superior buffalo breeding bull. *Current Science* **119**(7): 1077.