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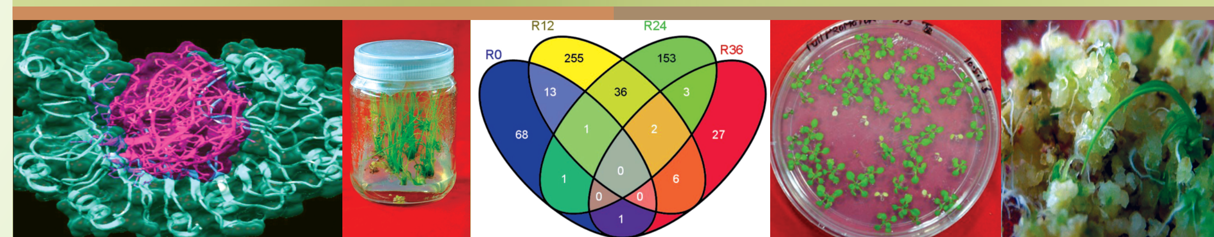
किसानों का हमसफर
भारतीय कृषि अनुसंधान परिषद

Agrisearch with a human touch

Vision 2050



भाकृअनुप
ICAR

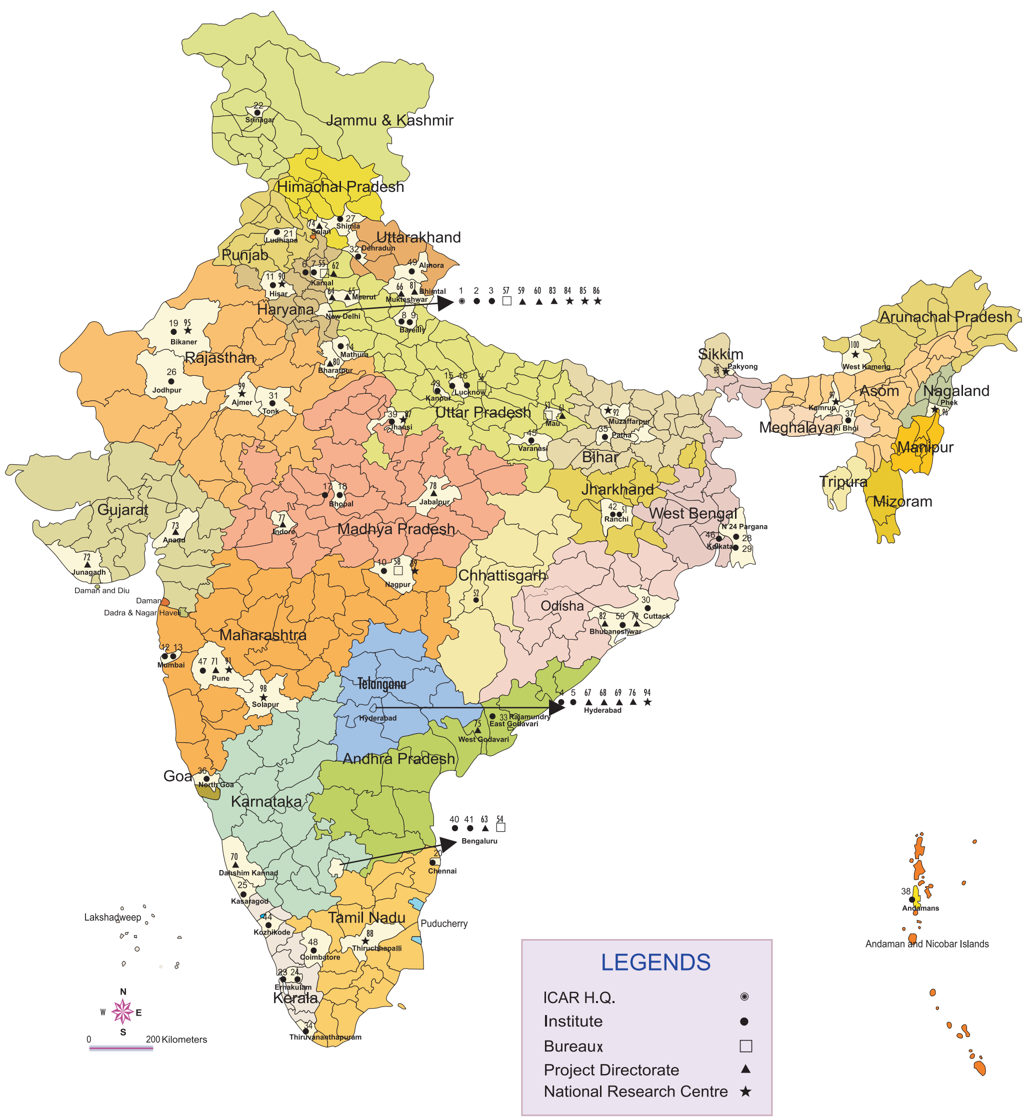
Indian Institute of Agricultural Biotechnology

Indian Council of Agricultural Research

ICAR

INDIAN COUNCIL OF AGRICULTURAL RESEARCH

Institutes, Bureaux, Directorates and National Research Centres



• 64 Research Institutes • 6 Bureaux • 15 National Research Centres • 15 Project Directorates

ICAR

INDIAN COUNCIL OF AGRICULTURAL RESEARCH

Agricultural Universities

LEGENDS

- State Agricultural Universities ○
- Central Universities with Agricultural faculties ■
- Central Agricultural Universities ☆
- Deemed Universities ●

Vision 2050

Indian Institute of Agricultural Biotechnology
(Indian Council of Agricultural Research)
Ghar Khatanga, Ranchi

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Printed : July 2015

संदेश

भारतीय सभ्यता कृषि विकास की एक आधार रही है और आज भी हमारे देश में एक सुदृढ़ कृषि व्यवस्था मौजूद है जिसका राष्ट्रीय सकल घरेलू उत्पाद और रोजगार में प्रमुख योगदान है। ग्रामीण युवाओं का बड़े पैमाने पर, विशेष रूप से शहरी क्षेत्रों में प्रवास होने के बावजूद, देश की लगभग दो–तिहाई आबादी के लिए आजीविका के साधन के रूप में, प्रत्यक्ष या अप्रत्यक्ष, कृषि की भूमिका में कोई बदलाव होने की उम्मीद नहीं की जाती है। अतः खाद्य, पोषण, पर्यावरण, आजीविका सुरक्षा के लिए तथा समावेशी विकास हासिल करने के लिए कृषि क्षेत्र में स्थायी विकास बहुत जरूरी है।

पिछले 50 वर्षों के दौरान हमारे कृषि अनुसंधान द्वारा सृजित की गई प्रौद्योगिकियों से भारतीय कृषि में बदलाव आया है। तथापि, भौतिक रूप से (मृदा, जल, जलवायु), बायोलोजिकल रूप से (जैव विविधता, हॉस्ट–परजीवी संबंध), अनुसंधान एवं शिक्षा में बदलाव के चलते तथा सूचना, ज्ञान और नीति एवं निवेश (जो कृषि उत्पादन को प्रभावित करने वाले कारक हैं) आज भी एक चुनौती बने हुए हैं। उत्पादन के परिवेश में बदलाव हमेशा ही होते आए हैं, परन्तु जिस गति से यह हो रहे हैं, वह एक चिंता का विषय है जो उपयुक्त प्रौद्योगिकी विकल्पों के आधार पर कृषि प्रणाली को और अधिक मजबूत करने की मांग करते हैं।

पिछली प्रवृत्तियों से सबक लेते हुए हम निश्चित रूप से भावी बेहतर कृषि परिदृश्य की कल्पना कर सकते हैं, जिसके लिए हमें विभिन्न तकनीकों और आकलनों के मॉडलों का उपयोग करना होगा तथा भविष्य के लिए एक ब्लूप्रिंट तैयार करना होगा। इसमें कोई संदेह नहीं है कि विज्ञान, प्रौद्योगिकी, सूचना, ज्ञान–जानकारी, सक्षम मानव संसाधन और निवेशों का बढ़ता प्रयोग भावी वृद्धि और विकास के प्रमुख निर्धारक होंगे।

इस संदर्भ में, भारतीय कृषि अनुसंधान परिषद के संस्थानों के लिए विजन–2050 की रूपरेखा तैयार की गई है। यह आशा की जाती है कि वर्तमान और उभरते परिदृश्य का बेहतर रूप से किया गया मूल्यांकन, मौजूदा नए अवसर और कृषि क्षेत्र की स्थायी वृद्धि और विकास के लिए आगामी दशकों हेतु प्रासंगिक अनुसंधान संबंधी मुद्दे तथा कार्यनीतिक फ्रेमवर्क काफी उपयोगी साबित होंगे।

(राधा मोहन सिंह)
केन्द्रीय कृषि मंत्री, भारत सरकार

Foreword

Indian Council of Agricultural Research, since inception in the year 1929, is spearheading national programmes on agricultural research, higher education and frontline extension through a network of Research Institutes, Agricultural Universities, All India Coordinated Research Projects and Krishi Vigyan Kendras to develop and demonstrate new technologies, as also to develop competent human resource for strengthening agriculture in all its dimensions, in the country. The science and technology-led development in agriculture has resulted in manifold enhancement in productivity and production of different crops and commodities to match the pace of growth in food demand.

Agricultural production environment, being a dynamic entity, has kept evolving continuously. The present phase of changes being encountered by the agricultural sector, such as reducing availability of quality water, nutrient deficiency in soils, climate change, farm energy availability, loss of biodiversity, emergence of new pest and diseases, fragmentation of farms, rural-urban migration, coupled with new IPRs and trade regulations, are some of the new challenges.

These changes impacting agriculture call for a paradigm shift in our research approach. We have to harness the potential of modern science, encourage innovations in technology generation, and provide for an enabling policy and investment support. Some of the critical areas as genomics, molecular breeding, diagnostics and vaccines, nanotechnology, secondary agriculture, farm mechanization, energy, and technology dissemination need to be given priority. Multi-disciplinary and multi-institutional research will be of paramount importance, given the fact that technology generation is increasingly getting knowledge and capital intensive. Our institutions of agricultural research and education must attain highest levels of excellence in development of technologies and competent human resource to effectively deal with the changing scenario.

Vision-2050 document of ICAR-Indian Institute of Agricultural Biotechnology (IIAB), Ranchi has been prepared, based on a comprehensive assessment of past and present trends in factors that impact agriculture, to visualise scenario 35 years hence, towards science-led sustainable development of agriculture.

We are hopeful that in the years ahead, Vision-2050 would prove to be valuable in guiding our efforts in agricultural R&D and also for the young scientists who would shoulder the responsibility to generate farm technologies in future for food, nutrition, livelihood and environmental security of the billion plus population of the country, for all times to come.

(S. AYYAPPAN)
Secretary, Department of Agricultural Research & Education (DARE)
and Director-General, Indian Council of Agricultural Research (ICAR)
Krishi Bhavan, Dr Rajendra Prasad Road,
New Delhi 110 001

Preface

The Indian population is growing at an alarming rate and is projected to reach more than one and half billion by 2050. Dwindling resources, shrinkage of arable land and global climate change does not augur well in attaining the ultimate goal of providing food security for the entire population. Nutritional security requirements will also burden the already stressed resources and subsequently lead to reduced crop/ animal productivity. To achieve this goal, technological interventions in agriculture are needed to attain this target of providing enough food for the growing hungry mouths.

Indian Council of Agricultural Research (ICAR) has the responsibility to facilitate the efforts of attaining National food security through its R&D support. To meet the technological challenges in improving the crop and animal productivity, ICAR- Indian Institute of Agricultural Biotechnology (IIAB) was established at Ranchi and destined to lead the national efforts in research and education (R&E) in biotechnology.

The major areas that would be of paramount significance in agriculture to address the needs of access to food in future are: management and protection; breeding and biotechnology and IT and engineering. The major contribution of agricultural biotechnology to the above goal would be facilitating a shift from chemical-intensive crop production to bio- intensive agriculture by providing appropriately engineered plant varieties, biological products and modified genomes to make the organisms productive, efficient and geared to combat all the climatic changes. Decoding of the genomes of indigenous plant and animal species will lead to the identification of new genes and promoters and densely populated molecular maps. The forthcoming decades will also witness convergence of disciplines like molecular biology, computational biology, nanotechnology, and engineering and information technology which will enhance knowledge and facilitate product development.

All the foregoing considerations of driving forces and emerging global scenario, brings out the dominant role biotechnology would be playing in future. It is therefore important that we should be fully prepared in terms of research and human resource development in different domains of agricultural biotechnology. It is hoped that this

Vision 2050 document puts this domain in the right perspective to enable the managers and policy makers to provide ample importance and support to this institute, to enable it evolve into a centre of excellence at the national and global level.

The inputs provided by the scientific team of IIAB and Dr. PK Jain and Dr. Kishor Gaikwad of NRCPB as well as the critical comments of the members of Research Advisory Committee namely, Dr. C D Mayee, Dr. George John, Dr. N K Singh, have been invaluable in shaping this document. We also acknowledge the technical input provided by Dr. S. Ayyappan, Secretary DARE and DG, ICAR, Dr. JS Sandhu, DDG (CS) and Dr. JS Chauhan, ADG (Seeds) at different stages of preparation of this document.

Dr. R. Ramani
Dr. T.R. Sharma
Officer on Special Duty
IIAB, Ranchi

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Context

India is facing a dual challenge of feeding the rapidly growing population with limited cultivable land and enhanced burden on natural resources, leading to less productivity and sustainability. It is now believed that the conventional approaches alone cannot deliver the desired output and the frontier areas of biotechnology and nanotechnology could provide path breaking solutions to overcome the above challenges. The potential of biotechnological interventions have already been demonstrated through the commercialized Genetically Modified (GM) crops. The first-generation GM crops involved genes for insect-resistance and herbicide-tolerance. Since their first introduction in 1996, the estimated cumulative area under GM crops is around 0.25 bn ha throughout the world. In India Bt-cotton now occupies >90% of cultivable area under cotton and there is a significant reduction in pesticide use, thereby improving environmental health and income of the cotton growing farmers.

There is thus an urgent need to establish a dedicated research and education institution in the country to provide desired impetus to the biotechnology-mediated revolution in agriculture. Establishment of the ICAR-Indian Institute of Agricultural Biotechnology (IIAB) is an important step in this direction for taking basic and strategic research in the realm of biotechnology and generate trained and specialized quality human resource in the frontier areas of biological research. This institute, slated to be a deemed university, dedicated to plant, animal, fish and microbial biotechnology under a single umbrella. It would serve as a national center of excellence in Agricultural Biotechnology for undertaking cutting edge research and impart education at post graduate, doctoral and post-doctoral levels and capacity building. It would also act as a platform for interaction and networking of national and international institutions in the field and provide appropriate support for policy framework to forge partnerships with different stakeholders for the development and delivery of products and processes of Agricultural Biotechnology. The institute is also envisaged to facilitate matters related to regulatory issues and to disseminate knowledge about the biotechnological products to users and the public.

Biotechnology, in conjunction with information technology (IT) is going to be a driver for ushering agricultural revolution in the country to meet and sustain the food and nutritional requirement of growing

Indian population. The Institute is strategically located in Jharkhand, a part of Eastern Hills and Plateau zone, offering unique agricultural challenges to be addressed through biotechnology.

In view of above considerations, the vision, the mission and the mandate of the Institute have been spelt out.

VISION

Support Indian NARS through generation of need-based competent academic manpower and undertake basic and strategic biotechnological research to achieve a robust, reliant, safe, efficient and sustainable agricultural production for a healthy nation.

MISSION

Basic and strategic research and human resource capacity building in the frontier areas of agricultural biotechnology and allied disciplines.

MANDATE

- Serve as national centre of excellence in agricultural biotechnology for undertaking cutting-edge research, post-graduate, doctoral and post-doctoral education and capacity building
- Create platform for interaction and networking of national and international institutions for the application of Biotechnology in agriculture and provide appropriate support for policy framework
- Forge partnerships with different stakeholders for the development and delivery of products and processes of agricultural biotechnology
- Entrepreneurial and other relevant areas for furthering the application of agricultural biotechnology

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Challenges

The biggest challenge for Indian agriculture is the ever growing population. As per UN projections (2012), Indian population would add around 400 mn and grow to 1.62 bn by 2050.Rapid urbanization would be marked in countries like India, which would add 404 million urban dwellers by 2050. There will also be changes in the requirement of various food commodities due to differences in food habits and dietary shifts, driven mainly by the demands of the growing middle-class and urban population.

Thus agriculture sector will have to respond to the increasing and changing needs of the growing population. At the same time, multiple challenges affect agricultural productivity including climate change; land degradation, availability and fragmentation; water and energy crises; and biodiversity loss. India is already in low agriculture productivity category coupled with low water availability. Since the scope for expanding the cropped area is limited, the only way to reach desired level of production has to be through productivity improvement.

Significant adverse impact of pollutants on the productivity of major crops has been demonstrated in Indian conditions. Agricultural crops, fishes and animals (ACFA) will be exposed to greater threat of contamination of toxic elements and chemicals, which has to be addressed as these would further bring down productivity of the livestock. Besides direct effect of climate change due to elevated temperature and changes in precipitation patterns, agriculture could be expected to witness increased frequencies of new pests and disease outbreaks affecting ACFA. Thus, early and efficient detection and prophylaxis and treatment of diseases and pests will have to be given greater emphasis in future.

The challenges in the realm of biotechnology can be attributed to three domains. One is the research domain, which is challenging in view of the intricacies involved in technology development as well as high expectations of output from this domain. There is high level of private participation in biotech research worldwide and their investments are also very high. The Indian biotechnology research also has to bridge the gap with advanced level of work going on in developed countries through adequate funding especially to public institutions. Therefore, we have to equip ourselves better both on skilled manpower and research areas to address country-specific issues and drive the biotech research programmes in the right direction in view of prevailing and emerging scenario. The second domain is government regulation of biotech processes and products. The process of getting clearance for commercially-ready product is rather tedious. The case of Aqua Advantage Salmon developed in 1989 illustrates the challenge of getting clearance for commercialization of an established technology; it also provides insights into the kind of requirements and underscores the need for careful analyses of implications and acceptability risk of any GM organism, at the conceptual stage. The third domain is public perception and acceptance of biotech products, especially GM organisms in the present context. Public pressures would influence political considerations and in turn policies. Clearance past regulatory processes is essential and indispensable, but gaining public acceptance can be achieved by systematic and powerful knowledge dissemination and a strong scientific base.

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Operating Environment

Indian agricultural scenario is characterized by fragmented and small land holdings; varied land, soil and climatic conditions; predominantly rainfed cultivation; constrained availability of quality seed and fertilizers; low mechanization level; low productivity; low input efficiency; inadequate storage facilities, poor economic condition of farmers; besides climate change-related problems. Chemical-intensive agriculture is leading to soil degradation and reduced input response, dampening productivity. Principal nutrients in chemical-intensive farming would become costlier in years to come and there is need for paradigm shift in agricultural production systems so that chemical inputs can be reduced without affecting productivity and retaining soil health. Biotechnology could play a major role in providing such a shift. Advanced tools of genomics and bioinformatics can also play pivotal role in developing superior organisms for optimum performance.

The forthcoming decades will continue to witness scenario change, probably at a heightened pace. The agri-challenges will include: global climate change; food and nutritional poverty; land degradation; energy and water scarcity. The regulatory mechanisms would gain dominance, especially in view of introduction of GM organisms in the system. The world, amidst industrial and urban growth, would strive to become greener. Clean technology would become nearly mandatory; impact on environmental quality would be applied in all domains.

Agricultural technology interventions should integrate and catch up with the changing world. Technological revolutions will happen in unprecedented manner within and outside the biotechnological domains. As more and more genomes are sequenced, the wealth of genome sequence data that would be created will require huge investments of human as well as computational resources. Explosive breakthroughs in Information Technology as well as automation including robotics would tremendously influence in fashioning agricultural production systems. They would facilitate development and application of biomolecule-based sensors for monitoring crop, environment, soil, diseases and pests. The future will also witness very cheap IT devices/systems and agricultural biotechnology would leverage such IT strides for better quality and yields of agricultural commodities as well as reducing manpower requirements in agricultural production systems.

Important factors that affect the realization of full potential of GM organisms including tedious and expensive regulatory mechanisms, low-level of awareness and negative public perception of GMOs as well as limited resources in public-funded research institutions need to be addressed on priority.

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New Opportunities

The productivity of agricultural crops is still low in India, compared to a number of other countries. Biotechnology can provide tools/processes/products that would help in increasing crop productivity on the existing land resources through development of high yielding cultivars/animals. It can also lead to development of drought tolerant, flood tolerant, salt tolerant, acidic soil tolerant, disease and insect pest resistant/tolerant crop varieties. It can also be used to develop well-adapted animal and fish genotypes for rapidly changing climatic conditions and reduced greenhouse gases. One major intervention needed in Indian agriculture is to reduce the input requirement, from the present level and achieve a quantum jump in input-output efficiency. Isolation of economically useful microbes from rhizo- and endospheres, their engineering and application in agriculture would provide significant impetus for input reduction. Conventional genetic improvement of crops, animal and fish genetic resources, which is labour intensive and time consuming would be complemented by biotechnological tools and become integral part of all breeding programs, saving time and energy.

New genes and their novel alleles that would be identified, through functional genomics, will have significant economic impact in agriculture. Genetic engineering will assist in incorporation of useful genes in entirely unrelated organisms in a tailored fashion to meet our requirements. Another important challenge would be unthinkable technological advancements in future for which one has to be well prepared. The following is a list of some key areas of agricultural biotechnology that would gain prominence in the forthcoming decades:

- Precise genome editing for getting altered and desired phenotypes across plant, animal, fish and microbial species
- Analysis of individual plant/animal/fish/microbial genome sequences for precise understanding of genotype-phenotype relationship and its application in getting desired products
- Doubling photosynthetic efficiency by gene transfer from microbes/algae; engineering C3 plants to C4
- Designer plants for enhanced nutritional and processing quality without the biosafety concerns
- *In silico* analysis of complex traits, and interactomes across agricultural domains for better productivity

- Nanomaterial and Nanostructure-based biosensors in monitoring, food analysis, pathogen detection, targeted delivery of DNA in genetic engineering and other molecules. Besides producing improved Nanoparticles from the GM plants and microbes
- Biosensors in crop/animal and environment monitoring; pest/disease detection in production systems
- Identification and genetic modification of Plant Growth Promoting Bacteria and their consortia for better crop growth and management of biotic and abiotic stresses
- Biotech-enabled agrowaste/farming-based non-food commodity production technologies such as feeds, biofuels, structural materials, etc.
- Cell-free synthesis systems for evolution of a number of *in vitro* production systems for proteins and unfolding of newer applications in future
- System biology approaches for developing designer plants, animal, fish and microbes

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Goals and Targets

The activities of the Institute can be grouped into two spheres, viz., research and education. The uniqueness of the ICAR-IIAB lies in the unified canvas, enabling convergence of expertise from microbial, plant, fish and animal sciences. Tremendous increase in requirement of professional manpower in the forthcoming decades is foreseen in agricultural biotechnology in view of the global trend. The biotechnology is likely to be a prime mover of research in the critical sectors of agriculture and health, in future.

Academic

The institute will be engaged in development of skilled human resources in agricultural biotechnology with national and international linkages. Besides post-graduate, doctoral and post-doctoral programs, the Institute will also organize regular short, medium and long term training programs as well as international bridge degree programs, including dual/sandwich programs, etc. Networking and time management would become important in academic programs in future. The academic programs envisaged in the initial phase are: Genomics and Molecular Breeding, Genetic Engineering, Bioinformatics, Molecular Diagnostics and Prophylactics and Nanobiotechnology

The emerging science like systems biology will be required to address complex problems in agricultural biotechnology. The advances in omics technologies including single-cell omics, genome sequence data would lead to greater interest in predictive computational models. Some anticipated fields of educational courses in future decades are listed in the box.

Research

The research programs would undergo dynamic changes within the time frame under consideration. The advances in information technology especially computational science, nanotechnology and engineering would have greatest influence on the nature of biotechnological research programs that would be unfolding in the next few decades.

Current Trends

GMOs: Transgenic crops were commercialized in 1996, which culminated into 1.7 million farmers growing them in about 170 m ha, across twenty-nine countries, by 2012. It is estimated that the land area under transgenic crops would double every 5-7 years. A number of GM crops are in the pipeline from different labs across the world to improve the nutrient content of food crops such as rice, sorghum, banana, soybean and cassava. Aqua Advantage Salmon is another example of the potential of genetic engineering in improving the productivity. However, despite all advantages the regulatory processes and public resistance have slowed down the pace of adoption of GM crops. It is expected that public perception will change slowly over a period of time and tested GMOs would gain acceptance. It could therefore be assumed that there would be paradigm shift in the environmental movement against GMOs leading to greater acceptance. The research efforts on useful GMOs would therefore be expected to continue. Other envisaged areas in agriculturally important microbes, plant, fish and other animals from short-term perspective are:

- Genes, gene systems and their delivery systems for improving productivity, quality and resilience to biotic and abiotic stresses
- Allele mining and identification of novel genes and promoters for useful agricultural traits
- Bioprospecting of plant, microbe, animal and fish genetic resources for useful genes
- Functional genomics, proteomics, transcriptomics, metabolomics, interactomics and phenomics
- Nanobiotechnology-based agricultural input delivery systems
- Development of high throughput molecular markers, strategies, diagnostic techniques/kits for various pathogens and diseases
- Development of vaccines and novel delivery systems and prophylactic measures against economically important diseases of finfish and animal
- Identification of novel biocontrol agents and development of new class of biopesticides
- Biofortification systems for plants, fish and animals
- Sequencing of agriculturally important organisms indigenous to India
- Bio waste management and production of valuable compounds

Future Trends

- Genome editing: Genome editing is a powerful tool for altering the gene sequences and manipulating them. Recent development of CRISPR-Cas system is a pointer towards the kind of precision genome editing can unfold in future. Genome editing provides tremendous scope in targeted animal/plant improvement.

- Reverse breeding: It is generally seen that plants/animals bred for superior productivity lose their tolerance to biotic and abiotic stresses. Reverse breeding approach would be helpful in restoring beneficial genes of their wild/ancestral counterparts in the improved varieties/breeds using techniques like engineered meiosis, apomixes, cisgenesis and precision mutagenesis.
- Individual genome sequencing: Technological advances have already ushered the era of cost effective large-scale sequencing projects. Further developments in the field of sequencing as well as quantum leaps in computational capabilities would enable comparison of individual members of population on large scale to detect even single gene differences. This would be greatly helpful in genome editing, gene expression investigations and high density trait specific mapping.
- Application of computational biology: Ultrafast processers would enable modelling to understand gene expressions and physiological/ developmental impact of genome editing through in-silico analysis. Genomic selection for complex traits across the agricultural domains using computation methods would assist in decision making before undertaking genome alterations experiments.
- Plant Growth Promoting Bacteria: Several microbes harboured in the rhizosphere and endosphere significantly affect the growth and health of the plant, and they provide lot of opportunities for biotechnological interventions in future. Plant Growth Promoting Bacteria (PGPB) influences the biomass, nutrition, growth characteristics and resistance of the plant. A limited number of PGPBs are commercially available and their numbers could be expected to grow exponentially. The genome of PGPBs can be engineered to produce the desired results and should receive greater attention in future. They also offer tremendous scope in bioremediation.
- Enhancing photosynthetic efficiency: Genes from photosynthetic microbes and algae would be added to plants which could double the photosynthetic efficiency by utilization of broader spectral range. C3 plants could be engineered for C4 photosynthesis. Computer modelling would facilitate fashioning efficient photosynthesis systems and its implementation.
- Plant immunity: Tremendous changes in transcriptional machinery, induced by pathogen, have been reported in plants. Similarly, insect pest-induced responses in plants are getting increasingly

documented. A deeper understanding of the triggering mechanisms and their control will provide novel approaches for disease and pest management in agriculture.

- Energy efficient food production: Almost one-third of the world's population lives on meat-based diet, while the remaining lives on plant-based one. It has been shown that a system based on meat-based food will require more energy and water as well as land. Producing 1 kg of animal protein would need 100 times more water than producing equal quantity of plant protein. Aquaculture is very promising as the fish converts the feed to protein more efficiently compared to other animal-based systems. Another way out could be a more energy and input-efficient way of producing animal protein. They could also be genetically engineered to incorporate animal protein genes to partially substitute animal protein requirement.
- Cell-free protein synthesis: Protein synthesis Using Recombinant Elements (PURE) has proved to be valuable for high throughput methods for functional genomics and proteomics. Success in cell-free protein synthesis has also opened up new vistas for synthesis of even complex proteins on small scale for research as well as commercial-scale; the latter will unfold a number of unimagined applications in future.
- Stem cell biology: Stem cell research would impact the way research is being carried out in animal system for producing highly efficient milch and meat animals.
- Microbial farming: Significant yields can be obtained by farming microalgae on marginal lands with non-potable water. It has been shown the yields of protein and oil of natural microalgae is much higher than that obtained by conventional terrestrial crops. Microalgae can be easily adopted for production of a number of nutrition supplements including essential fatty acids.
- *In vitro* culturing of cells and embryos: Technological breakthroughs in other domains like precision-controlled automated culture systems would facilitate breakthroughs to breed plants/animals for quality and resilience to biotic and abiotic stresses through cell and embryo culture. Embryo rescue would be very useful in intra- and inter-specific as well as inter-generic transfer of useful genes. Application of embryo rescue for development of superior variety for specific agro-climatic conditions in grapes illustrates the scope of such approach.
- Artificial food: Food processing would make giant strides to improve the taste, texture and shelf life of protein sourced from plant, algal,

and other sources. They could be easily made to mimic the animal-based products. Animal cell cultures can yield a number of useful components for such foods including muscle tissue. Such foods would be typically multi-sourced to meet the desired nutritional, textural and gustatory requirements.

- Unlocking non-coding DNA: The knowledge on non-coding complement of genomes of different organisms is limited, but their proportion is high in organisms, varying widely across taxa. Several functions have been attributed to non-coding DNA including genome protection and a number of regulatory functions. Identifying and understanding the role of these regions would open up hitherto unexplored ways of controlling/guiding the expression of genes in desired direction.

The research component of the Institute has adequate regional bias. Chota Nagpur is one of the agro biodiversity hot spots of India which holds very useful genes for hardiness and local adaptation of crops, especially paddy. Biotechnological approaches can be effectively used for combining the superior characteristics of local genetic resources with improved varieties/breeds.

Apart from undertaking research, the institute could also be envisaged to take up centralized services support for agricultural biotechnology research in future decades, probably on a PPP mode. The support for sequencing and synthesis of various molecules, kits, etc. for agricultural biotechnology research will be provided and may include:

- National facilities for DNA and Protein sequencing and related services
- Development of new synthetic molecules, development of biosynthetic systems, diagnostic kits etc.
- Accredited laboratory and testing facility to test various biotechnology products for release.
- Central proteomics and ionomics facilities
- High throughput genotyping and phenomics facilities
- Controlled facilities for animal testing, plant testing, environment safety testing, etc.
- Development of a central data warehouse across agricultural domain and computation facility
- National facility for biosafety testing of GMOs
- A central facility for maintaining plant and animal mutant lines

Way Forward

The ICAR-IIAB would have to establish itself as a premier national institute and lead from the front in the areas of cutting edge research in biology. It would play a leading role in steering the agricultural biotechnology research in the country. It would network with national institutions engaged in agricultural biotechnology in different sectors and provide required tools and technologies to facilitate conversion of knowledge into commercial products. It would also play a critical role in creation of competent and skilled human resource in biotechnology and allied disciplines.

The most important facet of agricultural biotechnology research in the country is setting priorities and proper directions. There is a need to consolidate the expertise available in the country and shift to top-down approach from the current bottom-up approach. One of the principal reasons for non-realization of optimum output from biotechnological research in the country is lack of strategic planning, sustained efforts and funding to achieve the set goals. This document envisions research focus on smart biotechnological approaches by the Institute to harness the methodology breakthroughs for developing superior varieties/breeds/microbes to minimize or obviate regulations by adopting approaches like reverse genetics, genomic selection, intra-specific gene swapping and editing, etc., as considered in the foregoing sections. The education system should evolve to international class to ensure quality manpower which is basic to ensure a powerful biotech research in the country, as envisaged in this document.

Biotechnology is a domain which attracted a very large manpower with tremendous investment in both public and private sectors. Therefore, it is very difficult to comprehend the status of development after a few decades. The speed at which technological breakthroughs are getting unleashed, whole organism modelling to predict the phenotype of higher organisms based on genome could become reality before 2050. Such developments can lead us to unimaginable possibilities and three-and-a-half decades appear far away to see. Great contributions in research will be meaningful, only if they are in the right direction. The way forward for IIAB could be pursuing cutting edge research in the areas, which have been discussed in this document and include: genetic engineering of organisms; genome editing; apomixes, intra-specific gene swapping and editing; reverse breeding; application of computational biology; big data analysis, metagenomics; enhancing photosynthetic efficiency; tuning plant immunity; energy-efficient food production; cell and embryo culture; embryo rescue; cell-free protein synthesis; unlocking the potential non-coding DNA; microbial farming and artificial food. It is expected that once fully functional, the institute will serve Indian Farmers with "Make in India" products and processes and will also help in skill development in the highly advanced areas of agricultural research.

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