POLICY PAPER 93

Enhancing Science Culture in Agricultural Research Institutions

NATIONAL ACADEMY OF AGRICULTURAL SCIENCES, NEW DELHI

May 2020

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CONVENER : Dr N.H. Rao, Former Joint Director and Dean & Professor, National Academy of Agricultural Research Management, Hyderabad

EDITORS : Dr Kusumakar Sharma

Dr P.S. Birthal

REVIEWER : Dr V.K. Gupta, Former ICAR National Professor, Indian Agricultural Statistics Research Institute, (IASRI), Pusa, New Delhi 110012

CITATION : NAAS 2020. Enhancing Science Culture in Agricultural Research Institutions. Policy Paper No. 93, National Academy of Agricultural Sciences, New Delhi: 20p

Published by Executive Director on behalf of
NATIONAL ACADEMY OF AGRICULTURAL SCIENCES
NASC, Dev Prakash Shastry Marg, New Delhi - 110 012
Tel: (011) 25846051-52; Fax: (011) 25846054
Email: naas@vsnl.com; Web site: http://www.naasindia.org

Preface

The success of agriculture is tied to the sustainability of natural capital and continuing prosperity of farmers. Both are under threat from deteriorating natural resource base, climate change, and volatility of agricultural markets. In response to these threats, national policy urgency has also shifted from farm productivity to farmer prosperity while dealing with global markets, consumer preferences, health and safety, climate change, water scarcity, soil health and environmental security. At the same time, technological disruptions arising from new sciences and digital and analytics technologies have shown potential to transform agricultural research and farming practices. These developments, as well as recent public concerns for higher integrity and responsibility in science enterprise, in general, have compelledthe Academy to revisit basic questions about the science culture in NARS to create work environments in public agricultural research institutions that allow seamless assimilation of new developments in science and technology to generate research of higher quality, relevance and impact, while attaining highest levels of scientific integrity and creativity.

To this end, the National Academy of Agricultural Sciences, New Delhi organized a Brainstorming Workshop on *Enhancing Science Culture in Agricultural Research Institutions* on June 25, 2019. Specifically, the workshop's purpose was to evolve a set of guiding principles for policy, institutional, and individual behavioral pathways for enhancing science culture in agricultural research institutions in India.

On behalf of the Academy, I express my gratitude and sincere thanks to Dr N.H. Rao for convening this workshop and to all the participants. I also thank Drs Kusumakar Sharma and P.S. Birthal for their editorial support.

(Trilochan Mohapatra)
President

Enhancing Science Culture in Agricultural Research Institutions

1. INTRODUCTION

The National Agricultural Research System (NARS) is a complex system of public research institutions and universities that are networked with farmers, businesses, consumers, start-ups, policymakers, donors, scientific societies, science academies, media and several others. Ideally, all these constituents must act in ways that nurture and sustain science culture in the NARS.

"Science culture"[1] is the system of shared principles, values, traditions, conventions, attitudes, knowledge, skills and behaviours of scientific communities. This culture shapes the scientist's identity, the progress of science, and the appropriation of science by scientific communities and societies. Scientific progress and appropriation require both conceptual and technological advances, and sustaining both the types of advances depends on *three core attributes of science culture - research integrity, scientific creativity, and scientific integrity*.

Research integrity is a system of universal and immutable principles, values, ethics, attitudes, standards and norms of scientific research practice which ensures *integrity in the process of doing science*. The system enables scientists to self regulate, evaluate and appropriate new knowledge from research, and sustain society's trust in science. Scientific creativity is the individual and collective ability of scientists to produce new scientific insights, ideas, and applications that drive both scientific advances and innovation. 'Scientific integrity', is about how responsibly science informs public policy to benefit humanity. *Both scientific creativity and scientific integrity require strong foundations in research integrity.*

Since modern scientific research is practiced in institutions, the three core attributes of science culture are embedded within organizational cultures. The latter evolve with organization's history, mission, value systems, and interactions among *organizational* governance processes, resources, performance assessment systems, and *personal* integrities, motivations, and behavioural responses of individual scientists. Public research institutions also have a complex interface with society, which they need to advance to remain viable. Like others, scientists too are susceptible to social and organizational pressures, incentives, biases, and manipulation by individuals and groups. The three core attributes of science culture can therefore manifest differentially in institutions depending on the interactions between science, organizational, and societal cultures. *Leadership of research* *institutions has a central role in aligning the interactions and behavioural responses to create working environments that protect and nurture the attributes of science culture.*

Concerns about integrity of the scientific enterprise, including the agricultural science enterprise, are increasingly expressed by science communities, policymakers, and public. They arise from: (i) rising incidences of scientific fraud and retractions of scientific papers, (ii) profound effects of institutional policies and performance metrics and incentive structures that can turn perverse in competitive environments, skew behaviours, and erode self-regulation, and, (iii) conventional scientific ethics being overtaken by new technologies, increasing size and diversities within and among research teams, and progressive engagement of science with markets, private funding, and academic entrepreneurship. This has forced scientific communities globally to revisit institutional policies and systems to reinforce the grounding of scientists and scientific institutions in research integrity principles, practices and behaviours, and enhance other attributes of science culture.

Any culture change in organizations is difficult. So, attempts at enhancing the science culture in NARS must be based on a balanced perspective informed by a comprehensive understanding of: (i) the universal attributes of science culture and their expressions in institutional contexts and in agricultural science; (ii) how the green revolution has shaped the agricultural science culture of Indian NARS, and how its attributes are enhanced or diminished in its present institutional framework; and (iii) the disruption in agricultural science and farming caused by convergence among emerging sciences, digital and analytics technologies, and the urgency for demand-driven innovation to reach the farmers' fields directly, which is forcing adoption of new scientific paradigms and business models in agricultural research. Based on such understanding, new policy, institutional, and behavioural pathways are identified to enhance, and sustain high levels of research integrity, scientific integrity, and individual and collective creativity in NARS, to accelerate innovation and sustainable wealth creation in agriculture.

2. SCIENCE CULTURE ATTRIBUTES: ADAPTATIONS IN INSTITUTIONS AND AGRICULTURAL SCIENCE

2.1 Universal attributes of science culture

Central to science culture attributes of research integrity, scientific creativity, and scientific integrity is the "scientific method", a *universal mental model* to creatively accumulate and appropriate new scientific knowledge[2]. The scientific method is a systematic, rigorous, and iterative process involving: (i) identifying a problem/question from observations and prior knowledge; (ii) formulating a testable hypothesis (tentative theory/solution to the problem/question); (iii) designing experiments with appropriate controls to generate data to test the hypothesis; (iv) accepting the hypothesis if it agrees with experiments, rejecting it or proposing a new hypothesis otherwise; and (v) communicating research results as a scientific paper for objective peer review, verification, and publication - after duly crediting prior work and taking full responsibility for own work. Successive iterations of the scientific method for a given topic can lead back to the same research question, but at deeper and deeper levels of knowledge to creatively and cumulatively advance knowledge and drive innovation.

2.1.1 Research integrity:

At an individual level, research integrity is about strict adherence to scientific method in research practice to internalize its system of *unique and immutable behavioural principles, values, attitudes, and standards in scientist identity.* These include:

i. *An attitude of skepticism*[3] - or, constant questioning of reasoning, evidence, and conclusions, exemplified in hypothesis tests by empirical falsification.

ii. *Adherence to scientific rigour* - or strict application of scientific method, characterized by robust, unbiased experimental designs and transparency in reporting experimental details and results, so that others may reproduce and extend the findings[4]. *Scientists apply the elements of rigor appropriate for their science*. (eg. physicists announced Higgs boson at certainty to a *P* value 3×10^{-7}; for biological/agricultural studies *P* can be 0.05.)

iii. *Self-regulation and self-governance:* The science enterprise is founded on autonomous processes of open communication, honorary peer review, and publication, to accumulate knowledge collegially, through trust, mutual respect, consensus and self-correction.

iv. *Premium on peer recognition:* The scientific community rewards and recognizes scientists in the currency of reputation, and severely punishes any breach of research integrity.

At institutional level, research integrity is about how its leadership and governance processes encourage those involved 'to exemplify these values in every step of the research process' [5].

2.1.2 Scientific creativity:

New scientific discoveries and innovation are driven by creativity. Creativity in science depends on cognitive skills of analysis, association, and synthesis to discover new connections or directions in seemingly unrelated observations, knowledge, questions, or ideas. These skills can be developed, and everyone can be creative. Creativity thrives best in open, interdisciplinary, interactive working environments of collaboration, and inspiration, with *free-flowing hierarchy*[6].Trust, self-awareness, mutual respect, empathy, sense of larger shared purpose, and higher comfort levels with risk-taking, diverse perspectives, and cross-fertilization of ideas, among members, characterize such environments. *These are essentially personal attributes representing high levels of emotional intelligence.* Investments in developing emotional intelligence skills, in addition to domain skills, can significantly enhance scientific creativity and innovation.

2.1.3 Scientific integrity:

Scientific integrity was till recently synonymous with research integrity. However, in present times, it has come to represent more the relationship between science, society, and policy, as science is increasingly called upon to inform public policy. Scientific integrity is about how "independent science fully and transparently informs policy decisions, free from inappropriate political, ideological, financial, or other undue influence[7]".

2.1.4 Perpetuation of science culture through education and mentoring:

Globally, the scientific method is the foundation of science education at all levels, so that the understanding of research integrity principles is universal. Historically, formal education in science is followed by a long incubation process of passive apprenticeship (PhD/ Post-doctoral) with established research groups or labs to internalize research integrity principles, skills, and behaviours, to license young scientists into independent research practice. This unique model has sustained the core culture of science for centuries.

2.2 institutionalization effects on science culture

Public research institutions, universities, and corporates have strived to embed science culture within their organizational cultures. The traditional, passive apprenticeship model of incubating young scientists in science culture has been outpaced by rapid expansion of scientific enterprise. Also, since research institutions exist in society, interactions between scientists, institutions, and society can increase pressures on organizational and individual decisions in ways that can enhance or diminish the attributes of science culture. Such decisions include those related to: research topic, funding, leadership, collaboration, career growth and incentives, knowledge sharing, and stakeholder engagements. The pressures can also generate a climate of perverse incentives for unethical practices[8]. This increases the vulnerability, particularly of young scientists facing intense competition, to compromises in research and scientific integrity principles for personal growth and benefits. Institutions will need to: *(i) replace the passive apprenticeship model of inculcating science culture by a fast track model of active, direct, and explicit instruction and mentoring to early career scientists and supervisors in research integrity, scientific creativity, and scientific* *integrity[9],and (ii)develop leadership capacities to manage external and internal stakeholder pressures, and create work environments in which science culture can be nurtured.*

2.3 Agricultural science culture - the field experiment paradigm and beyond

Agricultural science selectively identifies, integrates, and applies developments in natural sciences, engineering sciences, and social sciences to understand, improve and sustain agricultural systems. However, unlike natural sciences, field experiments are essential in agricultural research, as it has the responsibility to connect with and enhance farming practice. RA Fisher's publication of Design of Experiments in 1935 helped establish the field experiment paradigm to formulate and test hypotheses under natural field variability. In mid-twentieth century, the land grant system in USA institutionalized systematic use of randomized field experimental designs and farmer field trials in all sub disciplines of agricultural science, to accelerate science and technology development, and rapidly scale their adoption by farmers. Despite the huge success of the field experiment paradigm, its two main limitations were apparent by last quarter of the 20th century[10]:

i. Field experiments are possible only at few representative (soil-climate) locations. Recommended farming practices based on these cannot be precisely downscaled and channeled to heterogeneous small farms, leading to sub-optimal yields or yield gaps.

ii. The design of field experiments can include only a limited number of factors. Non-inclusion of other interactive factors (e.g. crop genetics, local environment, or management practices) excludes resource flows and feedbacks to and from the environment and social systems, which led to failures in anticipating negative externalities of farming practices.

To bridge yield gaps on farms, and reduce environmental and social footprints, agricultural science evolved to complement the field experiment paradigm first with the: (i)holistic systems paradigm of Agricultural Systems Models or the third paradigm of science that integrated field agronomy with simulation (1970s/80s), and later with (ii) data driven knowledge discovery or the fourth paradigm of science, that integrated (i) with advances in data science, sensing technologies, machine learning and AI(>2000s) .

3. SCIENCE CULTURE IN NARS - GREEN REVOLUTION YEARS TO PRESENT

3.1 Science culture of green revolution years

The science culture which evolved in NARS in mid-1960s green revolution years has its foundations in the field experiment paradigm of agricultural science. *Its uniqueness was* *in operationalizing this paradigm in a strategic framework that enabled a programmed co-evolution of research and technology transfer, leading to a rapid transformation of Indian agriculture in a short period of about 4 years.* The essential elements of the framework that established a unique *fit* between research goals, strategy, leadership, institutions, and individual behaviours *to generate a unique agricultural science culture in India included*[14,15]:

- *Higher level leadership* that connected scientists, farmers and policy makers to the greater purpose of national agricultural development.
- *Redesigning the institutional framework* by restructuring ICAR in 1965 into an autonomous national system of research institutions; creating an effective *national grid of coordinated experiments* through All India Coordinated Research Projects (AICRPs)that integrated different disciplines, institutions and environments.
- *Personnel policies* which emphasized high scientific standing in selection of Coordinators of AICRPs, (to ensure respect of peers, seniors, and administrators), and insisting that they engage in own research to guide experiments at different locations.
- *Prior planning* for a worldwide pool of crop germplasm and seeds by timely imports and creating seed corporations; fertilizers at required high intensities for new varieties; and National Demonstrations of new technologies on thousands of farmers' fields.
- *Stimulating individual motivations and behavioural change* by elevating status of agricultural scientists; cultivating a sense of pride and ownership by identifying research with nation building.

The green revolution model created a unique science culture in NARS, distinct from other scientific research establishments in India by fostering:(i) a nation wide problem oriented, interdisciplinary approach to research, (ii) a programmed co-evolution of research and technology transfer to rapidly influence farming practice, and (iii) a farmer-centric public service perspective among scientists.

3.2 Post green revolution –Influence of NARP, NATP, NAIP models on science culture

The science culture of green revolution years enabled NARS to become one of the largest agricultural research systems in the world. Some changes in the green revolution model were made in later years to improve research connect with farming to bridge yield gaps, and address new concerns of sustainability and falling farm incomes. The changes were implemented through three successive World Bank aided projects:

i. National Agricultural Research Project (NARP-1&2, 1978-96)[16], which created a nationwide regional research infrastructure to adapt a decentralized green revolution model in each region of a SAU with greater emphasis on participatory extension;

ii. National Agricultural Technology Project (NATP, 1998-2005)[17], which increased the regionalization to specific production systems (not a single crop) at district level, added the goal of sustainable management of land and water, and strengthened local extension;

iii. National Agricultural Innovation Project (NAIP, 2007-14)[18], which widened the scope of commodity based agricultural research by adding goals of market orientation (productivity + value addition) in PPP consortia mode, and improving farmer livelihoods at village level through integrated farming systems, with NGO partners. *It also institutionalized processes for PPP consortia research, and technology protection and commercialization.*

The field experiment paradigm is central to all three models. But, unlike the centralized approach of green revolution model, and its emphasis on high scientific standing criterion and competitive selection of Coordinators, the Bank supported projects aimed at regionalizing research to village level and emphasized *research process management*. This aligned with the Bank's development project approach and its metrics to increase impact and reduce uncertainties and risks by: (i) identifying, at project proposal stage itself, clearly defined goals, outputs, outcomes, milestones, methods, personnel and capabilities needed; (ii) monitor progress toward outputs and milestones in execution stage; and (iii) after the project is over, measure success by its outcome or impact. The difficulty with this approach is that research in complex agricultural systems is uncertain. A workable research strategy for complex systems is to let problems and solutions co-evolve (as in the green revolution model). The Bank's approach gave little flexibility to creatively explore new science frontiers or make mid-course corrections. Further, efforts to institutionalize new research paradigms of on-farm, production/farming systems, and market orientation, were not backed by scalable theoretical frameworks or institutional frameworks that could be internalized in science culture of NARS. As a result, expected gains in productivity (NARP), sustainability (NATP), or market orientation (NAIP) were not realized. This led to *increasingly greater dependence on extension based on research done several years earlier,* for impact at regional levels.

However, the need to connect research more directly with local farming conditions and the participatory processes of technology transfer have become strongly embedded in science culture of NARS. This is reflected increasing prominence of KVKs and ATMAs for transfer of technology to farms, and a robust support system for real-time weather-based agro-advisories and contingency planning at district and block levels.

4. PERSONNEL POLICIES INFLUENCE ON SCIENCE CULTURE

ICAR created the all India Agricultural Research Service (ARS) in 1975. Its original personnel policies (1975-86) allowed scientists to rise to highest salary level in ICAR without shifting to managerial positions. *In principle,* the policy enabled entry level scientists to be incubated in agriculture science culture with good mentoring support and attain high scientific standing over 15-20 years, before taking on managerial positions. But, before these policies could be tested, ICAR adopted UGC policies of 1989 (effective 1986), 1999 (effective 1997), and 2011 (effective 2009), with frequent changes to criteria and scorecards for performance reviews and selections to senior positions. The scorecards[20] divide a scientist's performance into many activities and arbitrarily assign and *cap* scores for each activity, thus *limiting the scope for striving for excellence in research*.

Frequent changes in personnel policies and scorecards have resulted in the sense of ownership and pride in research being overtaken by fears of career stagnation, which motivated young scientists towards short term career goals. The system is also *vulnerable for perverse incentives and gaming* by both scientists and research managers, as it enables them to hide behind easily achievable objectives. Early career scientists lobby for inclusion in many research projects, authorship in publications on a quid pro quo basis (bypassing authorship criteria and ethics), and for formal inclusion in non-research roles to make up scorecard points. The performance review system has also drawn some private journals with questionable editorial and review practices into the lobbying and gaming process for commercial advantage. At higher level, the system allows research managers to hide behind rules, defend status-quo or lower standards and judge all researchers indiscriminately as 'very good or outstanding'.

Devising effective personnel policies and performance review systems will always be a work in progress. But, *(i) putting greater faith in expert judgment despite its inexactness and proneness to error, (ii) greater focus on people by giving due credit to scientific creativity, intellectual excellence, research quality, research risks, collaboration, mentoring younger scientists, and (iii) ensuring consistency of review processes and criteria, will allow personnel policies to support continuous improvements in research culture in NARS.*

5. DRIVERS OF ENHANCED SCIENCE CULTURE IN NARS

The evolving landscape of agricultural research and farming globally and in India points to four key drivers for enhancing the science culture in institutions of NARS:

i. *Urgency for demand-driven innovation for sustainable and smart agriculture on heterogeneous small farms:* Creatively anticipating rapidly changing consumer preferences[21], and leveraging disruptions at convergence of new sciences and technologies, data sciences,[22,23] and paradigms (section 2.3), can scale real-time, two-way flow of data and knowledge between heterogeneous small farms and research labs. This allows problems and solutions to *co-evolve in continuous cycles* to enable smart agriculture on small farms.[24] The two-way flows will also enable a holistic understanding of agricultural systems at different spatial and time scales to anticipate and manage negative externalities from agriculture and address sustainability concerns. The Digital India Network can facilitate data and knowledge two-way flows in real time.

ii. *Urgency for NARS to seamlessly integrate with the emerging complex innovation web:* Corporate industry and agri-tech entrepreneurship are key participants in agricultural research and innovation. R&D investments of agribusiness multinationals are far higher than public investments. Agri-tech start-ups in India have also attracted high investment (40% of public agri-research expenditure during 2013-17)[25,26]. This implies that the technology generation and transfer cycle in NARS must complement its present public service perspective with commercial agribusiness and start-up perspectives.

iii. *Urgency to responsibly connect with a transforming and demanding society:* Pressures on NARS to bridge knowledge gaps in policy and regulation have begun to intensify, as policy urgency shifts from productivity to farmer prosperity, consumer health and safety, climate change mitigation, water and environmental security, soil health, and sustainable development. Recent directives to double farmers' incomes by 2022 in the face of climate and market risks, reduce GHG emission levels to limit global average temperature increases to 1.5°C by 2100, and ensure risk cover for farmers through insurance, are some examples. These point to (i) need for more structured science-policy-society interactions on specific public and scientific concerns, and (ii) ensuring that expert advice on policies and regulations is precise and includes associated uncertainties and risks. Advice based on current field experiment paradigm is too generalized to support policy needs.

iv. *Urgency to navigate the steep learning curve of individuals, teams, and institutions:* The competencies required to internalize the third and fourth paradigms of science (simulation, new sciences, data sciences, computer sciences, engineering sciences, behavioural sciences, mathematics, and AI) in agricultural science, are not readily available in NARS. The need is to develop capacities to effectively learn, interface, and collaborate with specialists in these domains in universities, technology institutions, corporates and startups. Agricultural scientists must not only learn to work in interdisciplinary teams, *they must also see real value in becoming transdisciplinary entities on their own, and in taking on more multidimensional roles in scientific enterprise. This is a very steep learning curve for individuals, leaders and institutions.*

6. POLICY PATHWAYS TO ENHANCE THE SCIENCE CULTURE IN NARS

A thriving science culture in agricultural research institutions can be nurtured and sustained only if its polices, processes and decisions, and behavioural responses of members are anchored on a firm foundation of explicit guiding principles to guide the organization under all circumstances. Based on such principles a systematic and transparent framework of policies, institutional mechanisms, and behavioural responses is designed to internalize the new perspectives, paradigms, mindsets, competencies and behaviours needed to address the challenges of the emerging agricultural research and farming landscape.

6.1 Guiding principles

- The challenges of emerging agricultural research and farming landscape need to be reflected in research funding, leadership selections, governance, personnel policies, learning systems, and technology transfer systems.
- Science culture needs to be nurtured and sustained, not just managed. This requires a joint effort by scientists, institutions,and external stakeholders to simultaneously nurture its core attributes: research integrity (doing the science right), scientific creativity (getting innovation right), and scientific integrity (ensuring that society and humanity get it right).
- Establishing a culture of *continuous learning* is necessary for individual scientists to become transdisciplinary and work creatively in teams at convergence of new sciences and paradigms.
- Most important from research integrity perspective is the individual scientist, particularly young scientists and early stage mentors. Institutions must fast-track explicit and continuous training in research integrity and professional ethics at all levels.
- Scientific creativity thrives in open, interdisciplinary and transdisciplinary interactive teams in a work culture of free flowing hierarchy. Targeted training must be provided in emotional intelligence and other skills required to generate such working environments.
- The most important from a scientific integrity perspective is the institutional leadership, followed by team leadership and the individual scientist. Leaders must learn to engage in *objective science communication* to effectively inform public policy.
- *Performance evaluation, recruitment, and incentive systems need to reflect higher confidence in integrity of experts and scientific judgments* on research excellence,

creativity, learning, risks/uncertainties, and intellectual and potential innovation impact; contributions to mentoring, peer reviews, and activities which reinforce research integrity, scientific creativity and innovation.

6.2 Policy, Institutional and behavioural pathways

Science culture attribute and policy objective	**Policy, institutional, and behavioural pathways to enhance the science culture**		
	Policy	**Institutional**	**Individual behavioural**
Research integrity <u>*Objective:*</u> *Fast track learning and implementation of research inteegrity principles and behaviours in agricultural research institutions*	*Formulate, and periodically update, institutional policies on research integrity and professional ethics, that enable both scientists and public to understand clearly the principled behaviours expected for:* • conducting and reporting research • reporting research misconduct • actions to be taken for alleged research misconduct, and • protection of whistleblowers on research misconduct	• *Widely communicate research integrity policy statements* (web sites, labs, field sites, lab notebooks, reports) to emphasize significance attached by institution to principles and practice of research integrity and ethics • Prioritize & sustain research integrity by creating mechanisms for: • Rigorous reporting, verification and peer review systems • Efficient detection of plagiarism, falsification, or misrepresentation • Avoiding conflicts of interest • More responsible approaches to publishing and technology transfer • Improving transparency in engagement with stakeholders • Investigating and taking stringent action against research misconduct • Continuous training on above • Study research integrity practices of other institutions to identify transferable good practices	• Understand and identify with institutional purpose, vision, and mission • Commit and adhere to research integrity practices and ethics policies of institution & discipline • Understand that research misconduct is detrimental to self, science, institution, and society • Continuously update and reflect on the state-of-art of own discipline and related sciences, the purpose of the research, its connect with farming, and the greater good to humanity it serves • Be responsible for the research process and sensitive to needs of stakeholders • Continuously improve scientific writing and communication skills

	Prioritize and facilitate fast track training of *early career scientists* (PhD students and entry level scientists) *in research integrity principles and practices*	• Develop an accredited *online course(s) on Research Integrity and Professional Ethics in Agricultural Research* and provide related resources for learning • Prescribe eligibility criteria to qualify in accredited course on Research Integrity before initiating research • Update course content and resources periodically	• Continuously train to update and internalize the principles of research integrity
	Prioritize and facilitate fast track training of *mid-career scientists* (PhD supervisors and PIs of projects) in *research mentorship*	• Develop accredited online training course(s) on Research Mentorship Best Practices for Agricultural Research and provide related learning resources • Prescribe eligibility criteria to qualify in a short accredited course/training in research mentorship before taking up the role of PhD guide or PI • Update the course content and resources periodically	• Lead by example • Develop emotional intelligence skills • Respect and treat mentees like colleagues • Demand research rigour, accountability for time, research progress, and direction • Create opportunities for regular candid scientific interactions within group and with other peers
	Define authorship criteria and credit sharing policies, standards and best practices based on principles of research integrity	• Develop and publicize authorship criteria and standards, and best practice guidelines grounded in research integrity principles, in association with scientists, disciplinary societies, and journal publishers (e.g. *Contributor roles taxonomy - CRediT taxonomy), being adopted widely by journals to define author contributions* [27]) • Devise disincentives to discourage honorary/ ghost authorship	• Understand that authorship implies both credit and accountability • Strictly adhere to institutional authorship criteria and standards • Resolve authorship issues through discussion early in research process

	Personnel policies for recruitment, promotions and incentives must reflect judgment of research excellence, research integrity, and contributions to research mentoring	• Design recruitment and performance evaluation systems based on expert judgement of actual research work done and challenges addressed creatively to reflect: • Research content and quality, rigour, risks/ uncertainties, learning, and intellectual and innovation impact of the research • Professional practices like mentoring and peer reviews which • Develop training systems to continuously support early career, mid career and senior scientists for enhancing research integrity and professional growth.	• Recognize that recruitment and career advancement decisions based on simple metrics undermine incentives to address challenging problems or enter new areas of research • Develop confidence in integrity of expert judgment based evaluation systems • Identify a mentor or role model to support learning and professional growth
Scientific creativity *Objective:* *Fast tracking a culture of individual and collective scientific creativity in agricultural research institutions to stimulate scientific advances and innovation*	• Formulation of research policies that help to continuously: • prioritize, encourage, balance individual, small team, and large team research • identify potential challenging areas and problems for new research • anticipate and track research outputs for potential scale up and impact • enable *ease of collaboration* with national and international institutions, agribusiness, tech startups, and organizations	• Design enabling work environments that increase opportunities to : • Raise domain expertise of individual scientists • Explore new ideas, disciplines and problems • Enable both small and large cross-disciplinary team science initiatives • Create a work environment of 'free-flow hierarchy' of openness, respect, mutual confidence, and continuous communication and information sharing by: • creating shared research facilities • cross-disciplinary training programs • other interaction avenues.	• Develop wider scientific perspectives and connect with the larger purpose • Develop an appreciation for the scope for intellectual excellence and scientific creativity available for creating value at all links of agricultural value chains • Develop expertise in at least one additional discipline • Read, read and read, not only scientific journals and books, but insightful publications by great scientists, science academies, philosophers, , public policy organizations, business leaders, think tanks- to develop the intellectual capacity to understand and frame research problems in relevant contexts

		• Develop systems to monitor and track research breakthroughs and accelerate the innovation cycle in collaboration with public, private and entrepreneurial organizations	
	Personnel policies for creating an enabling environment for enhancing scientific creativity	• Design training programmes and learning resources for enhancingemotional intelligence skills at all career levels • Develop principles and criteria for allocating credit for team-based work for promotions or selections • Create opportunities to learn/train in team leadership and team effectiveness • Incentivize early career scientists to engage in collaboration and transdisciplinary research	• Recognize importance of emotional intelligence skills empower and advance creativity of teams innovation • Develop shared understanding of core team processes for team effectiveness • Acquire team work and leadership skills from training and other resourcesto enhance science
Scientific integrity *Objective:* *Ensure quality, authenticity and transparency of scientific information for public policy*	Develop scientific integrity policies that ensure transparency in the preparation, identification, and *objective communication* of *authentic* scientific information to policy makers and public, together with its limitations, risks and uncertainties	• Design and widely communicate scientific integrity policy and code of conduct for scientific integrity • Develop mechanisms to : • access and use scientific data and information for public policy • assess limits, uncertainties and risks of research knowledge • Design training programmes and resources for scientists in objective communication of research resultsfor policy and for general public	• Understand and abide by the code of ethics of scientific integrity for policy advice • Develop expertise in objective science communication to policy makers and public • Develop expertise in including limitations, uncertainties and incompleteness of the scientific knowledge in policy communications • Avoid conflicts of interest in communications with policy makers and the public

		• Institutionalize mechanisms for structured interactions with policy makers and general public about current and future research and its potential implications	
	Personnel policies	• Institutionalize training in : • scientific integrity at different levels • objective science communication for informing policy makers and public • Incentivize contributions to public policy and science-policy-public interactions	
Continuous trans-disciplinary learning *Objective: Create opportunities for continuous interdisciplinary and transdisciplinary learning and collaboration in research and innovation*	Policies that enable and incentivize both formal and informal continuous, interdisciplinary and transdisciplinary learning and collaboration	• Develop institutional mechanisms for transdisciplinary learning and collaboration by decreasing friction and building bridges across disciplines through cultural changes and funding • Develop a virtual learning architecture for continuous interdisciplinary and transdisciplinary learning • Dedicate resources to enable scientists to access required learning resources from diverse national and international sources at every stage of their careers. • Design training programmes and learning resources to inculcate skills in computational thinking, and knowledge synthesis and integration	• Recognize that present day important problems need transdisciplinary knowledge and skills for their solution • Develop skills in recognizing important problems that need transdisciplinary and interdisciplinary approaches • Develop an attitude of humility and seek opportunities for continuous learning across multiple disciplines • Develop capacities for computational and synthetic thinking, and knowledge integration

	Personnel policies	• Incentivize learning new disciplines and collaboration with due recognitions in selections, career advancement, and awards/rewards • Develop resources for targeted Leadership training to enable interdisciplinary and trans-disciplinary learning, research and innovation	
Sustaining science culture attributes and accelerating innovation *Objective:* *Nurture and sustain the attributes of science culture to increase the ease of doing research and accelerating innovation*	• Discourage policies that lead to fragmentation of institutions and unfettered expansion to ensure critical mass of interdisciplinary scientists and resources • Sensitize early career scientists to the needs of stakeholders • Redesign administration and funding systems to enable ease of scientific research and innovation by: • providing for high quality infrastructure that meets the needs of modern vibrant scientific institutions • ensuring more enabling and efficient procurement and related processes • facilitating national, international and public-private-farmer-entrepreneur collaborations • access to learning resources from diverse sources • enabling professional interactions through national and international conferences, workshops, training, etc. • providing a platform for candid discussions on institutional goals, strategies, processes, and individual concerns • Ensuring transparency of research funding and evaluation • Personnel policies must put in place processes for: • filling vacancies in time to ensure continuity of research and keep scientists motivated • transparency in selection and career advancement, and • leadership succession planning		• Develop capacities to articulate views, concerns, and suggestions to improve institutional processes for enabling ease of research, transdisciplinary learning, and enhancing scientific creativity through collaboration • Develop empathy and good working relationships with colleagues in administration and non-research functions

The best public research institutional structures that can stimulate innovation and sustain a culture of research integrity, scientific creativity, scientific integrity, and transdisciplinary learning across the four paradigms of science, can be available only in university like environments . Universities have diverse faculty and most importantly a continuous flow of motivated young PhD students dedicated to intense research over extended periods. Many technology start-ups also have their roots in university laboratories. Such cultures *are not easy to develop and maintain in exclusively research institutions where Divisions or Specialization inevitably congregate to silos. In recognition of this, several exclusively research institutions, globally and in India, and corporates are transitioning to research university models (e.g., AcSIR of CSIR). Institutions of ICAR too can consider similar institutional models to fast track nurturing a thriving, impactful science culture in ICAR/ NARS.*

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List of Participants

Prof Panjab Singh, President, NAAS

Dr R.B. Singh, Former President, NAAS

Dr A.K. Srivastava, Vice President, NAAS

Dr A.K. Singh, Secretary, NAAS

Dr R.K. Jain, Treasurer, NAAS

Dr Kusumakar Sharma, Editor, NAAS and Former ADG, ICAR, Greater Noida

Dr N.H. Rao, Former Joint Director (R), NAARM, Hyderabad

Dr (Ms) Rintu Banerjee, Professor, Deptt of A&FE, IIT, Kharagpur

Dr Mahesh Chander, JD (Res), ICAR-IVRI, Izatnagar

Dr Pardeep K. Chhuneja, Head, Department of Entomology, PAU, Ludhiana

Dr P.K. Joshi, Former Director - South Asia, D-7, Pusa Apartments, Rohini, New Delhi

Dr Arvind Kumar, Vice Chancellor, CAU, Jhansi

Dr Biswapati Mandal, Professor, Bidhan Chandra Krishi Viswavidyalaya, Kalyani

Dr Suresh Pal, Director, ICAR-NIAP, New Delhi

Dr Himanshu Pathak, Director, ICAR-NRRI, Cuttack

Dr B.S. Prakash, ADG (Animal Sciences), ICAR, New Delhi

Dr Rajender Prasad, Principal Scientist, IASRI, New Delhi

Dr V. Praveen Rao, Vice Chancellor , PJTSAU, Hyderabad

Dr J.S. Sandhu, VC, Narendra Dev University of A&T, Faizabad

Dr R.S. Sangwan, Director AcSIR, CSIR, HRDC Campus, Ghaziabad

Dr N.K. Singh, National Professor, ICAR-NRCPB, New Delhi

Dr Man Singh, Professor/Project Director, WTC, IARI, New Delhi

Dr A.K. Singh, DDG (Ag. Extn), ICAR, Krishi Bhawan, New Delhi

Dr A.K. Singh, DDG (Ag. Horticutlure), ICAR, Krishi Bhawan, New Delhi

Dr A.K. Singh, Joint Director (Research), IARI, New Delhi

Dr R.K. Singh, Director, ICAR-IVRI, Izatnagar

Dr Ramesh V. Sonti, Director, NIPGR, Delhi

Dr S.K. Sopory, Former VC, JNU, New Delhi

Dr M.P. Yadav, Former Vice Chancellor, IVRI, Bareilly

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