



Memorabilia - An Invited Article

Progress of Biological Control Research in India - From CIBC to ICAR-NBAIR: A walk down the memory lane of legacy and the way forward*

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(A). PRELUDE

The National Bureau of Agricultural Insect Resources of Indian Council of Agricultural Research (ICAR-NBAIR), Bengaluru, celebrated its 27th Foundation Day on 19th October 2020. It was a virtual meeting due to the prevailing COVID-19 pandemic. Most of the present and former Directors as well as staff of NBAIR participated along with a few invited guests. I thank the Director, Dr. N. Bakthavatsalam, for inviting me as a Special Guest along with Dr. S. N. Puri.

Foundation Day is an opportunity for retrospection while celebrating the event. It is also an occasion to remember and pay tribute to those who have contributed to its founding as well as progress and success, and also to chalk out a plan for future growth and sustainability.

NBAIR has a very interesting legacy. As far as I know, there is no one who has witnessed the birth, transformation, growth and achievements of NBAIR, right from inception until now, more closely than me. In fact, I had an insight into NBAIR even before it was conceived and I am fully aware of its pedigree. I would like to avail this special occasion to go on a nostalgic trip and narrate how CIBC laid a strong and systematic foundation for R&D in biological control of crop pests and weeds in India and how, after a series of developments, NBAIR has inherited the historic premises and facilities, and is continuing to maintain biological control a vibrant area of plant protection. I will take another

opportunity to highlight the role played by various other government as well as private organizations for the progress of biological control in our country. For the present, I will limit it to the contributions of CIBC and ICAR-NBAIR.

(B). CIBC: COMMONWEALTH INSTITUTE OF BIOLOGICAL CONTROL

The Indian Station of Commonwealth Institute of Biological Control (CIBC), one of the major units of Commonwealth Agricultural Bureau (CAB), London, was established in 1957 at Hebbal, Bengaluru (then Bangalore), in the same premises where NBAIR is presently located.

If we look back, during the 1950s and early 60s, biological control was not a very familiar term. In fact, on seeing the sign board of CIBC displayed on the compound facing the main road (Bellary Road), most people used to assume it as 'Commonwealth Institute of Birth Control' because during those days, Govt. of India was vigorously campaigning for family planning and 'birth control' was a buzzword then. However, soon, CIBC created a niche for itself and biological control gradually became popular.

WORKING ENVIRONMENT

The CIBC building, located in Hebbal which was a desolate area in North Bengaluru then, was very cozy and centrally air conditioned, a very rare and luxury facility during those days. It is stretched east to west with large glass windows on the north side so that the rooms get only

*Largely based on a talk delivered on the occasion of the 27th Foundation Day of ICAR-NBAIR on 19th October 2020.

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reflected light, not direct sun light. There was a lot of open space in front as well as on either side with a few shade trees on the east side of the building to filter sun light. All these kept the building naturally cool. It was very well equipped for entomological research with the latest microscopes, insect rearing cages, insect storing cabinets, library, etc. It had a full-fledged carpentry section for making insect rearing cages, insect storage cabinets, shipping boxes, library racks, etc. and also there was a photography unit. I joined CIBC in 1961. It was my first job and there was only about a dozen staff then. Since then, for almost the last six decades, I have been very closely associated with biological control. Change of jobs or retirement has not interfered with my interest and involvement in the subject even now.

Dr. V. P. Rao and Dr. T. Sankaran

The work culture in CIBC was entirely different. Since we were dealing with live insect cultures, officially the working days included all the seven days in a week with Saturday, Sunday and all general holidays being half-day. Dr. V. P. Rao, the Founder Director (Entomologist-in-charge) of the Indian Station of CIBC, was truly inspirational. He used to take us to the fields and train us in insect collection and rearing. We used to spend more than half-a-day almost daily in fields, making large collections of insect pests for rearing, discovering and studying their natural enemies. He used to tell us that insects are our top-most priority, and we should try to establish a bonding with them and enjoy working with them. In a lighter vein, he used to say that the air conditioned facilities in the lab are actually meant for insects and that we are the indirect beneficiaries! He used to make each employee feel that he/she is very important and that the success of the lab depended on him/her! He was soft spoken and very considerate. He inculcated in us a sense of concern and passion for insects. Dr. Rao used to spend one or two hours

beyond the regular office hours to complete the day's work before he went home. Inspired by him, and also to impress him, a few of us, including the late Dr. H. Nagaraja, also used to sit extra hours daily, attending to mounting and labelling of insect specimens, consulting literature and preparing index cards for references, etc. It became a habit with us. Dr. Rao was a walking encyclopedia on biological control and a perfectionist. A systematic research on biological control of a number of major crop pests and weeds was initiated and a strong foundation laid in India under his leadership. He was truly the 'Father of Biological Control in India' and a great role model. Dr. T. Sankaran who worked closely with Dr. Rao and later succeeded him in 1973, was another stalwart. He had joined CIBC in 1963 as a project lead for biological control of weeds, but he also helped Dr. Rao in coordinating the work on various other projects being carried out all over India. He was dynamic, quick in thought and action, highly principled, forthright, an excellent writer and editor, and a great motivator. One should have been fortunate to have started a career under such great mentors. I remember that Dr. Chandish Ballal who recently retired as the director of NBAIR, started her research career under Dr. Sankaran at CIBC. Dr. Sankaran took voluntary retirement from CIBC in 1986. I had maintained contact with both Dr. Rao and Dr. Sankaran till they breathed their last.

PIONEERING CONTRIBUTIONS

Since biological control of crop pests and weeds was almost an unexplored area then, CIBC submitted several interesting projects on major crop pests and weeds and was able to get good funds from various sources, mainly from the US PL-480 scheme in the 1960s. Those projects, which were operated almost concurrently, included exploratory surveys for natural enemies, studying their bio-ecology, evaluation of their efficacy and developing techniques for culturing



CIBC main laboratory building then, now the NBAIR guest house.

them. The crop pests included those of rice (rice stem borers, leaf roller, mealybug), sugarcane (stem borers), maize (stem borers), coconut (*Oryctes rhinoceros* beetle), tea (scale insect), citrus (scale insect, citrus butterfly), potato (potato tuber moth), tomato, pulses, cabbage and other vegetable crops (*Helicoverpa armigera*, *Spodoptera litura*, *Plutella xylostella*,



Dr. V. P. Rao, Founder Director, CIBC Indian Station, Bengaluru.
'Father of Biological Control in India'

aphids, etc.), forest trees (cedar shoot borer, *Hypsipyla robusta*; conifer balsam woolly aphid, *Adelges spp.*, Indian gypsy moth, *Lymantria obfuscata*); apple (scale insects) as well as aquatic weeds like water hyacinth, *Pistia* and *Salvia* and terrestrial weeds like *Chromolaena*, *Striga*, *Orobanche*, *Lantana*, etc. Thus, almost all major crops and weeds were covered. With Bengaluru as the coordinating centre, CIBC had opened its sub-stations all over India depending upon the crops/pests which included those at Srinagar (Jammu & Kashmir), Dalhausie, Kulu and Shimla (Himachal Pradesh), Ludhiana (Punjab), Dehradun (Uttarakhand), Sri Ganganagar (Rajasthan), Lucknow (Uttar Pradesh), Surat and Anand (Gujarat), Bhopal (Madhya Pradesh), Parbhani (Maharashtra), Mandya (Karnataka), Coimbatore (Tamil Nadu), Palghat (Kerala), Ambajipet and Ramachandrapuram (Andhra Pradesh), Bhubaneswar (Odisha), Plassey (West Bengal), Motipur (Bihar), Shillong (Meghalaya), Jorhat and Guwahati (Assam), and Gangtok (Sikkim). These stations remained functional through the duration of the concerned projects. Besides working at Bengaluru, I had the opportunity of working at Guwahati, Shillong, Jorhat, Bhubaneswar, Dehradun, Anand and Mandya on various projects in the early part of my career itself. I have also toured several other states and Union Territories like Andaman & Nicobar Islands and Lakshadweep Islands in connection with various projects. Thus, working on diverse projects and at different places was

an invaluable opportunity and experience for most of us.

A large number of parasitoids, predators and pathogens of various crop pests and weeds mentioned above were discovered (many of them being new records), and their bioecology and breeding techniques were studied for the first time in India. A wealth of information came out from such pioneering efforts from different parts of India. Besides, several exotic natural enemies, including a few species of *Trichogramma*; parasitoids of San Jose scale (*Aphytis*, *Encarsia*) and potato tuber moth; specific natural enemies of water hyacinth (*Neochetina*, *Orthogalumna*) and *Salvinia* (*Cyrtobagous*), and several others were introduced from other countries and tried against some of the invasive pests and weeds. Similarly, natural enemies of Indian origin were shipped to other countries for screening and field trials. In both the cases, quarantine protocols were strictly followed.

I was often given the opportunity and challenge to culture most of the exotic natural enemies. These included the Tachinid parasitoids; the insect parasitic nematode DD-136 (*Neoplectana carpocapsae*); the Reduviid predator, *Platyeris laevicollis*, against *Oryctes rhinoceros*; the mosquito larvivorous fish, *Nothogranichius guentheri*, etc. The DD-136 nematode which was cultured and studied for the first time in India in the mid-1960 attracted a lot of interest. Scientists from various ICAR institutions like Central Rice Research Institute at Cuttack and Sugarcane Breeding Institute at Coimbatore as also from IARI, Agricultural Universities, etc. were deputed to CIBC to undergo training in the method of culturing DD-136 as well as other natural enemies and their hosts. The host insects cultured in large numbers included the rice moth, *Corcyra cephalonica*; wax moth, *Galleria mellonella*; scale insects, mealybugs and potato tuber moth. Further, there was a lot of confusion with regard to the correct identity of the indigenous as well as introduced species of *Trichogramma*. A separate project on the taxonomy of Trichogrammatids was initiated at CIBC and path-breaking contributions came from Dr. H. Nagaraja and Dr. Sudha Nagarkatti who developed authentic keys for identification and also described several new species. Thus, through the combined contributions of all these efforts, CIBC established a distinct niche for itself not only in India but also it placed India on the global map of biological control. With so many live cultures on display and with the reputation of being an international organization, CIBC had its own aura. We, the staff, used to bask in that image and feel that we were somewhat privileged! We used to get a lot of visitors which included scientists, officials, teachers, students, etc. from all over India and other countries. They used to be thrilled on seeing the facilities and live insects. These created awareness and interest in biological control at all levels. Thus, CIBC was truly the harbinger of a systematic approach to biological

control in India.

Dr. V. P. Rao was hugely responsible for the success of CIBC followed by Dr. T. Sankaran who succeeded him. They had left a lasting impression and a valuable legacy in the staff they trained some of whom rose to occupy responsible positions and contributed to strengthen biological control and other areas of plant protection. Both these stalwarts and the dedicated staffs of CIBC certainly deserve to be acknowledged for their invaluable contributions. I was fortunate to have been associated with such a vibrant team right from my early phase and exposed to the various facets of biological control. In fact, it was such an overall training that gave me confidence to take up the challenge of establishing Bio-Control Research Laboratories (BCRL) of Pest Control India Ltd. in 1981 which is the first-ever commercial insectary undertaking commercial production and supply of biological control agents in India. I thoroughly enjoyed my work.

END of CIBC INDIAN STATION

After a golden period from the 1960s to mid-1970 when CIBC handled several exciting projects, it faced a challenge in getting replacement projects as, due to political and other reasons, there were restrictions on US PL-480 projects. It had to close down most of the sub-stations and was facing an uncertain future. Most of the senior scientists, including me, left in search of alternative jobs. At that time, I joined the University of Agricultural Sciences, Bengaluru, as Jr. Entomologist in 1976 and was posted at its Regional Research Station (RRS), V. C. Farm, Mandya, to work in the All India Coordinated Research Project on Rice. However,

CIBC lingered on for a few more years and finally it was taken over by Govt. of India and handed over to ICAR in 1988. That marked the end of CIBC Indian Station, but a rich legacy was left behind for ICAR.

(C). ICAR: INDIAN COUNCIL OF AGRICULTURAL RESEARCH

Following the favourable environment created by CIBC, several organizations showed interest in biological control. These included the Indian Council of Agricultural Research (ICAR); Directorate of Plant Protection, Quarantine and Storage (DPPQ&S); Indian Agricultural Research Institute (IARI); Central Integrated Pest Management Centre (CIPMC); Agricultural Universities; State Departments of Agriculture and Horticulture; Bio-Control Research Laboratories (BCRL) of Pest Control India Pvt. Ltd. (India's first commercial insectary) and other private organizations. These made their own contributions and strengthened biological control programs, but only those pertaining to ICAR are discussed here.

C-1. AICRP on Biocontrol of Crop Pests and Weeds

Following the impetus created by CIBC Indian Station, ICAR has launched its own biological control programs as a part of its All India Coordinated Research Projects (AICRP) in 1977. A Project Coordinator's cell of the AICRP on Biological Control was created at the Indian Institute of Horticultural Research (IIHR), Bengaluru. The project was initially funded by Dept. of Science & Technology (DST), Govt. of India, but from 1979 onwards, the funding was exclusively from ICAR. Dr. (Mrs.) Sudha Nagarkatti, a well-known biocontrol expert



CIBC Staff, 1970: Seated, L-R: Sundari, Apitha, Victor Karunan*, Dr. T. R. Nagaraj*, Dr. P. R. Dharmadhikari*, Dr. V. P. Rao (Director, India)*, Dr. F. J. Simmonds (Global Director)*, Dr. Sudha Nagarkatti, Sumithra Manjunath*, Dr. T. Sankaran (Assoc. Director, India)*. Standing, 1st row, 4th from right (behind Dr. Sankaran): Dr. H. Nagaraja*. Standing, 2nd row, 7th from left with dark shirt, M. Narayana Rao; with tie, Dr. T. M Manjunath. (*late – It is unfortunate that most are no more)

who worked in leadership positions for several years at CIBC, joined ICAR and was appointed as the Project Coordinator. The project was operated on an all India basis with 10 centres spread across the country which included the Indian Institute of Horticultural Research, Bengaluru (Karnataka); Sugarcane Breeding Institute, Coimbatore (Tamil Nadu); Central Rice Research Institute, Cuttack (Odisha); Central Tobacco Research Institute, Rajahmundry (Andhra Pradesh); Central Plantation Crops Research Institute, Kayangulam (Kerala); Central Potato Research Institute, Shimla (Himachal Pradesh); Indian Agricultural Research Institute, New Delhi (Delhi); Gujarat Agricultural University, Anand (Gujarat); Punjab Agricultural University, Ludhiana (Punjab); and Kerala Agricultural University, Thrissur (Kerala). These helped to cover almost all major agricultural, horticultural, plantation, fibre, oil seed, cash crops and other crops for exploring adoption of biological control strategies. Annual workshops of all India biocontrol workers were conducted for reviewing the work done and to chalk out the program for the coming year. It also served as an excellent platform for exchange of ideas between scientists. I had the privilege of participating in such workshops as an invitee.

Thus, ICAR has successfully launched its own biocontrol operations in India. It is very appropriate that we acknowledge DST and ICAR for launching the Indian initiative for biological control and Dr. Sudha Nagarkatti for providing the much needed leadership in the initial stages of the project.

Meanwhile, CIBC, which was facing a daunting period due to lack of projects and funds as already explained, was taken over by Govt. of India and handed over to ICAR in 1988. Thus, ICAR acquired the entire premises along with the buildings and infrastructure. That marked the end of CIBC Indian Station.

Taking over CIBC was a huge asset for ICAR, both in terms of scientific facilities, including a large collection of identified and labeled insect specimens, as well as real estate. Following the transfer, the Project Coordinator's Cell of AICRP on Biological Control was moved to the erstwhile CIBC premises in 1988. It was then called 'Biological Control Centre.' By now, Dr. Sudha Nagarkatti had resigned her job at ICAR and left for the USA to settle down there with her family. Dr. S. P. Singh succeeded her as the Project Coordinator. With its own premises and a large staff, biological control project became very prominent.

C-2. Project Directorate of Biological Control (PDBC)

It was thought that the centre with its own premises, impressive infrastructure and trained staff, deserved to be upgraded as a Directorate. A strong document justifying the formation of a separate Directorate for Biological Control

was needed to be submitted to ICAR. I was back in Bengaluru since 1981. I had resigned my job at the UAS-Bengaluru and established Bio-Control Research Laboratories of Pest Control India Ltd. at Bengaluru in 1981. I, who was always in close contact with PDBC and also based on my vast experience, provided substantial input, highlighting the need, scope and importance of biological control. Dr. S. P. Singh and I together drafted the document. It was well received and the centre was upgraded as the Project Directorate of Biological Control (PDBC) in 1993. It was also designated as the coordinating centre for AICRP on Biocontrol. Dr. S. P. Singh became the first Director of PDBC.

C-3. National Bureau of Agriculturally Important Insects (NBAII)

In 2009, following certain policy decisions and considering that there was a need to establish a Bureau for Insects, the institute was upgraded and named as 'National Bureau of Agriculturally Important Insects' (NBAII). During a meeting of the Society for Biocontrol Advancement (SBA), most members felt the absence of the words 'Biological Control' in the new name, especially so because the centre/premises has a rich legacy of biological control, starting from CIBC. An appeal was made to ICAR, but since a policy decision was already taken on the nomenclature, it was not conceded to. Nevertheless, biological control remained as a part of the mandate of the Bureau for Insects – NBAII.

C-4. National Bureau of Agricultural Insect Resources (NBAIR)

Again, in 2014, with an expanded mandate, the name of the institute was changed to "National Bureau of Agricultural Insect Resources" (NBAIR) which is prevailing now. Thus, starting with the name PDBC in 1993, changed to NBAII in 2009 and then to the present NBAIR since 2014, the Institute has completed 27 years in 2020. The present Foundation Day celebration marked this event.

C-5. The Directors and achievements of PDBC/NBAII/NBAIR

The institute has accomplished a lot in the last 27 years and I would like to remember those who have served as the Directors of the Institute right from inception.

I have had the pleasure of knowing all the Directors of the Institute, no matter whether I worked in CIBC, UAS-Bengaluru, BCRL or Monsanto. I am also very familiar with most of the staff. I have regularly participated in almost all activities of the Institute, including the annual workshops of AICRP on Biological Control as well as national and international conferences organized by NBAIR and SBA, in one way or the other. I wish to recollect their major contributions on this occasion.

Dr. S. P. Singh, 1993-2002

Dr. Singh had played an important role during upgradation of the centre as a Directorate and served as the first Director of PDBC. He was responsible for planning both research and administrative activities. He was the mentor for most of the staff. The new laboratory complex and administrative building at NBAIR were constructed during his period. He had established an excellent rapport with the officials at the ICAR HQ in New Delhi and also other research and academic institutions. He managed to get several projects from ICAR with significant funding and also initiated several international collaborations. He nurtured and projected both PDBC and AICRP on Biocontrol at all levels in ICAR. PDBC emerged as a vibrant national centre for biological control during Dr. Singh's tenure. He was an excellent combination of a scientist and an administrator. It is unfortunate that Dr. Singh passed away in August 2015. Though he is no more, his memory continues to linger on.

Dr. R. J. Rabindra, 2002-2011

Dr. Rabindra succeeded Dr. Singh as the Director of PDBC after his retirement. He is a hard core Scientist with insect pathology background. I have known him right from his early career at TNAU. Dr. Rabindra was more inclined towards practical results. During his time, the control of papaya mealybug through introduction of an exotic parasitoid, *Acerophagus papayae*, was achieved. It is one of the outstanding successes of classical biological control in recent years. Another success obtained was the control of sugarcane woolly aphid through conservation and use of a few indigenous parasitoids and predators. He had very effectively projected these successes at the national level. The establishment of the Yelahanka campus of PDBC started when Dr. Rabindra was the Director. Meanwhile, the name PDBC was changed to NBAII in 2009 when he was the Director.

Dr. N. K. Krishna Kumar, 2011-12:

After Dr. Rabindra's retirement, Dr. Krishna Kumar served as the Director of NBAII for a period of one year during 2011-12. He was from IIHR. He always impressed as a very sharp and out-of-the-box thinker with a lot of new ideas. He was responsible for starting the Insect Molecular Biology and Insect Ecology Divisions and also strengthening the Taxonomy Section of NBAII. Several promising taxonomists were recruited during his period. Dr. Krishna Kumar initiated the plan for an Insect National Museum at NBAII. He also brought about certain physical changes in the campus. The current set up comprising the office of the Director, Finance and Administration, library and PME in one building and laboratories in an entirely different building was planned and executed by him. It was during his period that the new building

in the Yelahanka campus took physical shape. He initiated the process for commercialization of NBAIR technologies which has grown from strength to strength. While he was in NBAII for just one year, ICAR recognized his talent and snatched him away from NBAII and made him the DDG (Horticultural Sciences). He moved to New Delhi.

Dr. Abraham Verghese, 2013-16

Dr. Abraham Verghese succeeded Dr. Krishna Kumar and served as Director from 2013-16. NBAII became NBAIR in 2014 while he was the Director. He was also from IIHR. I have been aware that Dr. Verghese always believed in converting research findings into products and commercializing those products so as to find practical applications. I also firmly believe in it. That is the reason why I resigned my job at the UAS-Bangalore and accepted the challenge of starting BCRL for PCI in 1981 which is the first-ever commercial insectary in India dedicated to mass produce and supply biocontrol agents and pheromones to farmers for direct field applications. The products have to reach the end users who, in our case, are the farmers and farms. Dr. Verghese emphasized the need for commercialization of NBAIR technologies so as to benefit the farmers. Several meetings related to commercialization and Industry-Institute collaboration were held during his tenure. Dr. Verghese presented the 12th Plan Budget for the National Museum before the DG-ICAR and Planning Commission at New Delhi and got the approvals of funds as well as building plans. The foundation stone for the National Museum was laid in May 2016 while he was the Director. Another notable contribution was that he set up the Insectarium at NBAIR which attracted several school students and exposed them to the field of entomology.

Dr. Chandish R. Ballal, 2016 to May 2020

Following Dr. Verghese's retirement, Dr. Chandish Ballal took over as the Director of NBAIR in 2016. I have known Dr. Chandish since 1984 when she started her biocontrol career at CIBC. Later, she joined ICAR. Over the last 35 years, I have seen her personal as well as professional transformation. I have been a witness to her complete 'metamorphosis' from a Miss to Mrs, and then from a Mother to Mother-in-law! Similarly, in her professional career also, I have seen her growth from being a research scholar to a Principal Scientist and finally to the coveted position of the Director of NBAIR. She handled every position with grace and admirable commitment and discipline. She has been a hard core biological control specialist. During her tenure, AICRP on Biocontrol Programs increased from 15 to 29 funded centres covering different parts of India, thereby widening and strengthening biocontrol work. Sustainable solutions were developed for two notorious invasive pests, namely the fall armyworm and Rugose spiraling whitefly. Several NBAIR technologies were commercialized. The National Insect Museum which was under development during Dr. Krishna Kumar's and

Dr. Verghese's time, was completed and inaugurated. Another notable development was that she streamlined the procedures for international exchange of insect specimens for taxonomic studies through active interactions with NBA, enabling about 17 international collaborations for NBAIR. She organized several training programs and workshops specifically to benefit the agriculture department officials and farmers of the country including NEH regions. Dr. Chandish also encouraged her staff to participate in seminars and workshops both in India and other countries and arranged for necessary funding. She retired on 31st May 2020.

Dr. N. Bakthavatsalam, from June 2020

Dr. Bakthavatsam has taken charge as interim Director from Dr. Chandish with effect from 1st June 2020. He is one of those who have been associated with the centre right from the beginning and is the senior most now. He is a specialist in chemical ecology/pheromones which can co-exist and complement biological control. Dr. Bakthavatsalam has made some excellent contribution in this area over the years and one can expect more and something different from him.

Dr. B. S. Bhumannavar and Dr. Prashanth Mohanraj

Between Dr. Krishna Kumar and Dr. Verghese, Dr. Bhumannavar was the Director In Charge for about a year. He paid particular attention towards developing the Yelahanka campus. Similarly, between Dr. Verghese and Dr. Chandish, Dr. Prashanth Mohanraj was the interim Director for a brief period.

I would like to say that all the Directors had their distinct styles and significantly contributed to the growth and achievements of the Institute. On this journey, they deserve to be remembered and complemented.

The Staff

It should be realized that in an Institution, all the staff cannot become Directors because there is only one post. But, they all can contribute to the growth of the Institute. I am personally aware that there were several Scientists, who are now retired, who worked hand-in-hand with their Directors to achieve the overall objectives of the Institute. Similarly, there are several others who are presently making valuable contributions. The success of an Institute depends on the collective efforts of the staff with the Director as their representative. Therefore, along with the Directors, the Heads of various Divisions and all the staff deserve to be acknowledged for their magnanimous support and team work.

C-6. Major achievements of PDBC/NBAII/NBAIR

Some of the major achievements over the years include:

Improved technologies were developed for large scale production of a number of promising parasitoids

(*Trichogramma* spp., *Telenomus remus*, *Goniozus nephantidis*, *Anastatus* spp., etc.), predators (*Cryptolaemus montrouzieri*, *Chrysoperla zastrowi sillemi*, anthocorid predators, predatory mites, etc.) and pathogens (*Bacillus thuringiensis*, *Beauveria bassiana*, *Metarhizium anisopliae*, NPV of several lepidopterans, etc.) as well as their host insects (*Corcyra cephalonica*, *Spodoptera litura*, *Helicoverpa armigera*, *Spodoptera frugiperda*, etc.) and these were maintained year round. Improved strains of natural enemies (*Trichogramma*, *Chrysoperla*, etc.) were also developed. These were supplied to needy farmers, KVKs, research organizations and students and they were also given training in the production technologies. Several technologies were commercialized and offered to licensees. NBAIR has a very large live insect and microbial repository including entomopathogenic nematodes. Significant progress was also made in the area of chemical ecology.

NBAIR has played a great role in the biological control of some of the emerging pests. These included the spectacular control of the deadly invasive papaya mealybug through production, release and conservation of its parasitoid *Acerophagus papayae* which resulted in enormous economic and ecological benefits. Similar results were obtained with the effective management of the sugarcane woolly aphid through conservation of biological control agents. Yet another example was the identification and control of the invasive Rugose Spiralling whitefly infesting coconut and oil palm through conservation of the parasitoid *Encarsia guadeloupae* and utilization of the entomofungal pathogen *Isaria fumosorosea*. The rapid identification of the fall army worm *Spodoptera frugiperda* which has invaded India recently and development of a biological control strategy for its management is one of the significant developments in recent years.

Other than biocontrol, NBAIR has also focused on alternative methods to conserve and utilize insects: for example, technologies were developed for the black soldier fly mediated bioconversion of farm and kitchen wastes, and also for utilization of black soldier fly as fish and poultry feed. Another notable contribution was the identification and conservation of pollinators through habitat manipulation (creation of pollinator gardens) and creating artificial nesting sites.

Molecular characterization including barcoding of about 1730 insect species was generated for the identification of insect species. Over 1,88,430 insect specimens are held in the National Museum Repository at ICAR-NBAIR including 347 type specimens. Identification services for more than 1000 insect samples and insect derived resources have been provided to various stakeholders every year.

Constant vigil has been kept for new invasive insect pests and also on the status and spread of the existing indigenous and invasive insect pests.

NBAIR has conducted a number of national and international seminars and also participated in such events for exchange of knowledge.

The Bureau was recognized with the prestigious ‘Sardar Patel Outstanding ICAR Institution Award 2015’ and the scientists have received several National Awards from time to time. More details can be obtained from the website: <https://www.nbair.res.in>.

From the CIBC days till now, several changes have taken place in the premises. The old laboratory building of CIBC is now converted into a guest house. A large two-storied laboratory building, an administrative block, a Live Insect Repository, an Insect Museum, etc. have been constructed in the premises. Besides, NBAIR has established another campus with a laboratory complex and large fields at Attur in Yelahanka, Bengaluru.



ICAR-NBAIR Main Building



ICAR-NBAIR National Insect Museum

Although biological control is one of the major activities of NBAIR, it has an expanded mandate. It has emerged as a Centre of Excellence in the areas of insect genomics, molecular systematics, entomopathogenic nematodes, chemical ecology, management of invasive alien pests, large scale production of biological control agents and quality assurance.

It presently has 57 staff comprising 32 Scientists including the Director, 15 Technical Staff, 7 Administrative and 3 supporting staff. With excellent networking across the country, NBAIR is trying to take entomology/biological control to the next level.

The ICAR which is the parent body has provided all the support. All the DGs, DDGs (Crop Sciences), ADGs (Plant Protection) and other concerned officials were very encouraging and had a special place for NBAIR. They played a huge role in the growth and achievements of NBAIR in the last 27 years. Such patronage is continuing even now - kudos to ICAR and NBAIR.

(D). THE WAY FORWARD

Biological control is a fascinating branch of science. It is nature’s gift to mankind. With more than 95% of the herbivores being kept under perpetual check by the action of their natural enemies, biological control is truly the ‘Mother of all Plant Protection Measures.’ Such silent contribution is seldom realized and appreciated. It is only when certain pests escape the impact of such natural control due to various factor, they become major pests and attract our attention. Then we intervene and try to restore the balance in favour of natural enemies by conservation, augmentation or introduction, or by taking any other control measures. When successful, biological control is highly sustainable and incomparable.

One of the objectives of any Institution is to chalk out progressive plans for future. While doing so, one should be prepared to come out of the comfort zone and reorient the research priorities to meet the emerging challenges. As far as NBAIR is concerned, with very talented scientists specialized in various fields coupled with those associated with AICRP on Biological Control spread across the country, there is a great potential. I wish to make the following observations/suggestions:

1. Field visits: Scientists should try to spend as much time as possible in the fields so as to thoroughly understand the various environmental factors influencing the bio-ecology and behavior of the pests as well as their natural enemies so that these can be exploited for managing them.

2. Increase product range: Although a large number of natural enemies have been discovered and investigated, most of the scientists are concentrating mainly on *Trichogramma*, *Chrysoperla*, *Cryptolaemus*, *Trichoderma*, *Beauveria* and a few other well-known biocontrol agents which have already been studied in detail and used for several decades. One of the strong reasons for their choice is that they are readily amenable for mass production. It is time to work on other promising but not yet fully explored biocontrol agents so as to increase the product range. I will cite only a few examples:

A. *Cotesia plutellae*: One of the natural enemies that is very promising, but has not yet been exploited is *Cotesia plutellae*. It is an early larval, solitary, specific parasitoid of the diamond back moth (DBM) *Plutella xylostella*. This parasitoid has developed natural resistance to most of the chemical insecticides that are used in cabbage fields for control of DBM. It appears early in the season along with the pest and gradually builds up its population to give over 80% parasitism. Unfortunately, by the time it reaches that high level of parasitism, the pest would have already caused the damage. Here is an opportunity for us to intervene. If we produce this parasitoid in the laboratory and make adequate releases early in the season, it would supplement the natural population, resulting in early control of the pest. With minimum releases, we can maximize the impact. But, so far, no one has produced this parasitoid on a large scale. One of the reasons being that it does not accept a common unnatural or factitious hosts like *Corcyra*. Therefore, as in most cases in biological control, mass production of a suitable host insect is the first step towards successful production of natural enemies. Therefore, one should take it as a challenge to develop a mass production technology for DBM, either on its natural host plant or on artificial diet. Once this is accomplished, it would pave the way for production of *C. plutellae*.

B. *Tetrastichus schoenobii*: Another opportunity exists with *Tetrastichus schoenobii* which is an egg parasitoid-cum-predator of rice yellow stem borer *Scirpophaga incertulas*. When *T. schoenobii* parasitizes an egg mass, it brings about mortality of all the eggs (100%) in an egg mass. It is not so in the case of *Trichogramma japonicum* and *Telenomus dignus* where parasitization is only partial. They parasitize only those eggs laid on the upper surface of an egg mass and, therefore, not effective as the remaining eggs hatch and cause crop damage. In this respect, *T. schoenobii* is superior, but it has a limitation. It appears only late in the season to coincide with the panicle initiation stage of rice crop which is too late to prevent pest multiplication and damage. Here is an opportunity to find out what factor is responsible for attracting the parasitoid only during flowering. If it is a kairomone or so, we should try to synthesize it and apply in the field when the crop is young so as to attract *T. schoenobii*.

The other challenge is that *T. schoenobii*, being a specific parasitoid of rice yellow stem borer, cannot be mass produced on *Corcyra* eggs. At the same time, so far, no one has succeeded in mass multiplying its natural host, i.e. RYSB. We need to find a way out so that this promising parasitoid can be effectively utilized. There is another option. *T. schoenobii* has been recorded as a dominant parasitoid of RYSB in Sri Lanka. If that strain is active throughout the crop season and superior to ours, it is worthwhile considering its introduction into our country after making preliminary assessment.

C. *Zygogramma bicolorata*: Yet another opportunity that I would like to suggest is with regard to *Zygogramma bicolorata* which was introduced into India for control of *Parthenium* weed and has already become very well established. This beetle, a voracious defoliator, has an inherent weakness. It multiplies prolifically for a few months, builds up enormous population when conditions are favourable to it and then enters into hibernation for a couple of months. During this inactive period, the weed regenerates and we are back to square one. Scientists should investigate what triggers its hibernation – whether it is physiological, climatic or genetic factor – and see whether we can prevent it. For example, if it is a genetic factor, with the advances made in molecular biology, especially CRISPR technology, it may be possible to silence the concerned gene(s) and break its hibernation. This will enable the beetle to breed throughout the year and have better impact on the weed. However, a defoliator like *Zygogramma* alone may not be able to give effective control of *Parthenium*. Therefore, we should try to supplement its role with the introduction of specific flower/seed feeding biocontrol agents.

3. Shelf-life enhancement: Developing techniques to enhance shelf-life or to prolong storage of parasitoids, predators and pathogens deserve top-most priority as it helps a great deal towards stockpiling of biocontrol agents, gain time for transport and utilizing them when needed. Such studies should be comprehensive leading to practical utilization.

4. Integration: Biocontrol scientists should also try to exploit insect resistant transgenic crops, release of sterile males, sex pheromones, etc. which are compatible with biological control. Having worked extensively on Bt-cotton prior to, during and after its regulatory approval by Govt. of India in 2002 for commercial cultivation, I can vouch that this technology is compatible with all other plant protection measures, including biological control, and is most ideally suited as a major component of IPM. Utilizing molecular tools to enhance the beneficial traits of parasitoids and predators such as host searching, temperature tolerance, resistance to chemical insecticides, etc. may be a distant possibility. Judicious use of chemical insecticides should not be ruled out. All options should be explored without any bias.

5. Success/Failure: All attempts do not result in success. While success certainly calls for celebration, failure should not cause dejection. After making all the sincere efforts, if any biocontrol agent fails to deliver results, we should accept the reality and move on rather than hiding the failures and repeating them.

6. Non-availability & PPP: The central as well as the state governments have been proclaiming their support for organic farming. Biological control should fall within that purview. Non-availability of biological control agents in required quantities for timely releases continues to be a major hurdle in promoting practical biological control. One of the uncertainties faced by the producers, more so with macrobials (parasitoids and predators), is the assured demand. Being live, sensitive and short-lived, one cannot risk their huge production lest it may go waste. Here the governments can extend help. If they announce that they are willing to place confirmed advance orders for supply of required biocontrol agents, many industries may come forward to set up commercial insectaries/bio-factories. The governments may buy these products and make available to farmers at a subsidized rate. With my experience of managing BCRL successfully for about 16 years (1981-1997), I can say with confidence that our farmers are willing buy and use biocontrol agents and pheromones provided they are readily available. This will create a win-win situation for the producers, farmers and the governments, and would be the most realistic way of promoting eco-friendly farming and a model for Public-Private-Partnership (PPP).

7. Institutional & Individual goals: Some of the research areas mentioned above may take 3 to 5 years or more to get results. Therefore, I feel that there should be two levels of research goals: long term goals for the institutions while short term goals for individuals. Long term goals should tackle more difficult problems which may take several years to accomplish. It should be a team effort and ensure continuity of work even if one or two members of the team move out due to professional reasons.

Let us hope that scientists will undertake research on some of these and other challenging areas and strengthen biological control and integrated pest management.

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<https://databases.nbair.res.in/video-gallery/27%20foundation%20day/XVII%20ICAR%20NBAIR%20FOUNDATION%20DAY%20MESSAGE%20BY%20%20DR%20T%20M%20%20MANJUNATH.mp4>

Finally, I would like to end this article on a personal note. I confess that I am emotionally attached to the premises of NBAIR because my career was born there when I joined CIBC way back in 1961. Thus, there is an umbilical connection between ICAR-NBAIR and me. Since then until now, no matter where I worked, I have always maintained close contacts with ICAR as well as NBAIR and I wish to continue the same.