Vision 2050

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सत्यमेव जयते

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भारत सरकार
MINISTER OF AGRICULTURE &
FOOD PROCESSING INDUSTRIES
GOVERNMENT OF INDIA

Dated the 17th June, 2013

MESSAGE

The scientific and technological inputs have been major drivers of growth and development in agriculture and allied sectors that have enabled us to achieve self reliant food security with a reasonable degree of resilience even in times of natural calamities, in recent years. In the present times, agricultural development is faced with several challenges relating to state of natural resources, climate change, fragmentation and diversion of agricultural land to non-agricultural uses, factor productivity, global trade and IPR regime. Some of these developments are taking place at much faster pace than ever before. In order to address these changes impacting agriculture and to remain globally competent, it is essential that our R&D institutions are able to foresee the challenges and formulate prioritised research programmes so that our agriculture is not constrained for want of technological interventions.

It is a pleasure to see that National Bureau of Agriculturally Important Insects (NBAII), Bengaluru, a constituent institution of the Indian Council of Agricultural Research (ICAR) has prepared Vision-2050 document. The document embodies a pragmatic assessment of the agricultural production and food demand scenario by the year 2050. Taking due cognizance of the rapidly evolving national and international agriculture, the institute, has drawn up its Strategic Framework, clearly identifying Goals and Approach.

I wish NBAII all success in realisation of the Vision-2050.

(SHARAD PAWAR)

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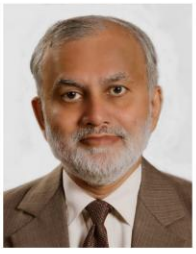

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FOREWORD

The Indian Council of Agricultural Research, since inception in the year 1929, is spearheading science and technology led development in agriculture in the country. This is being accomplished through agricultural research, higher education and frontline extension undertaken by a network of research institutes, agricultural universities and Krishi Vigyan Kendras. Besides developing and disseminating new technologies, ICAR has also been developing competent human resources to address the present and future requirements of agriculture in the country. Committed and dedicated efforts of ICAR have led to appreciable enhancement in productivity and production of different crops and commodities, which has enabled the country to raise food production at a faster rate than the growth in demand. This has enabled the country to become self-sufficient in food and emerge as a net food exporter. However, agriculture is now facing several challenges that are expected to become even more diverse and stiffer. Natural resources (both physical and biological) are deteriorating and getting depleted; risks associated with climate change are rising, new forms of biotic and abiotic stress are emerging, production is becoming more energy intensive, and biosafety concerns are growing. Intellectual property rights and trade regulations impacting technology acquisition and transfer, declining preference for farm work, shrinking farm size and changes in dietary preferences are formidable challenges.

These challenges call for a paradigm shift in our research approach to harness the potential of modern science, innovations in technology generation and delivery, and enabling policy and investment support. Some of the critical areas as genomics, molecular breeding, diagnostics and vaccines, nanotechnology, secondary agriculture, farm mechanization, energy efficiency, agri-incubators 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.

It is an opportune time that the formulation of 'Vision-2050' by ICAR institutions coincides with the launch of the national 12th Five Year Plan. In this Plan period, the ICAR has proposed to take several new initiatives in research, education and frontline extension. These include creation of consortia research platforms in key areas, wherein besides the ICAR institutions, other science and development organizations would be participating; short term and focused research project through scheme of extramural grants; Agri-Innovation fund; Agri-incubation fund and Agri-tech Foresight Centres (ATFC) for research and technology generation. The innovative programme of the Council, 'Farmer FIRST' (Farmer's farm, Innovations, Resources, Science and Technology) will focus on enriching knowledge and integrating technologies in the farmer's conditions through enhanced farmer-scientist interface. The 'Student READY' (Rural Entrepreneurship and Awareness Development Yojana) and 'ARYA' (Attracting and Retaining Youth in Agriculture) are aimed to make agricultural education comprehensive for enhanced entrepreneurial skills of the agricultural graduates.

I am happy to note that the Vision-2050 document of **National Bureau of Agriculturally Important Insects, Bengaluru** has been prepared, based on the assessment of present situation, trends in various factors and changes in operating environment around agriculture to visualize the agricultural scenario about 40 years hence and chalk out a demand-driven research agenda for science-led development of agriculture for food, nutrition, livelihood and environmental security, with a human touch.

I am sure that the '**Vision-2050'** would be valuable in guiding our efforts in agricultural R&D to provide food and nutritional security to the billion plus population of the country for all times to come.

(S. Ayyappan)

Dated the 17th June, 2013
New Delhi

PREFACE

Insects are six-legged creatures, a class within the phylum Arthropoda. They are the most diverse group of animals on earth. More than 50% of all the described organisms is constituted by insects. There are about 10 million extant species of insects representing over 75% of all animal forms. With insects also forming the bulk of the Indian fauna the mandate of NBAII to collect, characterize and document these hexapods is well founded.

Insects have caught man's attention primarily because of their pestilent nature (on humans, plants and animals) and perhaps secondarily through their commercial roles as honey, silk and lac producers, pollinators etc. Though the proportion of useful and harmful insects is low within the class Insecta, it is now widely acknowledged that interactions in the insect community impact the density and diversity of economically important insects. In this backdrop, the number of agriculturally important insects that need to be documented far outweighs the mere quantum of economically important insects, that visibly and directly influence mankind.

This is also true in the context of India which is essentially an agrarian country where sericulture and apiculture are also important industries. It is here that NBAII is geared up to a community analysis of the biodiversity of insects in agricultural and natural ecosystems. This calls for long term and intensive biosystematic studies involving the collection and naming of the 70,000 odd species that remain to be discovered and named, as well as collecting the over 60000 species already named. The vision is therefore to build up at least one lakh insects with a befitting latinized nomenclature, besides barcodes and relevant bioinformation by 2050. Of these at least 10-12% would be agriculturally important, with most of the others exercising indirect or other ecological impacts on these economically important insects.

To accomplish this the NBAII repository is envisaged to undertake three tasks. One: Maintenance of type specimens at the museum, as well as networking of entomologists from across the country to collect all the above number of species. Agricultural entomologists across the country and globe should have free access to investigate, examine and study these specimens. Two: to build up a virtual repository of insects in terms of bar-coded digitized domains for global and easy access for insect identification. These will be continuously updated as a knowledge bank. At this point, insects in India with a barcode amount to just 2%. This has to leap at the rate of 2-3 % per year to touch a 80% mark by 2050. This indeed is our vision and goal. Three: Live insectary or *in-situ* maintenance of insect germplasm (including mites and spiders, entomopathogens and entompathogenic nematodes). The NBAII is unique (even by international standards) in maintaining a vast repository of live cultures of over 100 species of insects. It will be NBAII's endeavour to augment this repository of live insect cultures and increase it to 500

insects by 2050. Besides this, the culturing of rare species for conservation and release in the field is an ambitious future plan.

NBAII has been successful in implementing programmes for the biocontrol based management of the papaya mealybug, eucalyptus gall wasp, sugarcane woolly aphid, borers in rice and sugarcane, etc. to cite a few examples. These successes have imbued us with the optimism to garner and develop more bioagents with high searching ability, fecundity, fitness, pesticide resistance, etc. to manage many pests by 2050. This should enable us to dispense with most of the harmful insecticides by then.

Needless to say, the number of insect species to be named is high while biosystematists are low in number. This number will hopefully grow through the capacity building programme of the Bureau. We are bound to undertake Darwinian type expeditions in quest of new insects with the added advantages of greater information and an arsenal of bio-technological tools, which Darwin lacked.

The Bureau in the next few decades will be the most sought after insect repository for all Oriental insects with impact even beyond this zoo-geographical region. This document I therefore place before all, on a note of optimism and a clear vision stemming from the mandate of the Bureau.

Abraham Verghese
Director, NBAII
Bangalore

CONTENTS

CONTEXT

Insects are the most abundant of all life forms on earth. India with about 2% of the global land area is among the top ten mega biodiversity nations in the world accounting for 7.10 per cent of the world insect fauna. It is estimated that over 60000 species of insects have been described from India with nearly as many species remaining to be discovered.

Agriculturally important insects include pests of agricultural crops and livestock as well as vectors that transmit diseases amongst plants, animals and humans. They also include beneficial insects - predators and parasitoids that can be used for biological control of agriculturally important pests. Other important insects are pollinators, detritus feeding insects and insects that are sources of silk, honey, resins and medicines. There are quite some insects that are bioindicators of environmental degradation. Insects like *Drosophila* are being widely used in genetics and neurobiology. Further insects are the dominant biota of any biodiversity component, playing crucial roles in the ecological food web and balance in nature. If insects are affected, a cascading chain of negative effects occur in the delicate natural balance. The National Bureau of Agriculturally Important Insects (NBAII), Bangalore was formed in 2009 during the XI Plan by reorganizing the Project Directorate of Biological Control. It has the mandate of acting as a nodal institution for the collection, characterization, and documentation of insects of agricultural importance and the conservation and sustainable utilization of beneficial insects.

The NBAII has its core capabilities in biosystematics, ecology and biological control of crop pests. Taxonomic studies in Coleoptera, Thysanoptera, Hymenoptera, Diptera, Hemiptera and Neuroptera at NBAII have resulted in the identification of more than a hundred new species and identification tools for several natural enemies and pests of crops in Indian agro-ecosystems. DNA barcodes have been generated for over a hundred insects. Being part of the Network Project on Insect Biosystematics, NBAII has intensified research in identifying new insect species that have applications in the integrated management of crop pests in all agro-eco-zones of the country.

Research based on the knowledge of insect taxonomy aided the utilization of a number of natural enemies for the biological control of crop pests in our country. Biological control has proved to be a phenomenal success in managing intractable pests like the sugarcane woolly aphid, the papaya mealy bug and the eucalyptus gall wasp in several parts of India. One example of the impact is area-wide adoption of non-chemical methods of pest management by releases of *Trichogramma* spp. and the application of *Pseudomonas* in 15000 acres of rice in Adat Panchayat of Thrissur district, Kerala in the last 5 years, resulting in significant increases in yields and mitigation of pollution due to insecticidal use. Exotic natural enemies introduced against several invasive pests such as subabul psyllid, spiralling whitefly, papaya mealybug, eucalyptus gall wasp and weeds like *Parthenium, Salvinia*, water hyacinth, etc. are providing economic benefit worth millions of rupees across the country.

Improved techniques have been developed for the multiplication of 27 egg parasitoids, 7 egg-larval parasitoids, 42 larval / nymphal parasitoids, 25 predators, 7 weed insects,13 strains of fungi, 10 cultures of EPNs and 2 cultures of Bt nucleus cultures of which have been supplied to bioagent producers and other stakeholders. Field efficacy of promising parasitoids and predators has been validated and demonstrated in different agro-ecological zones under the AICRP on biological control and video films have been made for popularising these successes.

The NBAII has also developed multiple insecticide and high temperature tolerant strains of natural enemies, which are being used in over 100,000 acres of different crops all over India in the past decade. Seven technologies have been commercialized resulting in revenue generation of Rs. 21.00 lakh in the last few years.

Fundamental molecular research on endosymbionts resulted in circumventing the problem of loss of reproductive potential under conditions of continuous rearing in insectaries.

The NBAII is also recognized as a centre for human resource development (HRD) in insect taxonomy and biocontrol technologies. The NBAII has linkages with the biopesticide industry for HRD in mass production, formulation, quality control and supply of cultures. This Bureau has popularized mass production technologies and bioagent delivery systems through linkages with stakeholders.

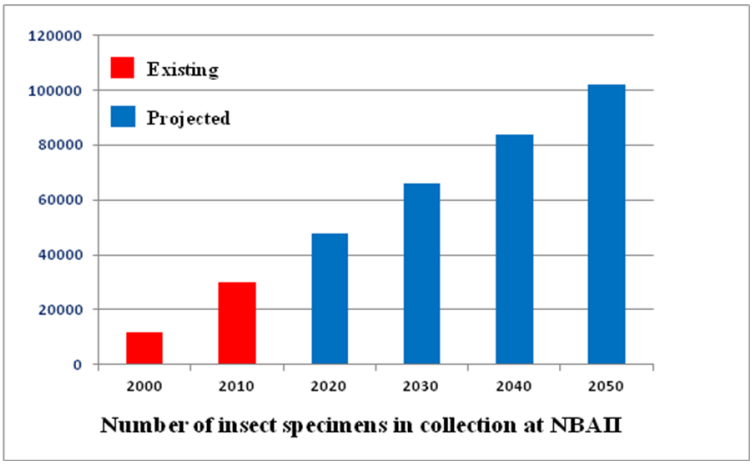
The NBAII has long term vision for fulfilling its mandated activities by taking up higher levels of research on biosystematics and biodiversity of insects with additional leadership in biocontrol in terms of supply of live cultures, identification services and the importation of exotics. The focus is now on biosystematics including inventorying, identification, curation and maintenance of insect collections with sustenance of its core strength: biocontrol.

In the case of agriculturally important insects, paucity of trained scientific manpower in insect biosystematics is one of the major problems in the National Agricultural Research Service (NARS) adversely impacting the quality of plant protection research and programmes. In 2006 the ICAR initiated the Network Project on Insect Biosystematics to address this issue, but the inadequacy in the availability of trained taxonomists is proving to be an impediment. An analysis of work done so far has shown that only one-third of the Orders have been getting some attention while two-thirds remain under-explored or neglected. Studies on insect diversity in agricultural and natural ecosystems are highly inadequate. That the very survival of ecosystems is insect dependant is overlooked. Lack of a well curated insect museum on the lines of the Natural History Museum, London or the US National Museum, Washington, etc., for exchange and study of insects is another impediment. The NBAII's long term vision takes into consideration these lacunae.

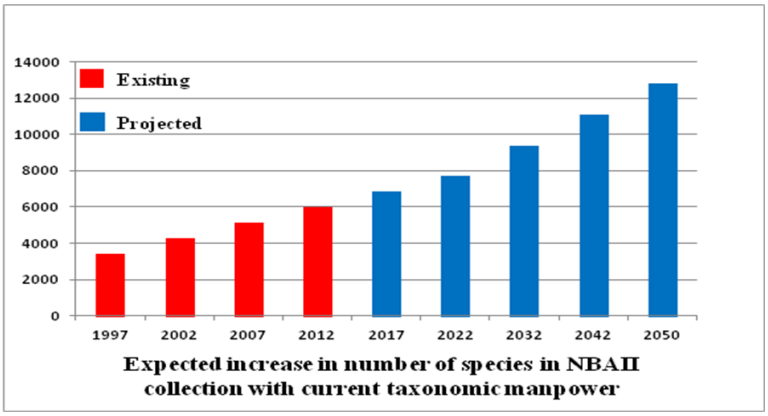
CHALLENGES

- Collection, identification and characterization of insects, mites and other arthropods that impact Indian agriculture and biosecurity, including pests of crops, alien invasive species, bioagents for insect pests and weeds, and species of quarantine significance are of fundamental importance for increasing agricultural productivity. This may number about 10,000 species of insects. In addition many insects indirectly affect agriculture as part of the trophic chain. These too come within NBAII's ambit increasing the number of species to be studied by many fold.

- The NBAII has been building on the collections bequeathed to PDBC by the erstwhile CIBC-Indian Station. These have been augmented manifold in the last decade. Nevertheless this has to be increased by about 10 fold of the existing collection (from the existing 6,000 or so collected to the estimated 60,000!).

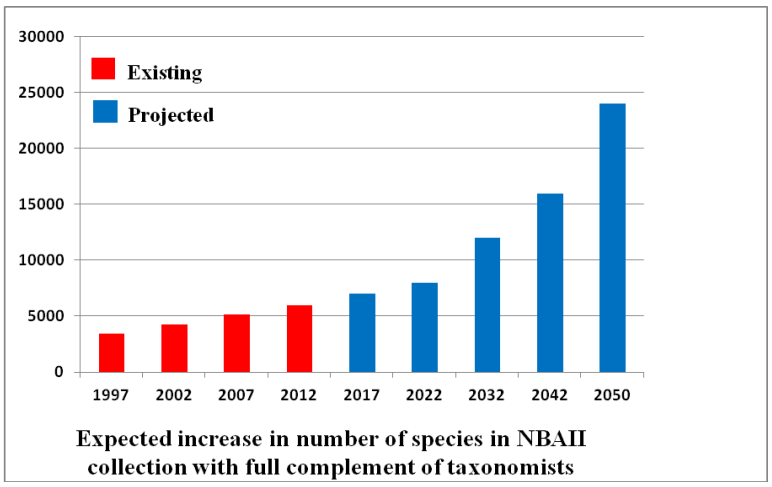


Number of insect specimens in collection at NBAII



Expected increase in number of species in NBAII collection with current taxonomic manpower

- If the number of taxonomists at NBAII is tripled, then the expected increase in the number of species at NBAII is likely to be about 25,000.



Expected increase in number of species in NBAII collection with full complement of taxonomists

- Taxonomic studies on identified groups of economic importance, including molecular characterization using CO1, ITS sequences, etc. have been taken up for building indigenous expertise. Developing core expertise in Indian biosystematics is the need of the hour.

- India faces a serious threat from alien invasive pests due to increasing volume of international trade and other porous ports of entry. The NBAII has to help monitor and prevent the introduction and spread of invasive pests and other species of quarantine significance. It will also provide expert identification and associated information on insects and mites to national agencies in support of quarantine activities and act as a nodal agency for classical biological control introductions. Success stories in containing recent invasive pests like the papaya mealybug and eucalyptus gall wasp indicate the NBAII is alive to these challenges.

- Identification of superior populations / strains of natural enemies for integration in IPM programmes is a challenge in the era of climate change and the ever changing agricultural scenario. Recent initiatives at NBAII have addressed this issue and populations of *Trichogramma chilonis* and *Chrysoperla zastrowi sillemi* tolerant to

abiotic stresses and pesticide pressure in different agro-climatic and geographic regions have been identified and improved for superior performance.

- In order to promote non-chemical methods of pest management, state-of-the-art mass production units for biocontrol agents need to be set up through KVKs at district level and by forging public-private partnerships. The NBAII has an active HRD programme for this and has strong ties with the State Departments of Agriculture, the Department of Forests, extension agencies and industry for transfer and commercialization of technologies.

- Determination and quantification of role of pollinators in crop productivity in cropping systems like oilseeds, pulses, fruit and vegetable crops is essential so as to optimize their utilization in improving productivity. At NBAII, research on *in situ* conservation of pollinators by the use of selective flora has been going on to address this issue.

- Deployment of pheromones and semio-chemicals for detection and management of insect pests. The semiochemical diversity of plants/ insects and their influence on the behavioral ecology of pests. Natural enemies and pollinators require studies. Utilisation of potential semiochemicals for the management of pests or conservation of natural enemies/ pollinators including the modernisation of delivery systems needs greater emphasis.

- Taxonomic support and education at the national level to researchers and students of economic entomology is an important goal that needs to be amplified to encompass the needs of the over 10,000 or so entomologists of India and South Asia. Training and building up a core group of taxonomists well versed in morphological and molecular taxonomy is a major vision. By 2050 India will need

about 400 active insect biosystematists to cater to the identification of over a lakh insects. The HRD programme under NBAII is geared to meet this requirement.

OPERATING ENVIRONMENT

The existing strength of NBAII is in the fields of biosystematics, biodiversity and biological control. Over the years, there has been a major change in the research thrusts of the institute to suit the socio-economic situation, modern agricultural practices, climate change and changing consumer needs. When the importance of non-chemical methods of pest management was recognized as the need of the hour, the Biological Control Centre at Bangalore was upgraded to the Project Directorate of Biological Control (PDBC) in 1993 and in 2009 the PDBC became the National Bureau of Agriculturally Important Insects (NBAII) with the identification and characterization of the Indian arthropod fauna including entomopathogens, endosymbionts, etc., becoming the major mandate of this fledgling bureau.

National institutions such as the Botanical Survey of India (BSI) and the Zoological Survey of India (ZSI) are carrying out activities such as surveying, cataloguing and preparation of Red Data Books of threatened plants and animals of India in accordance with various provisions of Articles 7 and 8 of the Convention on Biodiversity. Extensive inventories such as the Flora of India and the Fauna of India are constantly being updated. In this context the amount of attention received by different taxonomic groups of insects has been uneven, with little or no expertise available for several groups of economically important insects. Often they are the only remaining material of extinct species or the only record of species seen only once in the wild. Though insect collection in India has gone on for over 125 years, the greater part of the collections are housed in museums outside India, mainly the Natural History Museum, London. The major institutional collections in India are at the Zoological Survey of India, Kolkata and its regional stations (general faunistic collections); Indian Agricultural Research Institute, New Delhi (National Pusa Collection, mainly insects of agricultural importance); Forest Research Institute, Dehradun and KFRI,

Peechi (forest pests); Bombay Natural History Society, Mumbai; and NBAII, Bangalore (mainly parasitoids and predators of crop pests). Besides these, some agricultural universities under the NARS (*e.g.*, UAS, Bangalore; TNAU, Coimbatore, Rajasthan Agricultural University, Udaipur), zoology departments of traditional universities (*e.g.* Aligarh Muslim University, Aligarh; Panjab University, Patiala; University of Calicut, Calicut) and individuals working on specific groups are maintaining small collections. The reference collections in many institutions need proper curation and restoration. There are many type collections in foreign museums which are difficult to access for Indian taxonomists. The Biological Diversity Act, 2002 imposes restrictions on the free exchange of specimens adversely impacting taxonomic and biodiversity research in India. The regulation should be so liberalised to promote uninhibited exchange of specimens for taxonomic research as the existing regulation on a collaborative mode is very restrictive and often impractical.

The national agricultural policy seeks to attain a growth rate of over 4% in agricultural production which will necessarily entail technological advancement. However, due to various issues like climate change, free trade with the attendant increase in the threat to our bio-security and rapid urbanization leading to shrinking farm land it becomes necessary to look at technologies suitable for newly emerging and invasive pests as well as for stresses to crops in protected / polyhouse conditions. Biotic stresses to crops caused by insect pests amount to 20-30 % loss (both pre and post harvest) in total agricultural production requiring crop and region specific protection technologies based on sound knowledge of insect biosystematics, ecology, etc.

Climate change poses a formidable challenge since it tends to have a great impact on most natural habitats and the species inhabiting them. Climatic conditions due to higher / lower temperatures or increased carbon dioxide affect the geographical distribution, diversity and ecological behaviour of insects.

Demand for pesticide-free, organic and fair-trade produce in export markets is growing and has created new markets for producers, although farmers may have to

negotiate complex and costly certification processes. At this juncture, NBAII envisages taking up the major task of characterising and identifying new and potential strains / populations of bioagents, developing production protocols and standardizing technologies for their utilization as an integral part of organic farming. It is envisaged that beneficial insects and microbes will have a major role to play in the management of poly-house and storage pests. A comprehensive linkage and networking policy within and outside the country would be emphasized with a focus on genomics, bioinformatics, gene/allele mining and other frontier areas of biotechnology, bio-diversity and biological control. It is important to constantly monitor for the entry of invasives and continuously strive for obtaining potential exotic natural enemies to tackle the invasives, for which collaboration with international institutes like CABI, USDA and CSIRO national organizations like the Biodiversity Authority (BDA) and Department of Plant Protection & Quarantine (DPPQ) would be essential. For effective dissemination of technologies, networking with KVKs, State Departments of Agriculture and AICRPs could be effectively utilized. Private-Public partnership will be developed with biological control/ bio-pesticide producers for the development, scale up and commercialization of technologies.

NEW OPPORTUNITIES

The NBAII has been recognized and designated as a national repository by the National Biodiversity Authority for agriculturally important insects. This presents an opportunity for establishing linkages with other national agencies like the Zoological Survey of India, Forest Research Institute, Dehradun, National Pusa Collection, New Delhi, etc. so that collections, expertise and facilities are networked and optimized to benefit taxonomists, ecologists and other biologists working with insects. With strong inter – institutional linkages NBAII hopes to maximize its mandate of documenting the over 80,000 insects representing at least 12,000 agriculturally important species of insects by 2050.

Insect museum at NBAII, designated a national repository by the National Biodiversity Authority, housing over 6000 species of insects

Recent developments in the field of advanced imaging, microscopy and information technology have revolutionized insect taxonomy which will be harnessed for cataloguing, mapping, e-typing, digitizing, sharing of insect collections, creation of web-based interactive identification tools and databases on economically important insects. Increasing use of molecular techniques in systematics of insects and other arthropods including DNA barcoding is a boon as it will enable rapid characterization and identification of cryptic species and species of quarantine importance. Structural and functional genomics of insects, gene/allele mining, bioinformatics, nanotechnology are prominent fields, which offer vast scope for research.

Genetic improvement of beneficial insects (honeybees, silkworms, lac insects, etc.) and selection of natural enemies for traits such as resistance to pesticides, breaking of diapause and increased tolerance to extreme temperatures can be achieved by appropriate manipulation of insects by recombinant DNA techniques.

Endemic wild silk moths of the Andaman islands. Study of endemic Indian insects and their habitats is a prime concern of the bureau.

By 2050 it is proposed to develop more than 100 smart and super natural enemies. Success with strains of *Trichogramma* behoves well for the future**.** Genetic engineering of insect vectors (thrips, whiteflies, aphids) to make them refractory to pathogens is a lucrative option in the management of vector borne diseases. Para-transgenesis focuses on utilizing genetically modified insect symbionts to express molecules within the vector that are deleterious to the pathogens they transmit. Genome sequencing of agricultural insects and pathogens using high-throughput screening will help in better understanding insecticide resistance and vector transmission. Whole genome sequencing of Indian insects including vector and endosymbiont identification will be carried out.

Phenomics and insect behavioral studies enable the study of responses of insects to drought-stressed and normal conditions, the differential attraction of insects to quantitative differences in the secondary metabolite profile emanating from the plants in the form of volatile organic compounds can be explored to arrive at possible management strategies. Insect ethology in terms of intra and inter specific associations, niche overlaps, competition and exclusion, migration, etc., need to be constantly studied as these are

dynamic in space and time. Identification of volatile chemicals from plants / hosts and tritrophic ineteraction studies that will culminate in the management of pests will be carried out by NBAII.

RNAi technology has the potential to suppress cellular production of certain proteins in the physiological processes to halt undesirable processes or stimulate desirable ones of importance. In insect pest management, the potential use of RNAi would be suppression of expression of genes for insecticide resistance, molting hormones, temperature tolerance, silencing the hormonal activity, etc. for immunity and limiting metabolites for growth and nutrition. NBAII's role as the nodal centre for the correct identification and characterization of insects is a crucial back-up for RNAi research in the country.

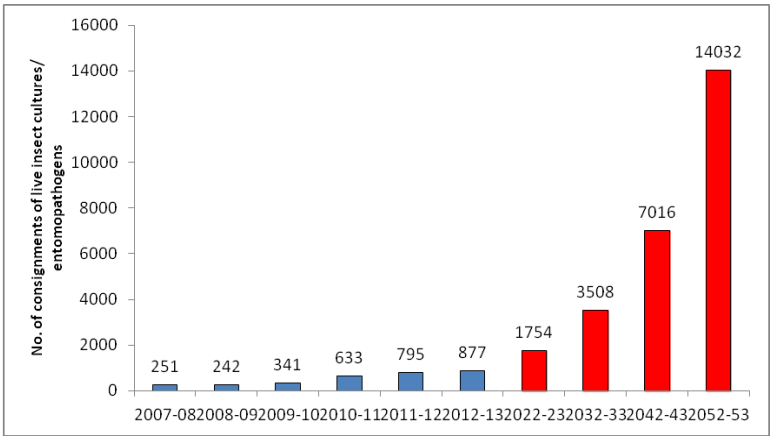
Nanotechnology can jump-start the advancement of agriculture in the coming decades. It can be used for early detection of pests using nanosensors and for management of pests with slow release nanoformulations such as nanogels. The proposed formulations of pheromones nanogels, nanoformulations, and nanosensors are in conformity with the standards prescribed by the Food Safety and Standards Authority of India (FSSAI) including the provisions of the Prevention of Food Adulteration Act 1954. Nanogel pheromone delivery systems will provide low cost, environmentally friendly means to manage crop pests. It is also possible that by 2050 nanostructures present in the wings of Lepidoptera may be harnessed to various ends like the killing of viruses, etc.

The Bureau has collaborative linkages with other research organizations of national and international repute, and private industries for advances in scientific research for innovation and commercialization of technologies generated by the institute. Working in close harmony in a public-private partnership mode would enable accelerating R&D and promote sale of products, formulations and stress tolerant bio-agents generated and developed by the institute.

GOALS / TARGETS

- Collection and characterization of agriculturally important insects and other arthropod biodiversity including pests, bioagents, honey bees and other pollinators, lac insects, silkworms, vectors, dung beetles, veterinary pests, etc. and preparation of field identification guides on priority. Taxonomic characterization of at least 12,000 species including rare and new insect fauna needs to be carried out on a war footing.

- Creation of a repository of genetic resources of agriculturally important insects with desirable attributes from different geographical regions of the country which will help research workers, students and farmers for future study and utilization. Efforts will be made to conserve quality beneficial organisms *ex situ* through a network of institutions in different parts of the country and to ensure their utilization for increasing crop productivity by developing mass production techniques for important resources like predators and parasitoids.



Consignments of live insect cultures/ entomopathogens supplied during the last five years (blue bars) and anticipated demand from 2020 to 2050 (red bars)

- Training a pool of indigenous expertise in the biosystematics of insects and mites of economic importance and establishing a credible identification service.

- Insect biodiversity informatics fully integrating morphological and molecular data including DNA barcodes and sequences with illustrations, keys, and other biological data using web-based tools, so as to know and understand our biodiversity to ensure preservation and sustainable use.
- Molecular profiling for characterization of genetic diversity and conservation of morphologically well characterized beneficial insects including insect bioagents, lac insects and associated endosymbionts, honey bees and other pollinators, silkworms, etc. and molecular techniques for rapid quarantine screening for alien invasives. These would also include biotypes / strains of insects especially vectors.
- Excessive use of pesticides is a major concern of NBAII. The use of bioagents (insects, entomopathogens,EPNs, etc.) as well as the conservation of insect pollinators, insectivorous birds, etc. will be encouraged and promoted by NBAII.One way of conserving pollinators is by planting crops and other plants in landscapes designed to attract pollinators by acting as sources of nectar and pollen.
- Use of nano-formulations of semiochemicals with increased shelf life and greater efficiency on targeted insect pests should be the order of the future. Besides nano-sensors can also be used for early detection of volatiles emitted by insect infested crops enabling the implementaion of management measures well before the pests attain damaging levels.
- Future IPM support by the Bureau will be by identifying semiochemicals and natural enemy friendly cultivars to attract parasitoids and predators. The *in situ* provision of shelters and refuges as alternatives for encouraging these beneficial organisms will be encouraged. This will reduce pesticide pressure on crops and result in development of pollution free and clean environment, quality output in terms of pesticide residue - free products and opportunity to export these products

to countries where they are valued the most. This will be the support module for all IPM in 2050.

- Use of nano-formulations of semiochemicals with increased shelf life and greater efficiency on targeted insect pests should be the order of the future. Besides nano-sensors can also be used for early detection of volatiles emitted by insect / pathogen infested crops enabling the implementaion of management measures well before the pests attain damaging levels.

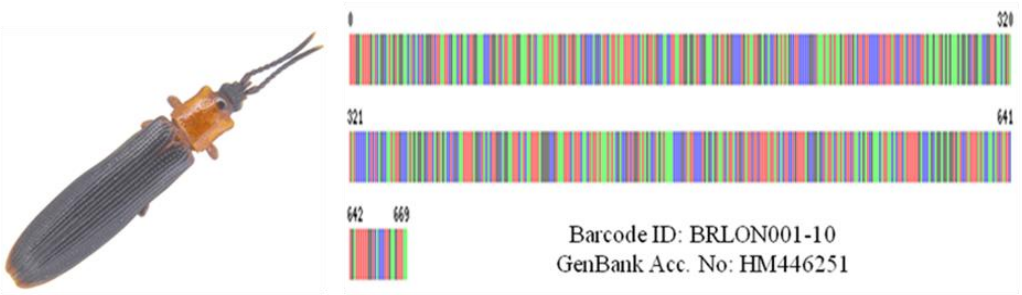
All the above mentioned practices aim at safe farming giving importance not only to quantity of output but also giving equal importance to the quality of the product being developed on the farm. Our targets will help in increasing residue - free agricultural products through sustainable and assured supply of quality agents required for achieving ecologically safe pest control and hygienic environment which go with "green IPM" technologies.

WAY FORWARD

- Creation of a national repository and insect museum of authentically identified insects, spiders, mites and entomopathogenic nematodes, including type material and voucher specimens, with trained staff for curation, cataloguing, maintenance and networking of collections at NBAII, IARI, SAUs, ZSI, FRI, BNHS and other universities for optimization of available resources of expertise, literature, reference collections, etc. Modalities for networking the collections at NBAII, IARI, NPIB centres, ZSI, and FRI and acquisition of neglected insect collections from universities will be worked out.

- DNA barcodes of Indian insects will continue to be generated and for this, protocols for DNA extraction from museum preserved specimens may be standardized.

- Fostering integrated taxonomy involving a combination of conventional morphology, DNA barcodes and sequences, biology and behaviour to place the systematics of Indian insects on a sound footing.
- Establishment of a national network for surveillance, monitoring and management of alien invasive pests in collaboration with national and international plant protection organizations.



Brontispa longissima **(left) an invasive beetle that has devastated coconut plantations in several countries but not present in our country. It could however gain entry from across our borders. The barcode (right) of this species developed at NBAII, for quick identification to initiate timely measures to prevent its spread in the event of its entry.**

- Documentation and surveillance of potential alien invasive insects.

Phenacoccus madeirensis Green

Phenacoccus solani Ferris

Pseudococcus jackbeardsleyi Gimpel & Miller

Wahlgreniella nervata (Gillette)

Insect pests detected by NBAII in our country which need close monitoring for timely management in the event of an outbreak

- NBAII in view of its broader mandate on agriculturally important insects and other arthropods will conserve the germplasm of insects, spiders, mites and entomopathogenic nematodes through *in situ* and cryopreservation approaches. Standardization of protocols for *in situ* and *ex situ* conservation of genetic resources of insects in the laboratory and in strategic locations and establishment of gene banks for bioagents, lac insects, honey bees and other pollinators, etc.
- Quantification of the impact of loss of habitat due to GM crops, alien invasive species, climate change, and chemicalization on beneficial insect fauna such as bioagents, honey bees and other pollinators, lac insects, silkworms, soil arthropod fauna, etc.

- Crop habitat diversity by intercropping, mixed cropping, border cropping and other such cultural practices such as need-based chemical intervention to encourage natural populations of parasitoids, predators, honey bees, pollinators, etc.
- Impact of global warming and increased CO_2 on arthropod biodiversity with focus on pollinator diversity, parasitoids, pests etc. will be constantly monitored in terms of geographical distribution, behavioural modification and ecological changes.
- Exploration for specific groups of agriculturally important arthropods (including pests, natural enemies and pollinators) and associated organisms to evolve protocols for their mass production.
- A knowledge platform on transgenics, paratransgenics and molecular toxicology of insects and their endosymbionts will be developed.
- Development of repository and library for culturable endosymbionts on insect cell lines.
- Continuous documentation of insects through Arthropod Germplasm Information System
- Documenting insecticide resistance and its impact on natural enemy complexes in selected agro-ecosystems
- Synthesis and field evaluation for persistence and improvement of pheromones/ nano-formulations of sex pheromones and commercialization for major pests
- Ecology of spiders and other arthropods and their role in agriculture

There are at least 60,000 insect species identified (and about a lakh or so to be identified) from the Indian sub-continent, of which nearly 30,000 species are in the collections of ZSI, IARI and NBAII. By 2050, the number of species to be maintained in these repositories will be five folds of the present. Consequently museum and related curating facilities needs to be scaled up. Apart from this, special attention needs to be given to agriculturally important insects whose number stands now at about 6000 species. This may also double by 2050 as the several secondary and new insects are becoming pests, with corresponding increase in the natural enemy complex.

Further, insect biotypes are expected to multiply, especially with changed climate and agrarian practices. The time to time molecular characterization will help in keeping a tab on these changes. To match this upscaling NBAII hopes to make a quantum leap in modernizing infrastructural facilities and the necessary human resources by three fold.
Insect management strategies are bound to change with regular phasing out of insecticides. While the long term hazards of current pesticides will manifest in terms of resistance build up and biomagnification, farmers will have only friendly bioagents as the viable option for pest management. The NBAII will then be the source for knowledge of bioagents (live) and for rearing protocols to tackle these insect pests.

Insects are playing an important role in the balance of nature.Therefore,conservation methods for insects that directly and indirectly influence the arthropod community and strength of an ecosystem,will be put in place.

The Arthropod Germplasm Information System will make available many faceted information on insects / arthropods of agricultural importance to entomologists from any part of the country or other parts of Asia.

Complete profiling of major agriculturally important groups of insects will be available, as for example: Ichnenmonoidea, Platygastroidea, Cynipoidea, Chalcidoidea, Proctotrupoidea, Apoidea (Hymenoptera), Staphylinoidea (Coleoptera), Cecidomyiidae, Syrphidae, Tabanidae, Bombylidae, Tephritidae (Diptera) to name a few, and other orders like Isoptera, Odonata, Mallophaga, etc.

In the next few decades, NBAII will be the main arm supporting quarantine and biosecurity related issues pertaining to insects. It will also document the insect biodiversity of the Himalaya, Indo-Burmese region, Andaman and Nicobar islands and Western Ghats.

The NBAII by 2050 would have conserved several rare insects and prevented the entry of exotic pests by its vigil models and alertness.

ICAR and NBAII would have drawn world attention for its professional approach to biosystematics, insect conservation and pest management.

This Bureau will also boost insect exchange globally with Indian interest in focus. Hitherto unexplored ento-business like commercial insect pollination service, insect parks for eco-tourisum, insects as animal feed, etc will get a fillip.

The NBAII is slated to grow even beyond - it is envisaged it will be a center for advanced insect studies encompassing all aspects like biosystematics, physiology, ecology, community analysis, museum curation, education, economical intervention, social and economic impact analysis.