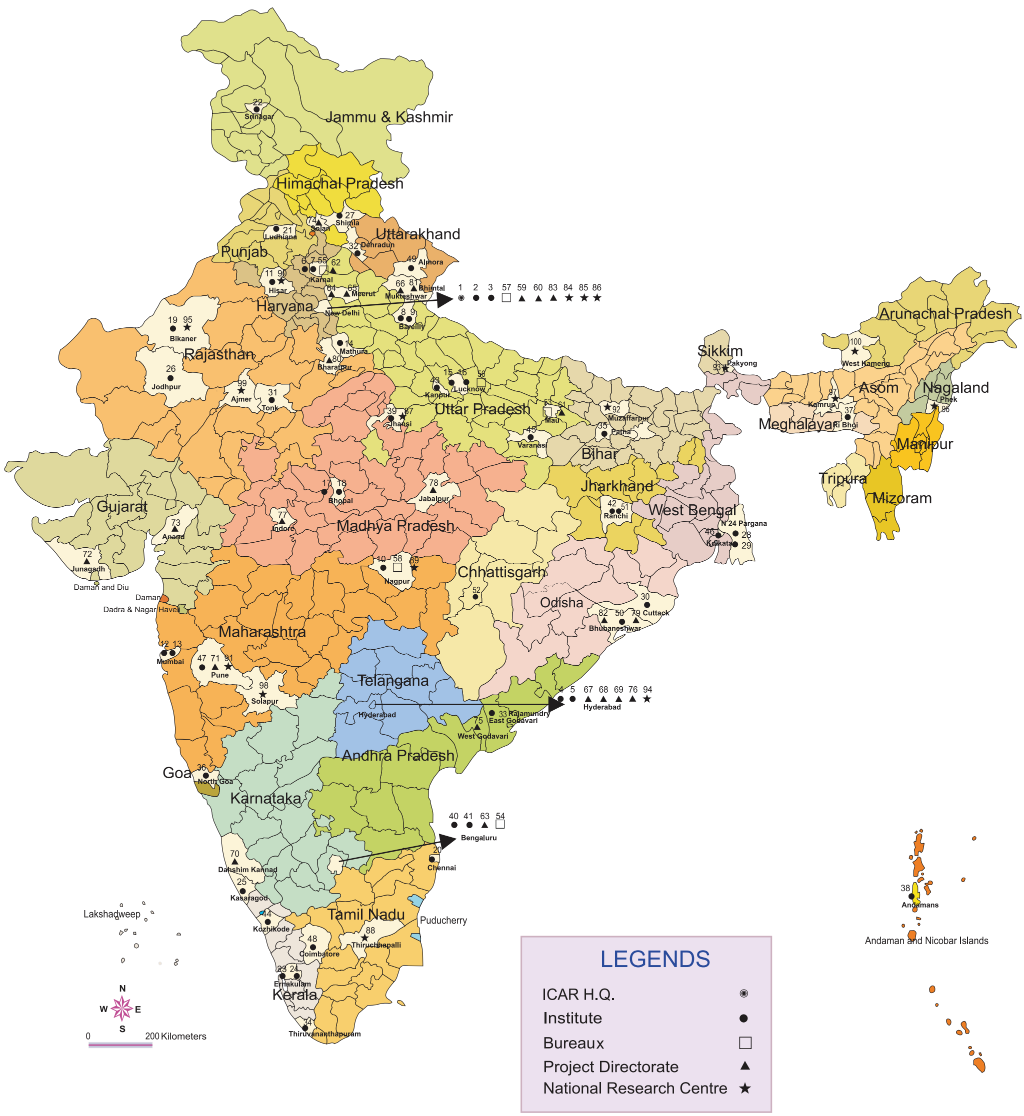
Vision
2050

National Bureau of
Agriculturally Important Microorganisms

Indian Council of Agricultural Research

INDIAN COUNCIL OF AGRICULTURAL RESEARCH

Institutes, Bureaux, Directorates and National Research Centres



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

Vision 2050

National Bureau of
Agriculturally Important Microorganisms
(Indian Council of Agricultural Research)
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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, and 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-National Bureau of Agriculturally Important Microorganisms (ICAR-NBAIM), Mau has been prepared, based on a comprehensive assessment of past and present trends in factors that impact agriculture, to visualise scenario for 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)
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and Director-General, Indian Council of Agricultural Research (ICAR)
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Preface

Agricultural development in India is one of the major success stories of the post-independence era. India has travelled from shortages to surplus, from ‘ship-to-mouth’ situation, to self sufficiency and the exports, that too in a short span of less than five decades. Now, the agriculture is threatened with the climate change and global warming, it is predicted that by the year 2050, the average temperature is likely to rise significantly. Global warming creates many new events, new climates, climatic aberrations and extreme weather events. So, there is a dire need to adapt to the new situations.

Microorganisms have adapted to inhabit in every extreme condition all over the world. Their role in environmental succession, biogeochemical cycle, plant interactions, food chain, soil fertility, agro waste recycling and bioremediation, are inevitable. They are the silent workers and their significance can be illustrated by the fact that the global active biomass of these usually unseen organisms is similar to that of all living plants and animals.

A large population of microorganisms lives in soil, sediments, aquifers and geological formations where they mineralize the organic compounds originating mainly from photosynthetic primary production. Microorganisms have gained importance as tools, playing an important role in the overall well being of the agro-ecosystem as well as crops, animal and human health. It is therefore, our utmost duty to conserve the real natural heritage and keep them for longer time for future needs because once lost, it is practically impossible to revive them in nature.

Realizing the importance of the microorganisms in the agriculture and allied sectors, the Indian Council of Agricultural Research took a visionary and thoughtful step towards long term conservation of microorganisms and their utilization in these sectors, by establishing the ICAR-National Bureau of Agriculturally Important Microorganisms in the beginning of the 21st Century. ICAR-NBAIM was established in 2001 in New Delhi and then shifted to its present location in village Kushmaur, District Mau (U.P.) during 2004. It has been given the mandate, “To act as the nodal centre at national level for acquisition and management of indigenous and exotic microbial genetic resources for food and agriculture, and to carry out related research and human resource development, for sustainable growth of agriculture”.

The present day science is moving at a very fast pace and so is the agriculture. Until the advent of metagenomics tools, which allow the investigation of microorganisms that cannot be cultured in the laboratory, we were unable to study the entire genetic makeup from particular environments, thereby losing a fruitful source of microbial biodiversity and functional novelties. The multi 'omics' approaches based on transcriptomics, proteomics, metabolomics and metagenomics has changed the way microbiologists approach many problems, redefined the concept of a genome, and accelerated the rate of gene discovery. The potential for application of metagenomics to biotechnology seems endless. Due to the fast developments in science, alongwith the changing climatic scenario, it has become pertinent to plan for future and reorient our programmes to meet the challenges and threats of future. The future challenges are compounded with the situation of increased population, climate change, global warming, shrinking natural resources like water and land, and the changing food habits of the population. Emphasis has already started shifting from 'food security' to 'nutritional security'.

It is predicted that by the year 2050, India will be a nation of young people. The population of youth, i.e., those in the age group of 18-35 years will be the highest in the world, ahead of USA and China. Hence, the ever increasing population, the increasing needs of the youth and the population in general, alongwith other threats and challenges, the planning has to be done for "preparedness for future". In this regard, ICAR-NBAIM as well as the microbial sector has to be prepared for the situation expected to prevail by the year 2050.

The future vision should be such that it is able to meet the expectations, for at least two to three decades, if not more. The microorganisms, in fact survive and thrive all those niches where no other forms of life are able to survive. Hence, they are expected to have a unique gene pool which can be utilized for the benefit of the mankind and the life on earth as a whole. India has entered the space research arena in a big way and the days are not far when frequent trips to space and exploration of other planets will be a normal activity. Hence, for ICAR-NBAIM or the microbial sector in general, it will be a great opportunity to "explore the unexplored"- the alien niches and the other unexplored or less explored niches like Arctic and Antarctic regions, icebergs and glaciers, hydrothermal vents and volcanoes, etc. This can help in making a 'novel' gene pool that can be utilized for improvement of crops and other living organisms. Similarly, when we talk of nutritional security, the mineral producing microbes can be utilized in developing the next-gen super crops with incorporation of microbial genes to produce nutrient and mineral rich plants for humans and animals. Research on various aspects of microbial utilization can have some unimaginable products and alternative crops, like photosynthetic edible mushrooms by transfer of cyanobacterial gene into mushroom. By developing microbial based 'Green Agriculture', microorganisms can also be utilized in developing the 'Vertical agriculture' concept in view of the shrinking land and water resources, and changing food and nutritional requirements. Some imaginary exploitation of microorganisms in the service of mankind can be in the areas of desalinization of sea water, mitigation of the threat of climate change to crops and agriculture, developing microbial based probes for rapid detection of diseases and pests, so and so forth. Microorganisms can also be a great help in managing the issues of environmental degradation like those of plastic pollution and waste-management.

Microorganisms have great potential for the improvement of quality and status of agriculture, environment and the human population. However, one has always to be careful about the mishandling of the microorganisms both genetically and physically, since, they can be a potential threat, more powerful than a 'Bomb', when used for biological sabotage or 'biological warfare'.

The Vision 2050 document lays out a pathway leading to the further emergence of ICAR-NBAIM, pioneering the management of standard microbial genetic resources for food and agriculture. It is expected that vision embodied in the document further ensures that ICAR-NBAIM continues to fulfill its mandate and address the future challenges for growth and development of Indian agriculture locally, regionally and globally.

With great pleasure, I extend my hearty thanks to Dr. S. Ayyappan, Hon'ble Secretary, Department of Agricultural Research and Education (DARE) and Director General, Indian Council of Agricultural Research for insight, guidance and support in preparation of Vision document. I am also thankful to Dr. J.S. Sandhu, Deputy Director General (Crop Science) for encouragement and guidance. Thanks are also due to Dr. P.K. Chakrabarty, Assistant Director General (PP) for cooperation, support and suggestions for developing the document. I am also thankful to my colleagues from the Bureau for their contribution and help to develop the "Vision 2050" document.

Arun Kumar Sharma
Director
ICAR-NBAIM

Contents

Context

The art of agriculture dates back to prehistoric times. The dawn of human civilization is marked by the realization of the importance of agriculture by mankind. It brought about self-sustenance and self-reliance to the prehistoric man as regards his food requirements and livelihood. Since then, the exploitation of arable land for crop production became a necessity for the survival of mankind. Ensuring sufficient food for all has remained one of the major challenges before the farmers, scientists, policymakers and all the stakeholders of agriculture in the country in the era of increasing chemicalization, industrialization and mechanization. Continuously growing population and day-by-day shrinking land size has led to the conversion of forest areas into arable lands and thus, threatening global biodiversity which is already under stress due to human action. By 2050 the world's population will be increased by a third and demand for agricultural products will rise by 70 per cent with mean consumption doubling. Lateral expansion of the agricultural sector through the clearing of land is untenable without significant negative implications on already stressed natural ecosystems and the range of drivers, including climate variability, that farmers will have to cope with, will require changes in the way we undertake agriculture. In meeting the future food production demands without consuming more land and water will require technological innovation and changes in the way agriculture is undertaken. If food production is to keep pace with an increasingly urbanized and growing population while formulating new food production strategies for developing countries, the great challenge for modern societies is to boost crop productivity in an environmentally sustainable manner.

The presence and activity of microorganisms is essential to the healthy functioning of ecosystems. The role they play in nature to maintain the dynamic equilibrium and integrity of the biosphere is of such magnitude that the continued existence of biological life itself is crucially dependent on the sustained microbe-mediated transformation of matter in terrestrial and aquatic ecosystem. The extraordinary activity of the microorganism is based on their remarkable metabolic diversity and genetic adaptability, and as a result the interest subsequently widened in the development of microbial technologies for the production of antibiotics and other therapeutic agents, management of pests and diseases, bioleaching of metals, increasing soil fertility, generating biofuels, monitoring air pollution, destroying persistent pollutants, wastewater treatment, bioremediation, and serving tools in biomedical research. The use of microbial derived compounds has now been extended to other areas of industrial applications such as the commercial production of sugars and syrups from agricultural products representing the principal commercial function of enzymes, where they have a large impact in reducing environmental pollution. Currently, the major markets are detergent enzymes as well as food and feed processing. However, pulp, paper, textile and leather sectors are the fastest growing markets for the microbial derived industrial enzymes. As a result, the direct exploitation of microorganisms in agriculture and industry is worth billions of dollars business each year. Not only this, the ecological services provided by these unseen entities in the farmers' field are enormous. Therefore, it is believed that the possibility to increase the chemical diversity of the compounds integrated into biotechnological programs for different industrial sectors exists through the exploitation of microbial diversity.

Need and rationale

The major human efforts during the past few decades are made in the development of new high yielding crop varieties with enhanced disease and pest resistance, greater drought and salt tolerance and better nutritional value through the introduction of desirable traits either by conventional breeding or genetic modification. The crop production technology for developing these high yielding crop varieties/hybrids has been done with emphasis on agrochemicals such as fertilizers and pesticides. The role of the microbial communities in various aspects of agriculture has been strongly perceived. The sustenance and impact of microbial wealth on the biosphere, the plants, the soils and the water ecosystem is recognized worldwide. The pervasive influence that other microbes have on plant health and growth in enhancing stress

Exploration and survey for extremophilic microorganisms tolerance, providing disease resistance, aiding nutrient availability and uptake to the soil and promoting biodiversity is key to agriculture. A greater understanding of the type of microbial communities inhabiting the ecosystem, what functions these communities perform and how plants and soil microbes live together and benefit each other, can therefore, provide new insights to improve plant productivity while helping to protect the environment and maintain global biodiversity.

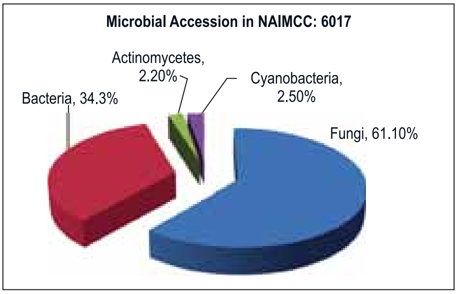
Soil microorganisms, such as bacteria and fungi, control ecosystem functioning through decomposition and nutrient cycling and may serve as indicators of land-use change and ecosystem health. Within this habitat, soil organisms are eating, respiring, competing, cooperating, and responding to changes in their immediate environment. Indeed, the majority of the microbial community may be dormant at any given time in most soils, ready to respond as conditions for a particular group become favourable. Certain bacteria and fungi tend to congregate in the soil immediately adjacent to plant roots (the rhizosphere), where they may feed on the sugars that plant roots exude or actually physically associate with the plant root system and exchange sugars and nutrients in a (usually) mutualistic relationship (mycorrhizas). The soil community and its habitat are influenced by an interconnected web of variables that differ among ecosystems, making each ecosystem somewhat unique in its microbial community. Across the globe, as with vegetation, community structure is perhaps most influenced by soil temperature and moisture though it changes with the seasons, and is strongly affected by soil acidity or alkalinity (pH). Soil organic carbon (SOC) is the largest terrestrial component of the global carbon budget. Worldwide, the top 1 m of soil contains two to three times more carbon than the amount stored in all aboveground vegetation. Studies of soil carbon and microbial communities often concentrate on the upper 20–30 cm of soil, as this is considered to be the most biologically active portion of the soil profile. Thus microbial communities play key role in solving many if not all, the problems of present day agriculture and environment and can be equally beneficial for public health, food and the society. They are fundamentally important for ecosystem functioning, breaking down complex animal and plant residues in the soil and thus, releasing essential nutrients for plant growth. They form beneficial mutualistic relationships with various plants, for example, nitrogen-fixing rhizobia with leguminous plants and mycorrhiza with forest trees. They can be harnessed for producing valuable drugs, being used as biocontrol agents for pests and pathogens as well as in breaking-down and detoxification of wastes. Microbes are therefore, key living components crucial for the ecological harmony, ecosystem function, agricultural sustainability, environmental wellness and human and livestock health. This is why the task of identification, characterization and judicious exploitation of microbial diversity and its long-term conservation and preservation is the national priority for the country for creation of sound health, human wealth and societal goodness. Their integration with crop plants over evolutionary period is poorly understood and hence could not be well-captured in the designing of agricultural production technologies for all the agro-ecologies. The driver that is set in motion for the exploitation of plant-animal-human chain of microbial associations is to be through fundamental and basic research that is in the ambit of global research plans in various countries. ICAR-National Bureau of Agriculturally Important Microorganisms (NBAIM) has evolved as the institutional mechanism to study the Agriculturally Important Microorganisms (AIMs) in order to utilise them in appropriate and desirable situations and contexts.

Salient Achievements

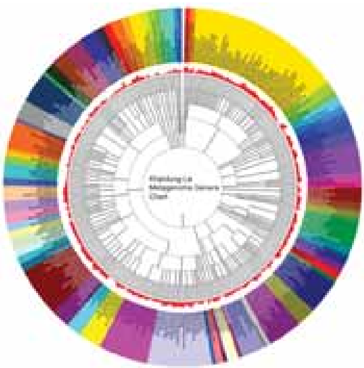
Since its inception in 2001, the ICAR-National Bureau of Agriculturally Important Microorganisms (NBAIM) has dedicated itself in exploring and deciphering the microbial wealth of the country and finding out functions of microorganisms for the benefit of agriculture. On-going research programmes of the Bureau were reoriented in the light of the thrust areas and priorities identified by bringing out all the activities in a network mode, as a sub-scheme of ICAR-NBAIM entitled, "Application of Microorganisms in Agriculture and Allied Sectors (AMAAS)" funded by ICAR. Six thematic areas were identified in the past plan year: Microbial Diversity and Identification; Nutrient Management, PGPR and Biocontrol; Agrowaste Management, Bioremediation and Microbes in Post-Harvest Technology; Microbial Management of Abiotic Stress; Microbial Genomics and Human Resource Development.

Major signal achievements of the Bureau in the recent past are:

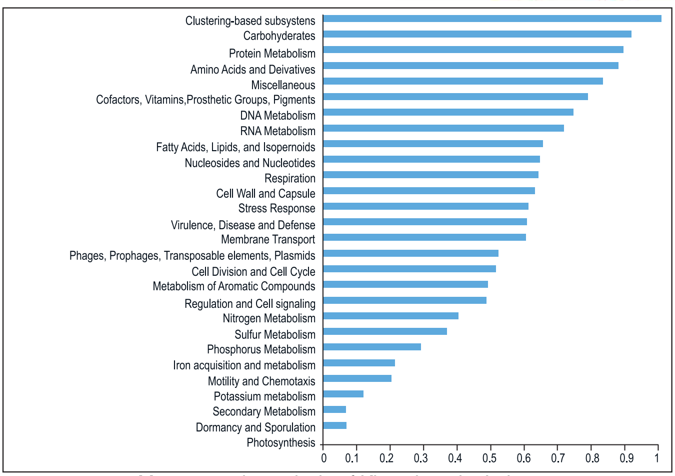
- ICAR-NBAIM is a National repository designated by National Biodiversity Authority ((NBA), Ministry of Environment and Forest (MoEF), Govt. of India, having more than 6000 microbial accessions and has become a member of World Federation of Culture Collections (WFCC). The Bureau generated baseline information and developed a huge database about microbial diversity of extreme environmental habitats of the country. Explorations are regularly undertaken to the regions with extreme environments and the regions of expected diversity. Microbial diversity of cold deserts, hot water springs, salt lakes, the Northern Hill region, the western ghats, Indo-gangetic plains and mangroves, etc. have been documented. The diversity of *Bacillus* and other predominant genera from different niches including hypersaline areas has been mapped and novel cry genes with insecticidal properties have been deciphered.



- The Bureau has established a Microbial Genomic Resource Repository (MGRR) in which more than 10000 accessions of genomic DNA, clones and gene constructs from various sources are being maintained. The genomic resources conserved under MGRR are the potential candidates may be utilized for development of superior microbial strains. Microbial Community of the Himalyan subglacial regions of Ladakh available online on Genbank constitute the first report on Leh metagenome.



- Draft genome sequence of *Mesorhizobium ciceri* strain Ca181



Metagenomic analysis of Khar-dung-la, Leh submitted in NCBI Genbank. Out of 6742 predicted genes, 36 genes for nitrogen fixation and 184 genes for salt tolerance have been identified. This discovery may open the doors for intensified research on *Rhizobium* strain improvement for biofertilizer applications.

- The Bureau has also taken up activities on selection of microbes with potential traits and their utilization in developing carrier-based bio-formulation of microbes for purpose of biofertilization, biotic- and abiotic- stress management and biocontrol of pests. NBAIM is taking keen interest in institute's training programmes for the farmers, with focus on management of biotic and abiotic stresses, biocontrol and biofertilizers, etc.

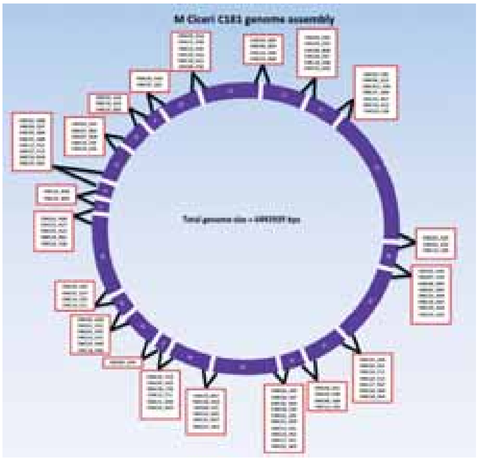


Fig. (A) Draft Genome of *M. ciceri* ca. 181

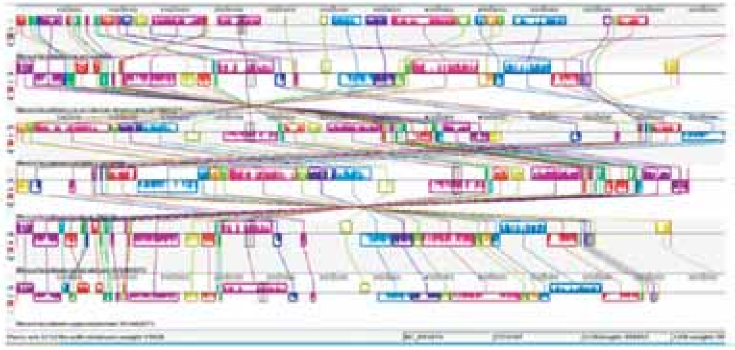


Fig. (B) Alignment of *M. ciceri* genome with other mesorhizobia species using MAUVE

- During XII Plan the sub-scheme on "Application of Microorganisms in Agriculture and Allied Sectors" (AMAAS) was re-evaluated to accommodate 54 sub-projects operative in SAUs, ICAR institutes, Central Universities, Conventional Universities, Institutions under CSIR, and in NEH, etc.
- Under AMAAS, several potential products were developed using the AIMs, *viz.* Biopower G (ICAR-IISR, Bhopal), Zincsol (ICAR-CRIDA, Hyderabad), Consortium for Coconut and Cocoa

(ICAR-CPCRI), Nano coated mycorrhizal spores (TNAU, Coimbatore), oil based *Trichoderma* formulations (ICAR-DOR, Hyderabad), Herbal wine (ICAR-CIPHET, Ludhiana, TNAU, Coimbatore), Candy and chocolates from Kinnow waste (ICAR-CIPHET, Ludhiana), Fast indoor composting technique for Mushrooms (ICAR-DMR, Solan), Commercial enzymes from mango pomace (ICAR-CISH, Lucknow), Microbial pigments for food and textile industry (TNAU, Coimbatore), Consortium for Poly Aromatic Hydrocarbon (PAH) degradation (DU, New Delhi), and Bioethanol production from Kinnow waste (ICAR-CIPHET, Ludhiana). Six patents have been filed by AMAAS Centres: ICAR-DOR, TNAU and ICAR-IISR.

- High Performance Computing System (HPC) has been established at ICAR-NBAIM. The super computing hub consists of hybrid architecture of high performance computing environment. The Bureau has developed bioinformatics databases namely, Stressmicrbio info, bioinfo knowledge base and Fungal SSR database hosted at main server of National Agricultural Bioinformatics Grid (NABG) and being utilized by Scientific community.
- Under HRD, Bureau has trained more than 600 researchers, scientists, faculty members of universities and research students in the areas of microbiology and biotechnology.

Specific reasons to propose long term vision

India is blessed with a rich microbial diversity of different biological forms that come from terrestrial, marine and other aquatic ecosystems. Till now only limited and fragmented efforts were made for tapping of the microbial diversity of agriculturally important microorganisms (AIMs), their identification and preservation for multifarious applications in agriculture and allied sectors and their proper and judicious utilization. The importance of microbial diversity in Indian agricultural sector is realized in a very big way in the last two decades because of the serious deterioration of the soil and plant health due to huge chemicalization in farming system. That is why need was realized by the Indian Council of Agricultural Research (ICAR) to establish the ICAR-National Bureau of Agriculturally Important Microorganisms (NBAIM) for exploration, characterization, conservation, evaluation and utilization of agriculturally important microorganisms (AIMs) in the year 2001 in the old Building of ICAR-NBPGR, Pusa Campus, New Delhi. The Bureau was later shifted to Mau Nath Bhanjan, Uttar Pradesh on 01 June 2004.

The rationale to establish an *ex-situ* collection of agriculturally important microorganisms at ICAR-NBAIM is mainly because of the recognized role of microorganisms in agriculture and closely related sectors, environment and human welfare. Not only are they global players in the metabolism and assimilation of nitrogen, phosphorus, oxygen and carbon, but many are of immense scientific and economic benefits in the form of resources as biomolecules, drugs and bioenergy. Even those that cause problems to humans, animals and plants in the form of diseases are also important because their understanding will lead to their control in efficient and cost-effective manner. Therefore, the beneficial microbes must be conserved and made readily available for research and utilization in academia and industry. The recognized importance of microorganisms in the countries depending on agricultural or industrial-based economies is the prime reason for the concentration of public collections in other parts of the world. In contrast, only a few collections are situated in those areas of the world which are rich in biodiversity like India. Here, their establishment appears significant in order to develop the bio economy and to provide the platform for training of isolation strategies, identification, biosystematics, conservation, preservation, management and utilization of functionalities. The number of novel species in bacteriology and mycology is too vast to neglect the "diversity hot spots" on this planet with their rich and untapped reservoirs of diverse metabolites and, hence bio economic potential. The human resources, facilities, technologies and knowledge necessary to maintain, preserve and exploit microorganisms require development in order to meet the demands to complete India's biodiversity inventory and to harness the world's genetic resources for the benefit of humankind.

Growing agro-ecological concerns due to deleterious practices, high external input-based agro-ecosystem, non-sustainable cropping pattern, climate change, loss in biological diversity due to human interventions always remains the major prerequisite forces keeping the scientific communities to think and rethink the need for sustainable conservation of micro-biotic life forms on the Earth. The conservation practices being applied for microbial communities in the agricultural fields are largely confined to specific areas and are under similar threats described above. Promoting ex-situ conservation of microbial entities therefore, remains the only way-out for the long time preservation, conservation and storage of the microorganisms that would be available for future researchers in the years to come for their utilization and judicious exploitation. Since only limited and fragmented storage and conservation services are available in the nation for the purpose of conserving microbes, presence

Lyophilization storage facility at ICAR-NBAIM

of ICAR-NBAIM, especially in agricultural sector at the national scenario will certainly strengthen the up-keeping, management and strategic planning of microbial biodiversity wealth and richness for the formulation of sustainable developmental practices for crop improvement and soil fertility. The task is in utmost National interest, and aims at the certified quality management which presents an overview of the efforts in the exploration, identification, characterization, conservation, preservation, data generation and storage of microbial entities and points out to the need for increased financial support to this challenging task.

This perspective document aims to provide vision of the Bureau reflecting its activities and planning for the future while mentioning the strategies for isolation, identification, characterization, conservation and utilization of AIMs and the challenges ahead in the coming days.

This proposed vision of the Bureau is based on using its existing resources, expertise and experiences as a Microbial Resource Center to constantly upgrade itself in pioneering the management of standard microbial reference materials, intellectual property resources and translational research applied to the development, standardization and application of the microbial genetic diversity entwined with the chemical diversity.

Since its establishment, the activities of the Bureau were mainly focused on the following major working areas which would be the main drivers of the future programs:

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Mandate of the Bureau

"To act as the nodal centre at national level for acquisition and management of indigenous and exotic microbial genetic resources for food and agriculture, and to carry out related research and human resource development, for sustainable growth of agriculture".

- Exploration, collection, identification and characterization of AIMs from different agricultural habitats including soil, plant, fresh water, marine ecosystem from various agro-ecological regions
- Isolation of extremophilic microbes from exotic zones and extreme environments
- Procurement of AIMs from existing culture collections
- Augmentation of cultures through exchange from various national Microbial Resource Centers (MRCs)
- Development of integrated electronic database covering the information of microbial entities, habitat, geographic, phenotypic, genotypic, morphological and accession information
- Functional and structural genomics of AIMs for exploitation in agriculture and allied sectors
- Development of the state-of-the-art microbial gene bank
- Strengthening linkages with different organizations and microbial resource centers (MRCs) in India and abroad

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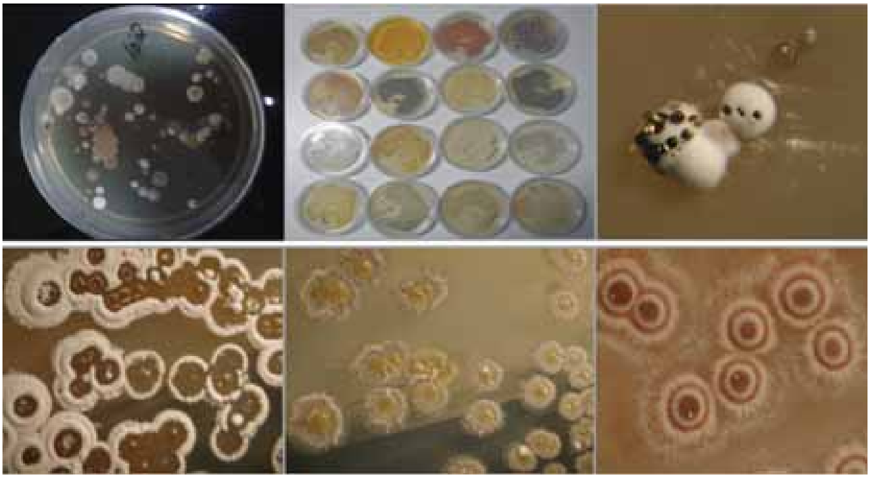
Challenges

The obvious function of a microbial culture collection to maintain the growth of organisms overlays an expanding list of other activities including, for example, the identification of isolates and contaminants, providing taxonomic descriptions of organisms, characterizing plasmids and hosts, comparing rRNA and other genomic sequences, conducting photomicroscopy, providing quality assurance and quality control, validating organisms in production and their products, determining the whole genome sequence of organisms of particular interest, exploration of new areas and regions for the collection and identification of new species, constructing and maintaining computer databases, and conducting research on the organisms themselves. The internal challenges are particularly restricted to evolve with a high end infrastructure and maintain the level of that for the work related to the proper functioning of the microbial accession collection. Other posed challenges are long term and short term conservation strategies because there are microbial entities that need specific environmental conditions for preservation for long time and therefore, require continuous research efforts.

Besides playing a major role in the microbial culture collection, preservation, conservation and maintenance, ICAR-NBAIM is also playing a critical role in facilitating high-end microbiological research in the area of microbial identification and systematic, taxonomy, adaptations within different extreme environments, genomics, proteomics and metabolomics, community structure analysis in different habitats, identification of microbial gene pool in different cropping systems, plant-microbe interactions, molecular plant pathology, evolutionary biology and bioinformatics. In the present era of microbial research, changes are so fast to cope with and therefore, critical knowledge will be required at both end, handling and data analysis with the instruments as well as at the concept development regarding research plans. Making the plans more operative, easy and free from errors with minimum manipulations, computer-aided services and programs including robotics is being applied. Regular enhancement in the working capabilities of NBAIM will be a great challenge both in short and in long time in order to get more obtainable and enhancements on focused research.



Extremophilic microorganisms

In the present era of microbial research, gene amplification and sequencing have led to the discovery of new microbial entities including pathogens as agents of disease and have enabled us to better classify microorganisms from culture. Sequence-based identification of bacteria and fungi using culture is more objective and accurate than conventional methods, especially for classifying unusual microorganisms that are emerging as pathogens in immuno-compromised hosts. Although a powerful tool, the interpretation of sequence-based classification is challenging as microbial taxonomy grows more complex, without known reference correlatives. Additionally, broad-range gene polymerase chain reaction and sequencing have emerged as alternative, culture-independent methods for detecting the presence of inhabited microbial communities and pathogens in the environmental samples. The promise of such technique has remained, limited mainly by contamination and inadequate sensitivity issues. In future, the data collection from many different habitats will be very huge, so that the development of new and customized algorithms for data analysis will be more challenging in the field of microbial taxonomy, identification services and microbial metagenomics.

Likewise, in the areas of microbial genomics, huge data is being generated all the way through the whole genome sequencing (WGS) of different microbes. In the future it will again pose the challenges of our preparedness for the WGS of indigenous microbial communities flourishing in our own habitats and fields. However, high level sophistication in instrumentation, false positive and false negative detections that result from inaccurate diagnostics often result in large

Metagenomics has changed the way microbiologists approach many problems, it has redefined the concept of a genome and accelerated the rate of gene discovery. The potential for application of metagenomics to biotechnology seems endless. Realizing the potential for discovery from metagenomics is dependent on the advancement of methods that are central to library construction and analysis. For sequence-based approaches, the speed and cost of nucleotide sequencing will be a barrier of rapidly diminishing significance as sequencing technology continues to improve. Sequence-based assignment of function will also benefit from advances in detection of homology, which will increasingly rely on the tertiary structures of predicted proteins rather than simply on primary sequence.

and unnecessary costs and risks. In the past decade the inability to reliably differentiate among bacterial pathovars and between closely related species has compromised the ability to intercept and prevent the establishment of exotic bacterial pathogens in many parts of the world including India. Therefore, looking in to the importance of the subject like disease diagnostics of phytopathogens and thereby, saving the National economy in the form of crop losses and restriction of heavy chemical farm inputs, this area should be one of the prioritized and challenging one to take up in the near future.

In summary, the major key challenges before the Bureau taking microbial research and development as a priority area will be:

1. Updating manpower with constantly changing research themes, technologies and trends
2. Equipping laboratories with high level infrastructure
3. Identifying regional, National and cross-boundary problems in the microbial culture collection and research from time to time
4. Acute preparedness for the management of in-house resources for taking up the challenges and acting accordingly
5. Establishing linkages with National and International institutions working in the area for collaborative efforts to meet out challenges
6. Integration and data-sharing for phenomic, genomic, proteomic and metabolomic data through the maintenance and management of databases
7. Addressing key issues for taking research and development efforts for the benefit of farmers in their own field
8. Translating microbial technologies at farmers field in collaboration with farmers in participatory mode
9. Partnering with agricultural industries for transfer of technologies

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Operating Environment

Agricultural systems are dependent on a range of ecological interactions intra- and interwoven by microbes. In recent time, a number of reports showed that climate changes modify the geographic distribution of fauna and flora including microbes and increase the impact of particular microbes beyond current ranges. This might be due to the ability of micro-organisms to adapt faster as compared to other higher organisms under major climate changes. As a result, it is felt that microbes are able to mitigate various challenges imposed by climate change on agriculture. During the phase of adaptation, microbes acquire and express some of the new genes, and simultaneously they may loose some of the genes not required for their survival in the changing scenario of climate change. Some of these genes may be highly useful for the growth of agricultural and industrial sector. From these facts, it is clear that in-situ conservation of microorganism existing during the regime of climate change act as a storehouse for the novel gene(s) of agricultural and industrial significance. Therefore, to mitigate the effects imposed by climate change, there will be a need to access information and MGRs from beyond their own borders in order to address invasive and emerging pests, diseases and environmental stresses. Therefore, there is a requirement to pool representative samples of microbial diversity as much as possible in various MRCs throughout the globe.

Microbial culture banks are established to provide various general but essential functions: to establish repositories of interesting, rare or useful microorganisms; to protect useful microbial entities from the sudden loss due to changing environmental conditions; to provide the research community with (i) taxonomic type strains, or (ii) control/reference strains for experimental use and standardized testing, or (iii) specialized genetic strains, and to establish a repository of organisms necessary to permit enablement of patented inventions in the era of intellectual property rights (IPR). Selection criteria for a particular collection thus depend upon the mix of these functions within the collection's intended mission and vision. The general collections should have an active user community which considers the deposits to be valuable. The collection should have a database or catalogue and well characterized quality control procedures in place and well documented deposits.

Operational support for culture collections is justified because, culture collections serve important national interests, i.e., technological and commercial competitiveness; they are necessary for advancing the missions of many agencies like agriculture, rural health, education and commerce etc.; they are an important national infrastructure for the biological and agricultural sciences; they advance the protection of intellectual property rights and hence commercialization of new technologies; adequate revenues cannot be obtained from user fees or service charges; no other source of independent public funds are available; and the research community, both academic and industrial, is dependent upon open and equitable access to cultures, and their selection for archival.

Therefore, looking in to the importance, fool proof operative environment for the establishment and long term maintenance is essentially required. Specific operational factors may include:

Political

Recognizing the values of MRCs, and the need for wise utilization and conservation of microbes, policies and legislation have been and continue to be promulgated. Such policies are also spurred by the need to protect the right of any region and nation to conserve their own microbial resources. This will be achieved by setting the guidelines and action plans towards the realization of the overall goal of harnessing microbial resources for improving the livelihood of people.

India is signatory to the Convention on Biological Diversity (CBD) and therefore has the obligation for the conservation and sustainable utilization of their microbial resources. The CBD gives a comprehensive framework for conserving and sustainable utilization of biological diversity to provide the solutions to natural resource depletion, environmental, agricultural, food, forestry and public health concerns which should help to alleviate poverty and boost national economics by utilizing the strategic advantage that India has.

Economic

- Working on microbial genomics, biodiversity, and on other functional aspects of agriculturally important microorganisms is economy-extensive job and like other high-end institutions working on similar lines in National and International arena, investment in this area is high.

- The institutionalization of microbial-based biomolecules production and national sovereignty rights on biodiversity has made access to germplasm more difficult.
- With the signing of CBD and WTO and the emerging new implementation of IPRs, the microbial germplasm introduction would become difficult and expensive.

Socio-cultural

- Societal issues like involvement of local rural people, marginal farmers and socially-deprived population in the functional areas of ICAR-NBAIM like microbe-mediated improvement in crop production, abiotic stress tolerance, bioremediation and biodiversity conservation can have greater impact on the working of the Bureau.
- Lack of "Experts" in policy issues of microbial conservation e.g. biosafety, biopiracy, GMOs, biowarfare, IPR, etc. is of major concern.

Technological

- Lack of good expertise in microbial taxonomy and systematics, microbial genomics and genome annotation and microbial bioinformatics
- Nano-microbiological research
- Systems biology approach to understand integrated plant-microbes interactions as a whole
- Weak linkage between microbiologists of the country
- Lack of microbial gene bank facilities

Scanning electron microscopy unit at ICAR-NBAIM

- Lack of facilities of modern and state of the art identification of large number of diverse AIMs.

Environmental

- Issue related to field testing of the microbial formulations for disease management, growth promotion, bioremediation, agrowaste management etc.
- Outbreak of pests and disease
- The narrow genetic base of the available microbial information and the genetic vulnerability of host pathogen relation.
- Liberalization in trade is leading to greater movement of microbes and their product, consequently leading to the chances of introduction of new and alien pathogenic races in country. Some of the new pest may pose serious threat.
- Climate change

Legal

Application of genetically modified microorganisms in the areas of disease control, growth promotion, bioremediation, etc., and the issues related to patenting, registration of microorganisms, their products and processes.

Stakeholders

1. State Agricultural Universities, Research Organizations and other Government & Non-Government organizations
2. International Institutes
3. ICAR Institutes
4. Extension and development agencies
5. Farmers & Industries

Opportunities

National Agriculture Research Systems (NARS) comprising of ICAR institutions as well as all those that are directly or indirectly related to research on various issues of agriculturally important microbes serves to strengthen Indian agriculture. The Bureau is playing a pivotal role in the area of acquisition, management and research of indigenous and exotic genetic microbial resources directly linked with the agricultural applications. Futuristic vision of the Bureau lies as projection of its own capabilities that need to be strengthened by the intensification of linkages with reputed National and International organizations. In future, the ICAR-NBAIM will be one of the India's largest holders of microbial germplasm and a readily available microbial resource of agriculturally important microorganisms for researchers, industries and farmers'. The "National Gene Bank" facility could also be offered at regional scale to store germplasm of AIMs of South Asian countries.

Integration of fast emerging biotechnological tools along with development of in-house capabilities for their applications with microbial germplasm resource management need further strengthening in the future to enhance effectiveness of utilization. Using molecular markers, screening of large collections for specific traits can be done, allele mining for useful genes would help In identification of single nucleotide polymorphisms (SNPs) and variants of specific genes that could be exploited for specific use. Until the advent of metagenomics tools, which allow the investigation of microorganisms that cannot be cultured in the laboratory, it was difficult to study the entire genetic makeup from specific environments, thereby losing a fruitful source of microbial biodiversity and functional novelties. Metagenomic analyses of natural biological communities are revolutionizing our understanding of the diversity, function, and inter-relationships among organisms in diverse ecological niches. Microbial culture collection and research both are relatively new fields and therefore, there exist plenty of new opportunities before ICAR-NBAIM and the agricultural scientists.

Major goals and targets for the Bureau will include:

1. Tapping novel microbial diversity by employing new isolation techniques for isolation and documentation

2. Characterizing efficient microbial strains that grow in extreme habitats to ensure their involvement in biogeochemical processes
3. Developing efficient strategies for microbe-mediated biotic and abiotic stress management in plants
4. Whole genome sequencing of important microbes and their functional characterization
5. Exploring rhizosphere - a hot spot of belowground biodiversity for the benefit of the cropping systems
6. Isolation and characterization of novel microbes for biofuel production
7. Evaluation of the existing and identified microbial resources for field applications
8. Development of farmer-friendly microbial technologies for field applications
9. Development of efficient microbe-mediated bioconversion processes

Way forward

The microbiology research will build on the successes of the past using new techniques and approaches. Uncultivated microbes hold great promise for industry, medicine, and the recycling of precious resources, and research and technology must make inroads in overcoming the barriers that prevent their study. In many cases, we will no longer be able to rely on isolated, pure cultures of microorganisms, but must use communities of microorganisms, which presently are poorly understood. Indeed, community-level studies can benefit from deconstructing microbial communities and analyzing the component members separately, but this is not feasible in every system.

Future research must address current limitations in detecting micro-scale interactions among microbes by enhancing current technologies and fostering new microscopic tools, biosensors, and gas sensors for appropriate small scales. Genomics, which has enabled great progress in microbiology research of individual species, must be applied to communities of microorganisms. This will require improved methods of DNA extraction and amplification from environmental samples and improved strategies for DNA sequence assembly. In the future, genome sequencing efforts should continue exploration of evolutionarily diverse microbes, as well as help reveal the mechanisms by which closely related microbes evolve and make their own adaptations in the diverse environmental conditions. To achieve the goals training in some of the long-established disciplines, including enrichment, isolation and characterization, taxonomy, physiology, enzymology, and biochemistry, needs to be revitalized.

Major areas that are identified for moving forward are as under…

- Microbial Genetic Resource Management
- OMICS research & bioinformatics
- Bioenergy & environmental perspectives
- High-value products from microbes

A scheme is presented here highlighting ICAR-NBAIM research plans and goals in the future:

Future Perspectives: Capacity to cater predictable and unexpected technological innovations

Over the next several decades, both predictable and unexpected

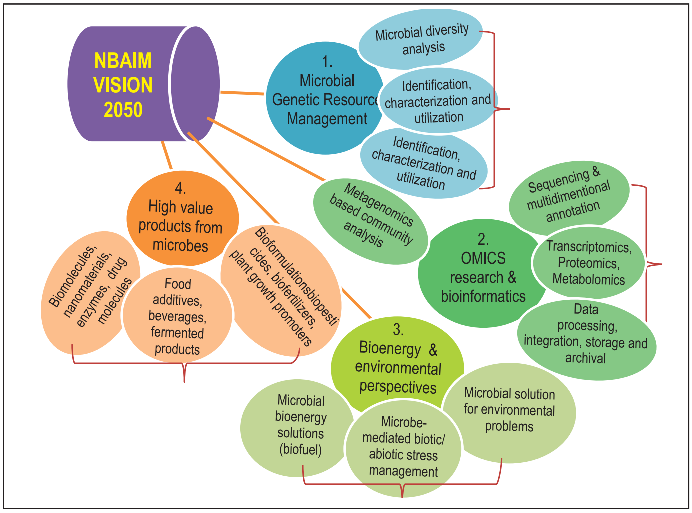

Fig. Science Drivers for Future Research Priorities and Integration

technological innovations in the microbial biotechnology and bioinformatics will continue to propel genomic, proteomic, metabolomics and also the basic research on microbial interactions, biofuel, high-end products and environmental bioremediation. New challenges will appear before us as soon as the existing grand challenges are met. The evolutionary and self-evolving strategies for taking up these challenges in positive way is intended to provide ICAR-NBAIM the access to cutting-edge science-based approaches as well as other synergistic capabilities, to reinforce the Bureau in unique position as the world's leading user facility in microbial conservation, identification and diagnostics, bioenergy, system biology, agriculture and environmental genomics and microbial nanomaterials.

Strengthening the Microbial Resource Centres: Assessing Environmental Impact and Searching for Novel Biochemical Properties

Culture collections are known to be the cornerstone of biotechnology. However, reliable and adequate collections are needed if biotechnological processes and innovations are to be furthered. Culture collection plays an important role in the exchange of information on cultures as a significant step towards sustainable development. While the threat to biodiversity is being documented with increasing regularity and purpose today, it still continues. This threat has its origins in environmental mismanagement resulting from chemical pollution, overexploitation of natural renewable and non-renewable resources, large scale physical interventions leading to changes in land and water use and population growth. Prediction of the loss of microbial diversity is much more difficult due to scanty information and anecdotal evidence for loss. Many microorganisms appear resistant to environmental changes. However, those found in unspoiled setting and closely associated with specific niches may be less ubiquitous, and thereby susceptible to habitat disturbance. This is why they have great potential and thus their collection has a great significance.

Exploring the Un-explored: Development of National Microbial Map and Mapping of Uninhabitated and Alien Niches

With over three decades of molecular-phylogenetic studies, researchers have compiled an increasingly robust map of evolutionary diversification showing that the main diversity of life is microbial, distributed among three primary related groups or domains: Archaea, Bacteria, and Eucarya. The application of molecular-phylogenetic methods to study natural microbial ecosystems without the traditional requirement for cultivation has resulted in the discovery of many unexpected evolutionary lineages. Extremophile research is entering an exciting phase. The commercial potential has been recognized, but is far from being realized.

Molecular ecology has undoubtedly revealed the extent of our ignorance but it has still not provided the ability to detect and identify organisms and define ecological niches in terms of organisms. The poorly/un-explored habitats like Arctic and Antarctic regions, glaciers, hydrothermal vents, volcanoes, and alien spaces might serve as reservoirs for the novel gene pools while in future may be utilized for the benefit of agriculture and humanity. The three fundamental questions that exist while discovering and characterizing any natural or artificial ecosystem are the following: what type of microorganisms are present; what do these microorganisms do; and how do the activities of these microorganisms relate to ecosystem functions (e.g., energy flow, biogeochemical cycling and ecological resilience, etc.. ICAR-NBAIM aims to answer these central questions and deals with the study of microorganisms and their interactions with each other and with their environment. In future, a plethora of biochemical and molecular methods including metagenomics will be applied to reveal the microbial community composition over time and space in response to environmental changes. These new approaches allow linkage between ecological processes in the environment with specific microbial populations and help us to answer important questions in microbial ecology such as what factors and resources govern the enormous genetic and metabolic diversity in an environment or alien species.

Whole Genome Sequencing of Elite Agriculturally Important Microorganisms and Bioprospecting for Novel Genes through Metagenomic Approaches

The current concept of the bacterial species – a 'genomically coherent' group of strains that share many common traits rests squarely on the availability of reliable techniques to quantify the relatedness of bacterial genomes. An alternative approach to quantification of genome relatedness is to compare selected DNA sequences for a group of bacterial strains. The core technology for this method, DNA sequencing, is relatively rapid and inexpensive, highly reproducible and readily available to virtually any research group through specialized sequencing centres. For these reasons, DNA sequence analysis has to take an increasingly important role in taxonomic studies in coming years. The field of microbial genomics has moved away from the primary initial focus on pathogens genome to include the sequencing of diverse prokaryotes that occupy a range of environmental niches, and which are responsible for an array of environmental processes. Every genome that has been sequenced to date has provided new insight into biological processes, activities, and potential of these species that was not evident before the availability of the genome sequence. The goal of the study is to obtain the genome sequences of elite AIMs and to reflect the overall rate of genome divergence and to identify genes that could best serve as predictors of genome relatedness.

Microbe Based Green Agriculture and Next Generation Super Crops

Development of nano-bioformulations for biocontrol of phytopathogens, insect pest and weeds

The role of molecular biology techniques as a means of inventing natural processes and cellular phenomenon of microbial cells at systems level and to the extent of microbial diversity, has remained very significant in the past and is growing day by day. Using taxon, species and strain-specific probes, scientists easily detect novel member of the species of interest even in constantly changing or well-studied agricultural ecosystems. The implications of such techniques will be increasingly developed and applied for microbial ecologists and also for biotechnologists who will desire to screen the newly revealed genetic and chemical diversity of microbial world for useful purposes as nano biological applications to develop bioformulations of identified bioactive constituents from the potential AIMs. In order to optimize stability and bioavailability of constituents, new processes as well as formulations will be used (micro and nano emulsions, microencapsulation). The Nano particle formulation will improve the bioavailability of hydrophobic active ingredients, nanophase soil additives (biofertilizers, biopesticides and soil conditioners, etc.). Nanoparticles may also be utilized as unique nano structured vehicle for biocontrol agents.

Microbial gene in action

Fruitful genetic research into microbial populations with novel diversity using genotyping by sequencing combined with bioinformatics will generate much knowledge that is directly relevant to crop improvement. These advances can assist the molecular biologists in associating genetic makeup with traits of commercial value in the development of next generation super crops such as: mineral and vitamin rich green vegetables, development of autotrophic mushrooms, etc.

In recent years, efforts have been made to grow food by minimizing the use of chemical pesticides and mineral fertilizers. The “green technology (GT)” is a broad term for more environment friendly solutions. GT for that matter can be used as environmental healing technology that reduces environmental damages created by the products and technologies for peoples’ convenience. The AIMs and compounds produced by them, either naturally or through metabolic engineering will help to combat the effect of different abiotic and biotic stresses under changing climatic scenario. Microbe based technology can be imagined for future, where crops can be produced and harvested without use of any chemical and without loosing the yield gains as well as keeping the environmental issues at bay.

Research in the area of application of microorganisms in Green Energy and Bio fuels

The world is facing a potential energy crisis due to fossil fuel energy demand and population increase. Pollution from fossil fuels affects public health, and causes global climate change because of carbon dioxide (CO_2) release. The solution to solve this problem is to use microorganisms that can provide both renewable energy and CO_2 removal from the atmosphere. The objective of this theme is to convert solar energy and waste CO_2 (carbon dioxide that is released in power plants by burning fossil fuels) into an array of biofuels by sequential use of microorganisms in bioreactors.

Vertical farming with microbial consortia

Shrinking land resources and increasing population load is likely to put pressure on food productions in the years to come. Vertical farming will be legitimate and be promoted in future for these and also the environmental reasons. The cultivation of plant life within skyscrapers will produce less embedded energy and toxicity. These artificial environments that have little to do with the outside world will mainly depend upon the endophytic microorganisms, fast decomposers and translocators. The microbes will be the central with regards to energy consumption as they will be the vehicle for uptake and translocate the nutrient to sustain the plant life within the skyscraper. The vertical farm will be designed to be sustainable, and to enable nearby inhabitants to work at the farm.

Management of Environmental Degradation and Allied Sectors

Microbes for plastic degradation

Plastic is a common term for a wide range of synthetic or semi synthetic organic solid materials. The major chemicals that go into the making of plastic are highly toxic and pose serious threat to living beings of all species on earth and is mostly non-biodegradable. The microbes capable to degrade the polypropylene, polyethylene, polyvinyls, etc., be discovered. As per the information available, plenty of microbes from sea environment may be utilized for the degradation of plastics, a major environment pollutant.

Desalinization of sea water

In future, water is likely to be a major constraint for agriculture as well as for life on earth. However, our oceans and seas are full of water but it can not be utilized for above purpose due to salinity. A microbial desalination cell (MDC) is a new approach for desalinating water based on using the electrical current generated by exoelectrogenic bacteria. In future MDCs can be used for salt removal and efficient desalination of seawater while at the same time achieving power densities comparable to those obtained in Microbial Fuel Cells (MFCs). This desalination of sea water will make plenty of fresh water available for agriculture, drinking purposes, as well as other uses by the mankind.

High-end computing infrastructure for data analysis & processing

Processing and integration of a rapidly increasing number and size of sequence data sets require scalable methods running on a high-performance/high-throughput computing infrastructure. High end computing power is essential for the future research and development. To respond to challenge identified with the whole genome data generation and analysis, ICAR-NBAIM in the future will have expanded technologies and competencies for: processing data samples, adding functional information to sequence data and integrating and displaying the data to accelerate the discovery of new patterns and insights within the data. In addition to large-scale DNA sequencing, multiple different complementary, state-of-the-art biological and high end supercomputing capabilities will strengthen our capabilities in the future.

Human Resource Development (HRD) and Man-power Capitalization

Discovering, studying and integrating new branches of microbial life and new metabolic activities through massive-scale isolation, characterization, identification, conservation and sequencing of unexplored microbial and fungal genomes will put a demand of efficient, skilled and technology-friendly manpower in the coming future. All such and other many more customized and time-bound activities and problems arising from time to time can only be mitigated by the skilled human hands and equipping them with the ideas of data integration and knowledge sharing. In this manner, HRD component of the Bureau will be considered as a prime need in the coming future.

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PHOTO GALLERY

Cyanobacterial culture collection

Scanning Electron electron microscopy unit

Lyophilization unit

Cryopreservation unit

Trainees in action

HRD and capacity building programme at ICAR-NBAIM, Mau

ICAR-NBAIM for farmers

Secy. DARE & DG, ICAR with ICAR-NBAIM family

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