PROJECT DIRECTORATE OF BIOLOGICAL CONTROL BANGALORE

जैनिपनि
PDBC

वार्षिक प्रतिवेदन
ANNUAL REPORT
2004-2005

भाकृअनुप
ICAR

परियोजना निदेशालय जैविक नियंत्रण, बेल्लारी रोड, बेंगलूर-५६० ०२४, भारत
PROJECT DIRECTORATE OF BIOLOGICAL CONTROL
BELLARY ROAD, BANGALORE-560 024, INDIA

Hon. President of India being explained the biocontrol programmes of AICRP on biological control of crop pests and weeds.

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Bangalore 560 024

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Published by
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August, 2005

Hindi Text
Mrs.Sobha Kaveri, IIHR, Bangalore

Correct citation **PDBC-ICAR, 2004-2005, Annual Report, Project Directorate of Biological Control Bangalore 560 024, India**

Printed at
Precision Fototype Services,
#51, Car Street, Ulsoor,
Bangalore. Phone - 25546146 / 25364349

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PREFACE

The Project Directorate of Biological Control, since its inception in 1993, has made rapid strides in basic research on different aspects of biological control forming the base for technologies in Biointensive Integrated Pest Management. It has a network of 16 crop-oriented field centres under the All India Coordinated Research Project on Biological Control of Crop Pests and Weeds in different state agricultural universities and ICAR Institutes. The achievements made in this specialised field include introduction of potential natural enemies for managing exotic pests, development and standardisation of improved breeding techniques for host insects and their natural enemies, mass production techniques, storage technology for natural enemies, understanding the tritrophic relationship between host plants, pest insects and natural enemies, development of superior strains of natural enemies for different crop ecosystems and pesticide tolerance and development of biocontrol based-technologies for pest management in sugarcane, cotton, rice, tobacco, grain legumes, vegetables, fruit crops, etc. Several of these technologies have been transferred to stakeholders including private enterprises for commercial exploitation.

The twelfth annual report embodies the endeavours of my scientist colleagues in the Project Directorate as well as the AICRP centres for the period from April 2004 to March 2005. I am sure that the findings presented will be of use to scientists, research workers, administrators, policy makers, farmers and others who are involved or interested in biological control of crop pests and weeds. Suggestions for improvement, collaboration, future research needs and priorities from peer groups have been given due consideration for implementation.

I am extremely grateful to **Dr. Mangala Rai**, Secretary, DARE & Director General, ICAR, New Delhi, for his encouragement and valuable guidance. The support extended by **Dr. G. Kalloo**, Deputy Director General (Crop Sciences & Horticulture), ICAR, New Delhi, is gratefully acknowledged. Thanks are due to **Dr. O. P. Dubey**, former Assistant Director General (Plant Protection), ICAR, New Delhi, for providing all necessary encouragement and support throughout the period of 2004-05 in conducting the various research activities. I thank **Dr. T. P. Rajendran**, Assistant Director General (Plant Protection), ICAR, New Delhi, for his active involvement, guidance and support. Sincere thanks are due to all project workers at Project Directorate of Biological Control and different co-ordinating centres of AICRP for completing the allotted research programmes. Thanks are also due to the Vice-chancellors, Directors of Research of SAU-based centres and Directors of ICAR Institute-based centres for providing the facilities.

R. J. Rabindra
Project Director
Project Directorate of Biological Control
&
Coordinator
AICRP on Biological Control of Crop Pests and Weeds

कार्यकारी सारांश

यह प्रतिवेदन वर्ष 2004-05 के दौरान जैव नियंत्रण पर अखिल भारतीय समन्वित अनुसंधान परियोजना के अंतर्गत पी.डी.बी.सी., 10 कृषि विश्वविद्यालय तथा भारतीय कृषि अनुसंधान परिषद के छः संस्थान एवं निजी केन्द्रों द्वारा किए गए अनुसंधान की प्रमुख उपलब्धियों को प्रस्तुत करता है। प्रमुख पीडक, रोग तथा खरपतवारों के पर्यावरण तरीके से प्रबंध हेतु जैव नियंत्रण प्रौद्योगिकी विकसित करने के उद्देश्य से मूल तथा प्रायोगिक अनुसंधान के विस्तृत कार्यक्रम निरुपित किए गए। इस कार्यक्रम में सम्मिलित मुख्य कारक हैं - गन्ने के वूली एफिड एवं बी.टी. कपास के चषूण पीडकों का पर्यावरण प्रेमी तरीकों से प्रबंध तथा जैविक खेती में जैव नियंत्रण को शामिल करना आदि। वर्ष 2004-05 में तकनीकी कार्यक्रम के अंतर्गत निर्धारित परीक्षणों को सफलतापूर्वक कार्यान्वित किया गया।

मूल अनुसंधान

जैव नियंत्रण परियोजना निदेशालय, बेंगलूर

जैव वर्गिकीय (बायोसिस्टेमेटिक्स)

उत्तर पूर्वी क्षेत्र से दो दुर्लभ जातियां *ओइनोपिया एकसेलेन्स* (क्रोच) तथा *प्रोटोथेया क्वाड्रीपन्कटेटा* (मल्सन्ट) और बेंगलूर से एक नई जाति स्यूडोस्किम्नस रिकार्ड की गई।

भारतीय प्रदेशों में कोक्सीनेलीडे की सामान्य जातियों तथा उनके प्राकृतिक शत्रु कीटों की इमेज गैलरी तैयार करके एक वेबसाइअट विमोचित की गई है।

काइलोकोरस की 10 भारतीय जातियों की, कंप्यूटर की सहायता से, द्वीवभक्तिकरण कुंजी विकसित की गई है।

भारतीय टेकीनीडे के परपोषी परजीव्याभ की सूची के साथ-साथ *हेलीकोवर्पा अर्मिजेरा* को परजीवी करने वाली 24 जातियों को संकलित किया गया है।

प्राकृतिक शत्रु कीटों की प्रस्तुति

भारत सरकार के पादप संरक्षण परामर्शदाता से *स्मीक्रोनिकस लुटुलेन्ट्स, नेफास्पिस बाइकलर, गानास्पिडीयम निग्रीमनस* (=गा. यूटीलिस), *क्राइसोकारिस पर्किस, डेल्फास्टस यूसीलस, टेलीनोमस ट्रीप्टस, टे. लीवीसेप्स, टे. यूलेयति* तथा *ग्लेब्रोमाइक्रोप्लीटस क्रोसीपेस* के आयात हेतु अनुमति प्राप्त कर ली गई है। *हेलीकोवर्पा अर्मिजेरा* के मूल्यांकन के लिए के निया से *ट्राइकोग्रामा* जाति *टे. म्वान्जाई* शूलेटन तथा फेजेन के आयात किया गया।

अरहर तथा चने पर *हेलीकोवर्पा अर्मिजेरा* के अंडों पर परजीवीकरण दर क्रमशः 3.3 से 6.7 तथा 5.0 से 32.5 रहा। फरवरी 2004 में श्रीलंका से *इरीबोरस ट्रोकेन्टेरटस* का लाया गया जिसे *कोरसाइरा* डिम्भक की मदद से शुद्ध संवर्ध प्राप्त किया गया। *ज़ाइगोग्रामा बाइकोलोराटा* तथा *स्टर्मियोसिसस इग्न्फरेन्स* का श्रीलंका तथा आई.सी.आई.पी.ई., केनिया को निर्यात किया गया।

प्राकृतिक शत्रु कीटों का पालन एवं मूल्यांकन

हेलीकोवर्पा अर्मिजेरा के अण्डनिक्षेपण हेतु चने के सात किस्मों (जे.जी. 74, एल 550, जे.एस.सी. 6, जे.जी. 315, आई.सी.सी.यू. 2, काला चना तथा जे.जी. 130) का परीक्षण किया गया। जे.जी 130 पर सबसे न्यूनतम अण्ड निक्षेपण हुआ।

टेलीनोमस वर्ग के पोत-लदान के लिए बीच-बीच में चीरे गए पोलीस्टाइरेने की पट्टिओं से लगे हवादार प्लास्टिक डिब्बों की तकनीक का मानकीकरण किया गया। *टेलीनोमस रीमस* का एक परजीवीकृत कार्ड जिसमें 10 अण्डों का समूह होता है, असली उत्पन्न लागत 4/- रुपए पडता है। एक हेक्टर के लिए (50 कार्ड) 200/- रुपए खर्च पडता है। *केम्पोलेटस क्लोरिडे* के बहुगुणन हेतु 1.7x1.7x2.5 वाले पंजरों का इस्तेमाल किया जाता है। बहुगुणन के लिए 26-28° सेन्टीग्रेड तापमान तथा 70-80 प्रतिशत आपेक्षित आर्द्रता उचित पाई गई। प्रत्येक पंजर में तीन परजीव्याभ 5-8, 10-13 तथा 20-23 घनत्व का मूल्यांकन किया गया। प्रति पंजर ककून की संख्या, 72, 73.3 तथा 115 थी और ककून मादा की संख्या क्रमशः 14.4, 5.2 तथा 6/मादा थी।

साइटोट्रोगा सिरिल्ला के अण्डों से ग्रसित चावल पर *ब्लाप्टोस्टेथस पेलेसेन्स* को विमोचित करने के परिणाम स्वरुप केवल 8 प्रतिशत मौथ ही निकले। *ब्लाप्टोस्टेथस* *हे. अर्मिजेरा* अण्डों तथा चने के डिम्भक को भी खाता है।

सेराटोवाकुना लेनीजेरा के परभक्षी कीट

माइक्रोमस इगोरोटस सेराटोवाकूना लानीजेरा को खाता हुआ रिकार्ड किया गया। *से. लेनीजेरा, स्यूडोरेग्मा बम्बूसिकोला, एफिस क्रेसिवोरा* तथा *एफिस स्पैरीकोला* पर इसकी जैविकी का अध्ययन किया गया। *से. लोनिजेरा* की तुलना में प्रौढ दिर्घायु, पूर्व-अण्ड निक्षेपण अवधि तथा कोशित अवधि बढाई जा सकी। *फेरीशिया वरगेटा, प्लानोकोकस सिट्री, माकोनेलीकोकस हिरसुटस, कोरसिरा सेफालोनिका* तथा *एस. सेरेलेला* पर *एम इगोरोटस* के डिम्भक पनप न सके। कर्नाटक के गन्ने के खेतों में *मल्लाडा बोनिनेन्सिस, स्पालिगिस एफिस, क्रिप्टोलोमस मोन्ट्रोज़ेरी* तथा *सैनोनैका ग्रेन्डीस* जैसे परभक्षी कीट रिकार्ड किए गए। प्रयोगशाला में उत्पन्न किए गए *यूपीयोडेस कान्फ्रेटर* के क्षेत्र मूल्यांकन से ज्ञात हुआ कि परभक्षी अण्डावस्था में सैनिक एफिड के आक्रमण के प्रति संवेदनशील हैं।

मगालोकारिया डाईलेटाटा तथा *डाइफा ऐफिडिवोरा* नामक गन्ने के वूली एफिड के परभक्षी कीट को वैकल्पिक शिकार के रुप में *ए. क्रेसिवोरा* पर पाला गया। *डा. ऐफिडिवोरा* ने *ऐ. क्रेसीवोरा* पर अपना जीवनचक्र पूर्ण किया किन्तु *मा. डिलाटाटा* की मृत्यु संख्या अधिक रही खासकर अण्डावस्था तथा प्रथम इंस्टार अवस्थाओं में. अण्ड निक्षेपण के लिए *डा. एफिडीवोरा* को पोलेथिन अथवा कपडे की अपेक्षा खुरदरा कागज़ अधिक पसंदीदा पाया गया। *से. लेनीजेरा* के माहू कीट का सेवन करने पर *डा. एफिडीवोरा* का विकास बिलकुल नही हुआ।

क्रिप्टोलिमस मोन्ट्रोजेरी का बहोत्पादन

क्रिप्टोलेमस मोन्ट्रोज़ेरी को पांच पीढियों तक *साई. सिरेलेला* के अन्डों पर पाला गया। प्रति शत प्यूपेशन 67.57 प्रतिशत थी तथा प्रौढ निर्गमन 84 प्रतिशत रही, डिम्भक तथा प्यूपा की औसत अवधि क्रमश: 13.61 तथा 7.36 थी और प्रौढ का जीवनकाल 52.02 दिन था।

कीटविषाणुओं का प्रयोग

क्रोसीडोलोमिया बाईनोटेलिस एन.पी.वी. (सि.पी.एन.पी.वी.) का 10^5x10^9 पी.ओ.बी. / मि.ली. के दर से डिम्भक के दूसरे इन्स्टार के प्रति परिक्षण करने पर प्रति खुराक 33.3-90.% प्रतिशत मृत्युसंख्या पाई गई।

1x10^4 पी.ओ.बी. / मि.ली. कम खुराक का इनोक्यूलम देने पर प्रति डिम्भक से सि.बि.एन.पी.वी के 850 मिलियन पी.बी.ओ. / मि.ली. का औसत उत्पादन प्राप्त किया गया।

बाम्बिक्स मोरी, हे. अर्मिजेरा, स्पोडोपेट्रा लीटुरा, प्लूटेल्ला जाईलोस्टेला, हेलूला अन्डालिस, ट्राइकोप्लूशिया नी., स्पो. एक्सीगुआ, को. सेफालोनीका तथा *क्राइसोपेरला कारनिया* एवं *सी. मोन्ट्रोज़ेरी* के प्रति सी.बी.एन.पी.वी. संकर प्रभावी नही पाए गए।

पहले दिन ही एड्जन्वेन्ट्स जैसे 1.0 प्रतिशत मांड (स्टार्च) + 10 प्रतिशत कच्चा शक्कर के साथ संबंधित एन.पी.वी. से *हे. अर्मिजेरा* तथा *स्पो. लिटुरा* से डिम्भक की मृत्युसंख्या अधिक रही।

कीट कवकी रोगजनक

मेटाराईजियम एनिसोप्लिये (आईसोलेट - 4), *सी. लानीजेरा* से अधिकतम (30.14) कवकार्ति प्रतिशत उत्पन्न किए गए और इसके बाद *बेवेरिया बसियाना* (बी.बी.-5ए) (20.46) की प्रतिशतता रही।

बेसिलस थूरेन्जेनेसिस प्रभेदों का पृथक्करण एवं अभिलक्षणन

बेसिलस थूरेन्जेनेसिस के कुल तीन बियोजन - दो पंतनगर से और एक आणेकल से प्राप्त किए गए। पंतनगर से प्राप्त दूसरा नमूना पत्तागोभी में पत्ता जैव आमापन (बायोएसे) में प्लूटेल्ला ज़ाइलोस्टेला के प्रति अधिकतम अविषालुता दखा गया।

अंत:पादपी जीवाणुओं का पृथककरण

पौधे के अंत: मंडल से चार नए जीवाणु - *बेसिलस मेगाटेरियम* (एम.टी.सी.सी. 6533), *बेसिलस एसपीपी.* (एम.टी.सी.सी. 6534), *एन्टोरोबेक्टर अग्लोमेरान्स* (एम.टी.सी.सी. 6536), तथा *इरवीनिया हर्बिकोला* (एम.टी.सी.सी. 6720) का पृथक्करण किया गया।

कवक विरोधी

पी.डी.बी.सी द्वारा *ट्राइकोडर्मा हर्जियानम* के पृथककरण में से टी.एच. 17 तथा टी.एच. 7 उदीयमान पाए गए। आई.आई.एस.आर. कालीकट से टी.एच. पी. 26 और पी.डी.बी.सी. से टी.एच. 7, टी.एच. 8 तथा टी.एच. 10 मेक्रोफोमीना फासियोलि के प्रति अत: विरोधी पाए गए।

कोलाइडी काइटिन के संवर्धित माध्यम (सी.सी.ए.एम.) पर टी.एच. 14, टी.एच. 14, टी.एच. वाराणसी, टी.एच. जीटीएच. 7, टी.एच. कूडलू, टी.एच. कलंगाय, टी.एच.आई.टी.सी.सी., टी.एच.सी.पी.सी.आर.आई, टी.एच. सी.आई.सी.आर. तथा पी. 26 का विकास तीव्र रहा। एस. रोल्फसी कोशिक के भित्ति संशोधित यूष में काइटिनेस पर पी. 26, टी.एच. 10 तथ टी.एच. 14 का पता लगाया गया। कोलाइडी काइटिन संशोधित यूष में पी. 26 तथा टी.एच. 10 में काइटेनिस की सक्रियाता का पता लगाया गया। आलू डेक्सट्रास यूष में काइटिनेस की सक्रियाता नही देखी गई।

ट्रै. हर्जियानम तथा *ट्रै. विरीडी* के संचयन के तीन महीने तक काइटिन रहित की अपेक्षा 2 अथवा 5 प्रतिशत शुद्ध काइटिन सहित टेल्क संरूपण में जीवनक्षम कालोनी (सी.एफ.यू.) एकक की संख्या अधिक रही। काइटिन के स्त्रोत के रूप में झींगों के कवच के चूर्ण से जीवनक्षम (सी.एफ.यू) की संख्या, प्रतिजीवी की उपस्थिति हेतु आटोक्लेव करने के उपरान्त भी, कर कर दी गई। संचयन के दौरान टी. हार्जियानम तथा टी. विरीडी उत्पादन माध्यम में सी.एन. अनुपात अधिक होने (10:1 और 15:1) के परिणामस्वरूप अच्छा बीजाणुकजनन तथा जीवनक्षम प्रवर्ध्य हुआ। उत्पादन माध्यम में 3-9 प्रतिशत ग्लाइसोरोल मिलाने से संचयन अवधि में तीन महीने तक सी.एफ.यू. की संख्या बढ़ी। संचयन के दौरान टी.वीरीडी तथा टी. हर्जियानम के अचल अवस्था में 30 मिनट तक 40°सें. अथवा 45 मिनट तक 35° ऊष्मा प्रघात देने से महीने तक सी.एफ.यू. की संख्या बढी। उत्पादन माध्यम में 2 प्रतिशत कोलैडी काइटिन मिलाने पर बी. बेसियाना तथा एम.एनीसोलिए में जीवनक्षम सी.एफ.यू. की संख्या बढ़ी। बी.बासियाना के उत्पादन माध्यम में 1.5 प्रतिशत ओस्मोटिकेन्ट (पी.ई.जी. 6000) मिलाने के परिणाम्स्वरूप बिजाणुप्रजनन कम हुआ।

पादप रोग तथा जैव नियंत्रण

गोबर खाद को 32° सें. तापमान 40 प्रतिशत (डब्ल्यू/डब्ल्यू) नमी स्तर

पर *स्यूडोमोनास फ्लोरोसेन्स* के बहुगुणन के लिए सबसे उत्तम साबित हुआ। टी. हर्जियानम तथा पी. फ्लोरोसेन्स से उपनिवेशित गोबर खाद में टमाटर तथा भिंडी में अंकुरण तथा पौधों का विकास अच्छा रहा। गोबर खाद आधारित एन्टागोनिस्ट में फास्फोरस, पोटेशियम, सोडियम, जिंक तांबा तथा आयरन का घुलनशील वस्तु तथा ह्यूमसी पदार्थ अधिक देखा गया। जैविक तरीके से विकसित मटर के खेतों में पर्णिल छिडकाव के रूप में मटर के दानों को पी.बी.ए. 3 का जैविक उपड़चार देने पर पौधे सशक्त बने और उपज भी अधिक मिली। *स्यूडोमोनास, ट्रै. हर्जियानम* तथा *ट्रै. वीरेन्स* के विभिन्न वियुक्त से बीजों का उपचार करने पर क्रमश: 72.2, 52.33 तथा 41.33 प्रतिशत आच्छाद शीर्णन (शीथ ब्लाइट) का दमन हुआ।

कीटरोगजनक सूत्रकृमि

गेलेरीया मेलोनेल्ला के अत:जीवे उपज में सूत्रक्रिमि का प्रारम्भिक निवेश द्रव्य के प्रभाव से *स्टैनरनीमा कार्पोकाप्से* तथा *हेट्रोरेब्डीटिस इंडिका* की रोगजनकता तथा निर्गमन समय निश्चित किया जा सका। प्रति डिम्भक पर *एस. कार्पोकाप्से* का 1000 सूत्रक्रिमि से छ: दिनों के अंदर अधिक उपज प्राप्त हुई। जबकि *एम. इंडिका* के 3300 सूत्रक्रिमि से 10 दिनों में अधिकतम उपज मिली। *स्टे. कार्पोकाप्से* की उपज की अपेक्षा *हे. इंडिका* की उपज तीन गुना अधिक थी। छांव तथा खुले वातावरण में *स्टे. कार्पोकप्से, स्टे. अब्बासी, हे. इंडिका* तथा *बेक्टीरियोफोरा* 60-10 दिनों तक स्थायी रहे। शेल्फ आयु के लिए परखे गए *स्टे. कार्पोकाप्से* तथा *हे. इंडिका* के दो वियुक्त 3 महीने तक जीवनक्षम पाए गए। *स्टे. कार्पोकाप्से* का टेल्क आधारित संरूपण मार्ग परिवहन के लिए उचित व टिकाऊ पाया गया।

पोचोनिया क्लोमाइडोस्पोरिया में बीटा-ट्यूबिलिन का अनुक्रमण

पी.डी.बी.सी में पोचोनिया क्लेमाइडोस्पोरिया के स्थायी वियुक्त के आण्विक तत्समक को बीटा-ट्यूबलिन के अनुक्रमण द्वारा स्थापित किया गया और अमरिका के मेरीलैंक के एन.सी.बी.आई. जीन बैंक में पंजीकृत भी किया गया।

पादपभक्षी माइट के जैविक दमन हेतु रोगजनक

हिरसूटेल्ला थामसोनी का विकस 25° सेंटीग्रेड पर उत्तम रहा। 37° सन्टीग्रेड पर उसके कोनिडिया उत्पादन में बाधा पडी। *एच. थामसोनी* की किस्म *सिनेमोटासा* भी 37° सें तथा 40° सें. पर विकसित नही हुआ। साबूराडे डेक्स्ट्रोस यूष (एस.डी.बी) में एच. थामसोनी के बायोमास में जब ओटमील अगार (ओ.एम.ए.) का हल्लन संवर्ध के रुप में प्रयोग किया गया, तो संरोप भार, सी.एफ.यू., गोलियों की संख्या, नमी व शुष्क भार, अनुपातिक रुप से बढा। ओ.एम.ए. प्लग तथा सी.डी.बी. माध्यम का सम्मिश्रण सबसे उत्तम तथा जिसमें सी.एफ.यू. संख्या तथा नमी व शुष्क भार अधिकतम रहे। थामसोनी तथा *एच. थामसोनी* की जाति सिनेमोटोसा की गोलियां कमरे के वातावरण में निर्जर्म पानी में 10-11 महीने संचित करने के बाद अच्छी तरह विकसित हो सके।

हि. थामसोनी के शीघ्र बहु उत्पादन के लिए साधारण चुम्बकीय विलोडन तकनीक विकसित किया गया है।

ही. थामसोनी के रिसाव से सात दिन बाद *टेट्रानिकेस उरूटीके* का 77.8 प्रतिशत मृत्युसंख्या रही और जैसे रिसाव का सांद्रण घटता गया मृत्युसंख्या भी घटती गई। एक महीने के हल्लन संवर्ध से एकत्रित एच. थामसोनी के उपापचयज *टे. उरुटीके* के प्रति विषैले रहे (7 दिनों बाद 68.9 प्रतिशत) किन्तु तनुता के साथ मृत्युसंख्या घटती गई।

कोयम्बतूर (तमिलनाडू) के भिंडी के खेतों में *एच.थामसोनी* का माइक्रोहिट नामक जलीय चूर्णसंरुपण जब 50 ग्राम / ली. के दर से दो बार छिडकाने पर *टे. उरुटीके* की संख्या 62.7 प्रतिशत तक घटाई जा सकी।

पादप परजीवी सूत्रकृमि का जैविक दमन

बेंगलोर के आस-पास के अंगूर के बागों में पृथककीकृत *पोचोनिया क्लेमीडोस्पोरिया* (पी.डी.बी.सी. पी.सी. 51) से रेनीफार्म तथा मूलग्न्थि का प्रभावकारी नियंत्रण हुआ। काली मिर्च के बागों में *फाइटोफ्थोरा* मूलग्रन्थि सुत्रकृमि म्लानि कांप्लेक्स को मान्कोज़ेब 72 ड्ब्ल्यू.पी. तथा अकोमिन के मिश्रण से पूर्व उपचारित कटींग लगाकर और *ट्राइकोडर्मा* एस पी तथा *पेसिलोमाइसस लिलेसिनस* के रोपण से प्रभावकारी ढंग से नियंत्रित किया जा सका।

प्राकृतिक शत्रु कीटों का व्यवहारिक अध्ययन

मक्का, कपास और टमाटर से 133 पादप वाष्पशील योगिक पहचाने गए और ई.ए.जी. अध्ययन द्वारा क्राइसोपर्ला कानियी के संकेत के लिए मूल्यांकित किए गए। *क्रै. कारनिये* से अधिकतम प्रतिक्रिया लीनालूल फिर अल्फा पैनीन और एन. टेट्राडिकेन के प्रति पाई गई। *क्रै. कारनिये* के मादा से तीनों के मिश्रण से सही अनुपात में पूरा अथवा आधा सांद्रण से अधिकतम प्रतिक्रिया प्राप्त हुई।

ट्राइकोग्रामा किलोनिस के विरूद्ध पांच वाष्पशील योगिकों का परीक्षण किया गया। जिसमें माइरसेने (58.66 प्रतिशत) ने अधिकतम प्रतिक्रिया दिखाई, जो मिथाइअल सेलीसाइलेट (48.66 प्रतिशत) के बराबर थी। इसी प्रकार टी. चिलोनिस के लिए मूल्यांकित 133 योगिको में से अल्फा-पीनेने + लीनालूल + अल्फा-टर्पिनेने (2:2:1) प्रतिक्रिया अधिकतम थी (50.00 प्रतिशत)। खुले वातावरण में टी. चिलोनिस की अधिकतम प्रक्रिया लीनालूल (27.50 प्रतिशत) फिर माइरसेने (21.25 प्रतिशत) के प्रति पाई गई। डाक्का के नर एवं मादा फूलों से विमोचित वाष्पशील के प्रति टी. चिलोनिस की

प्रतिक्रिया के लिए मक्के के 18 संकर / किस्मों का मूल्यांकन किया गया। डेक्कन (14.87 प्रतिशत) और आई.टी.सी. एडवेन्टा ने अधिकतम प्रतिक्रिया दिखाई।

रायचूर के क्षेत्र परीक्षण में, अनुपूरक आहार के साथ प्रबलित एजेन्ट के रुप में केरोमोनेस का प्रयोग करने पर क्राइसोपिड्स की संख्या बढी। नियंत्रण विधि का अपेक्षा केरोमोने द्वारा उपचारित प्लाट में टी. चिलोनिस की पुन:प्राप्ति अधिक रही।

संचयन की उन्नत तरीकों का विकास एवं मूल्यांकन तथा ट्राइकोड्रमा का विमोचन

पीडकों के 1, 2, 3 और 4 पीढी के दौरान अनुपचारित नियंत्रण की तुलना में *ओपीसीना अरेनोसेल्ला* के विरुद्ध *ट्राइकोग्रामा एम्ब्रीयोफेग्म* तथा *ट्रै. चिलोनिस* को 1000, 2000, 3000 तथा 4000 / नरियल के दर से निर्मुक्त करने पर *ट्रै. एम्ब्रीयोफेगम* में डिम्भक की संख्या 88.8, 75.0, 66.7 और 75.0 प्रतिशत तक कम हुई और *ट्रै. किलोनिस* में 75.6, 60.0, 33.3 तथा 50.0 तक कम हुई।

ट्राइकोग्रामा की ग्यारह जातियों में से प्रयोगशाला परीक्षण के दौरान चार *ने. एरियस विटेला* द्वारा अधिकतम परजीवीकरण देखा गया। *ट्रै. ब्रेसिलियसिस* तथा टी. चिलोनिस को 5 जोडी / 50 अण्डे के दर से विमोचित करने से क्रमश: 46.7 तथा 41.3 प्रतिशत परजीविता हुई, जो खेतों में उनकी सामर्थता दिखाता है।

कोरसेरा सेफालोनिका के अण्डों को पैक तथा संचय करने की नई संशोधित वातावरण तकनीक विकसित की गई। पारम्परिक विधि की अपेक्षा नवीन तकनीक से सी. सेफालोनिका के अण्डों की शेल्फ आयु 3-4 गुना अधिक हुई।

विमोचन के लिए लाया गया समय, विभिन्न वाकहों द्वारा प्रौढ निर्गमन, अण्डों की परजीविता प्रतिशतता आदि के आधार पर *ट्राइकोग्रामा* जाति की प्रभाविकता निश्चित की गई।

अण्डों के वाहकों जैसे टेल्क (1:1) तथा अगार घोल (1 प्रतिशत) के साथ मिलाने से उपचार हेतु न्यूनतम समय रिकार्ड किया गया। अगार घोल सबसे उत्तम जलीय वाहक साबित हुआ। ट्राइको-विट, ट्राइको-कैप्सूल में बिना वाहकों के शिथिल अण्डों (15-100 प्रतिशत) की तुलना में ठोस व जलीय वाहकों में शिथिल परजीवित अण्डों से निर्गमन कर रहा (40.5 से 5.1 प्रतिशत)। प्रौढ विमोचन वर्मीक्यूलेट तथा सेमोलीना के साथ मिश्रित शिथिल पर्जीवित अण्डो को अलग-अलग छिडकाने से अन्य की अपेक्षा अधिक परजीविता प्राप्त हुई।

परजीव्याभ और परभक्षी कीटों के लिए कृत्रिम आहार

डाइफा एफीडोवोरा को दो प्रकार के कृत्रिम आहार पर पालने से सीमित सफलता मिली। तीन प्रकार के अर्द्ध कृत्रिम आहार देने पर *माइक्क्रोमस इगोरोटस* का डिम्भक 2-13 दिन तक जीवित रहा और प्यूपीकरण अवस्था तक नही पहुंच पाया।

कृत्रिम आहार के साथ मक्के का पराग और सेम के मिश्रण से ओ. टेन्टेलस को पालने में खासकर अर्भक विकास, जीवनक्षमता, जननक्षमता तथा मादा दीर्घायु की दृष्टि से प्रभावकारी रहा। सी. कार्नियै की एक दिवसीय डिम्भक को कृत्रिम आहार पर 338 पीढी तक पाला गया और औसत प्यूपीकरण तथा प्रौढ निर्गमन क्रमश: 87.0 तथा 84.8 रहा।

परपोषी कीटों के लिए कृत्रिम आहार

ओपीसीना अरेनोसेला को पालने के लिए नारियल के पत्तों के चूर्ण आधारित आहार उचित पाया गया। प्यूपीकरण तथा प्रौढ निर्गमन क्रमश: 733.2 तथा 66.2 प्रतिशत था। कृत्रिम आहार पर पले ओ. अरेनोलेसा, जोनियाजस नेफान्टीडिस, प्राचिमेरिया नोसाटोय तथा *बी. नेफान्टीडिस*, परजीव्याभ का सफलतापूर्वक बहुगुणन किया गया।

पत्तागोभी तथा वसा रहित सोय के कृत्रिम आहार पर प्लूटेला ज़ाइलोस्टेला पालने से क्रमश: 60.6 तथा 58.4 प्रतिशत प्यूपीकरण और प्रौढ निर्गमन हुआ।

नया साफ्टवेयर

कीट जैवएजेन्ट (सी.डी.) पर एक सचित्र मार्गदर्शिका तथा हेलीको-इन्फो नामक साफ्टवेयर की एक सी.डी. वर्जन विकसित की गई है।

फसल पीडकों का जैविक दमन

गन्ना

अ. वूली एफिड

ए.ए.यू. जोरहाट (असम) में गन्ने के वूली एफिड (एस.ड्ब्ल्यू.ए.) का *एन्कार्शिया फ्लेवोस्कूटेलम* नामक परजीव्याभ देखा गया। जनवरी 2005 के पहले सप्ताह में *ए. फ्लेवोस्कूटेलम* की संख्या सबसे अधिक थी जो धीरे-धीरे कम होती गई। *एन्कार्शिया* की संखाय अधिकतम तापमान, न्यूनतम तापमान तथा वर्षा से नकारात्मक रुप से सहसंबंधित थे (ए.ए.यू.)।

आंध्र प्रदेश में जून-अगस्त और नवम्बर-जनवरी के दौरान एस.ड्ब्ल्यू.ए. अपनी चरम सीमा पर थी। तटीय जिलो की अपेक्षा दक्षिणी तथा उत्तरी तेलंगाना में अधिकतम आपतन रिकार्ड किया गया। जिन क्षेत्रों में कीटनाशकों का प्रयोग नही किया गया वहां *डी. एफिडीवोरा* का प्रकोप अधिक था और नवम्बर-जनवरी के दौरान में दिखाई दिया। (ए.एन.जी.आर.ए.यू.)

कर्नाटक में एस.ड्ब्ल्यू.ए के विरुद्ध कीटरोगजनक कवक (*मेटा. एनीसोप्लीए, बे. बासियाना* तथा *वी. लोकानी*) प्रभावी नही रहे। *एस. इगोरोटस* (100

प्यूपे / विमोचन) के दो विमोचन से 45 दिनों में एस.इब्ल्यू.ए. का सफलतापूर्वक प्रबंधन किया जा सका (यू.ए.एस., धारावाड)। महाराष्ट्र के पांच मंडल में एस.इब्ल्यू.ए. का सफलतापूर्वक प्रबंधन किया जा सका (यू.ए.एस., धारवाज)। महाराष्ट्र के पांच मंडल में एस.इब्ल्यू.ए का सफलतापूर्वक प्रबंधन किया जा सका (यू.ए.एस। धारावाड)। महाराष्ट्र के पांच मंडल में एस.इब्ल्यू.ए का ग्रसन देखा गया। महाराष्ट्र के अभाव वाले क्षेत्र में 27 प्रतिशत तथा मध्य महाराष्ट्र के पठारी क्षेत्र 18 प्रतिशत की अपेक्षा पश्चिमी महाराष्ट्र के मैदानी क्षेत्र में 27 प्रतिशत सबसे अधिक थी। जुलाई-सितम्बर के दौरान दूसरे पखवाडे में ग्रसन देखा गया और अक्तूबर-नवम्बर 2004 में अधिकतम रहा जुलाई 2004 में माइक्रोमस एस.पी.पी. की संख्या अधिक थी और सितम्बर में *डी. एफिडीवोरा* की संख्या अधिक थी (एम.पी.के.वी.)।

मई 2004 की शुरुआत में तमिलनाडू के वेल्लूर जिले में एफिड का ग्रसन देखा गया और अधिक वर्षा वाले क्षेत्र को छोडकर अन्य क्षेत्रों में यह फैलता गया। ग्रसन की तीव्रता प्रारम्भ में 1.78 थी और मार्च में 4.73 तक हो गई। परभक्षियों की सक्रियता सही क्रम में रही। *डी.एफिडीवोरा* (1.833 / पत्ता) *सिर्फिड्स* (1.35 / पत्ता) *एम.एगोरोटस* (ओ.4/पत्ता) (टी.एन.ए.यू.)। डीफा की सक्रियता सितम्बर में देखी गई (एस.बी.आई)।

सहारनपुर (उत्तर प्रदेश) में अक्तूबर 2004 के दौरान सी.ओ.एस. 767 तथा सी.ओ.एस 88230 किस्मों में एस.इब्ल्यू.ए. की औसत संख्या कर रही। *डी. एफिडीवोरा* अधिक सक्रिय रहा अर्थात 9 डिम्भक / पत्ता (आई.आई.एस.आर.)

आ. ऊतक बेधक

अप्रैल के मध्य से जून के अंत तक 50,000/हे. के दर से *ट्रै. किनोलिस* का 10 दिन के अंतर पर 8 विमोचन, मई-जून के दौरान 50,000 हे. के दर से टी. जेपोनिकम के 6 विमोचन तथा जुलाई-अक्तुबर के दौरान 50,000/हे. के दर से 7-10 दिन के अंतर पर टी.चिनोलिस के 12-14 विमोचन क्रमश: *काइलो इनफस्केटेलस*, *सिर्पोफेगा ऐक्सेर्पटेलिस* तथा काइलो *ओरीसीलस* के विरुद्ध प्रभावकारी पाए गए।

इ. सफेद ग्रब

हेट्रोरेब्डीटिस इंडिका का 2.0 बिलियन आई.जे.एस. / हे. उपचार के परिणामस्वरुप सफेद ग्रब की संख्या बहुत कर हुई (सी.सी.एस.एच.ए.यू.)।

कपास

अ.बी.टी. कपास में जैव नियंत्रण

बी.टी. कपास तथी बीटी.रहित कपास में चूषक कीट तथा *स्पोडोप्टीरा लिटुरा* के नियंत्रण के लिए किसानों के पैकेज आफ प्रेक्टिस की तुलना में *ट्राइकोडर्मा* का बीज उपचार, *क्राइसोपर्ला कार्नेयी* का विमोचन, आवश्यकतानुसार कीटनाशक का प्रयोग युक्त बी.आई.पी.एम. मोड्यूल का मूल्यांकन किया गया। बी.आई.पी.एम. तथा एफ.पी.पी से बी.टी.रहित कपास की अपेक्षा उपचारित बी.टी.कपास में बाल वर्म से हानि कम हुई और बीज कपास उपज अधिक रही तथा प्राकृतिक शत्रुओं की संख्या भी अधिक रही (टी.एन.ए.यू.)। बी.टी. के साथ किसानों के प्रेक्टिस की अपेक्षा बी.टी.कपास के सॉथ बी.आई.पी.एम उपचार से चूषक कीट वर्ग की संख्या अपेक्षाकृत कम रही। बी.टी.कपास में बी.आई.पी.एम. तथा एफ.पीपी. मोड्यूल से हे. *अर्मिजेरा* द्वारा हानि भी कम हुई (ए.एन.जी.आर.ए.यू.)। बी.टी.कपास + बी.आई.पी.एम. पैकेज से कली एवं बाल वर्म की हानि कर हुई, चुषक कीटों की संख्या भी घटी और बीज की उपज बढी। (जी.ए.यू.)।

आ). ट्राइअकोडर्मा के बहु-पीडकनाशी सहिष्णु विभेद

खेतों में रसायनिक छिडकाव से उपचारित प्रयोगशाला विभेज की अपेक्षा *टी.किलोनिस* का बहुपीडकनाशी सहिष्णु विभेद। उत्तरजीवित रहे और ऐसे खेतों में बीज कपास उपज अधिक रही (यू.ए.एस. (धारवाड)।

तम्बाकू

नोमूरेइया रिलेयी @10^{13} बीजाणु/ हे.*अर्मिजेरा* को प्रभावकारी ढंग से दमन किया जा सका। *टी. रिमस* तथा *कीलोनेस* फार्मोसनस का बारी-बारी से विमोचन करने से *स्पोडोपेट्रा एम्सीगुआ* का परजीवीकरण अधिक हुआ और पौधे की हानि भी बहुत कर हुई (सी.टी.आर.आई.)।

दलहन

अरहर में प्रयोग किए गए समन्वित पीडक प्रबंध पैकेज जिसमें सम्मिलित है - 4.0 ग्राम / कि. बीज के दर से सी. ट्राइकोडर्मा बीज उपचार, नीम बीज अर्क 5 प्रतिशत, बेधक वर्ग के लिए 1.0 कि/हे, के दर से बी.टी., 1.5 x 10^{12} पी.ओ.बी./हे. के दर से हे.एन.पी.वी तथा अंतर सस्य के रुप में मक्का लगाने (10 प्रतिशत बेढंगी रोपण) से एच. *अर्मिजेरा* और *माइलाब्रिस पुस्टुलेटा* का प्रभावी नियंत्रण हुआ तथा फलों व बीज की हानि कम हुई और उपज अधिक प्राप्त हुआ।

अरहर के ब्लिस्टर बीटल तथा *एच. अर्मिजेरा* के नियंत्रण के लिए अन्य उपचार की अपेक्षा *हेट्रोहेब्डिटिस एस.पी.* 1.5 बिलियन सूत्रकृमि / हे. का उपचार सबसे उत्तम पाया गया (जी.ए.यू)।

लैब-लैब में *एच.अर्मिजेरा* डिम्भक के नियंत्रण के लिए 1.0 कि/हे. बी.टी. बहुत प्रभावकारी रहा और उपज उत्कृष्ट रही जितनी 1.5x10^{12} / हे. के दर से हे.एन.पी.वी. डालने से मिलता है (जी.ए.यू.)।

सोयाबीन में एस.लिटुरा के विरूद्ध 100,000/हे. के दर से टी. रेसम का विमोचन, स्पो.एन.पी.वी. के तीन छिडकाव (1.5x10^{12} पी.ओ.बी./हे. दर से) अडजुवेन्ट के रुप में 5 प्रतिशत कच्चा शक्कर का बी.आई.पी.एम. पैकेज का प्रयोग करने पर रसायनिक नियंत्रण विधि की अपेक्षा 17 प्रतिशत अधिक उपज प्राप्त हुई।

धान

बीज उपचार के रुप में साधारण रोधी किस्म *टी. विरीडी* का प्रयोग, 50,000/ हे. / सप्ताह *ट्राइकोग्रामा जेपोनिकम* के 6 विमोचन, *स्यूडोमोनास फ्लोरिसेन्स* का छिडकाव, आवश्यकतानुसार कीटनाशकों का प्रयोग तथा पक्षीसाद (10/हे.) के जैव गहन समन्वित पीडक प्रबंधन से धान के तना बेधक का मान 2.9 प्रतिशत मृत्यु हुई तथा उपज एवं अधिक लाभ हुआ (ए.ए.यू., जोरहाट)।

जैविक तरीके से उगाए गए धान के पर्ण कुंचन के नियंत्रण के लिए *टी. जेपोनिकम* (1 लाख/ हे.) उतना ही प्रभावी था जितना *टी. किलोनिस*। रसायनिक नियंत्रण विधि में निचला पौधा तथा पत्ता फुदकी की संख्या रिकार्ड की गई जिसे बाद में *एम.*एनीसोपिलिये तथा *बी. बेसियाना* का उपचार दिया गया। *बी.बेसियाना* से उपचारित खेतों में अधिकतम अनाज उपज रिकार्ड किया गया। रसायनिक नियंत्रित खेतों की अपेक्षा जैविक खेतों में मकडी तथा कोक्सीनेलिड की संख्या अधिक थी (के.ए.यू.)।

जैविक खेती से उगाए गए धान में *टी.*किलोनिस तथा *टी. जेपोनिकम* के अलग-अलग विमोचन की अपेक्षा रोपण के 30 दिनों के बाद से प्रारम्भ करके 1,00,000/हे. के दर से साप्ताहिक अंतर पर सात मिश्रित विमोचन करने से पर्ण कुंचन तथा तना बेधक का प्रभावी नियंत्रण हुआ।

तिलहन

सरसों में *इशवियोडान स्कूटेलारिस* का 1000 प्रौढ/हे. (50,000 डिम्भक/ हे.) से *लियाफिस एरीसिमी* की संख्या घटी और उपज में बढोत्तरी हुई (जी.ए.यू.)।

नारियल

ओ. ओरेसोनेला के नियंत्रण के लिए *गोनियोजूस नेफान्टीडिस* का शीर्ष अथवा तने पर विमोचित करने से कोई विशेष अंतर नही पडा। *कार्डियास्टेथस ऐक्जीगस* का 50/पेड के दर से विमोचन करने पर लोपीसीना की संख्या में महत्वपूर्ण कमी हुआ (के.ए.यू)।

उष्णकटीबंधीय फल फसलें

मेटाराइजियम एनीसोपीले $1.0x10^{9}$ बीजाणु / मि.ली. से 72 घंटे बाद आम फुदकी की मृत्यु संख्या 77 प्रतिशत हो गई। मीमूसोप्स एलीनो, माडूका लोगीफोलिया तथा रीघाशिया ाक्लिंटोरिया औषधीय पौधों पर 20/ पौधों के दर से *क्रिप्टोलेमस मोन्ट्रोज़ेरी* छोडने पर ग्रीन शील्ड स्केल का पूरी तरह सफाया हो गया।

शीतोष्ण फल फसलें

कश्मीर के विभिन्न में (एस.के.यू.ए.एस.व टी.) सेब पर सेन जोस शल्क की परजीविता 4.73-15.2 प्रतिशत रही। मशोबरा की अपेक्षा नौनी में *एफाइटस* तथा *एन्कार्शिया पर्निसियोसी* द्वारा परजीवीकरण अपेक्षाकृत कम थी। सितम्बर - दिसम्बर के दौरान वूली एपल एफिड उपस्थित थे। ग्रीष्म छिडकाव तेल से उपचारित पेडों से ममीकृत एफिड से *एफेलिनस माली* का निर्गमन 60.7 - 68.5 प्रतिशत रहा जबकि अनुपचारित पेडों से 82.9 प्रतिशत रहा। परीक्षित ग्रीष्म तेल एब्लासियस एस.पी.पी जैसे परभक्षी माइट के लिए अहानिकारक रहा किन्तु *पेनोनीयस उल्मी* तथा *टेट्रोनिकस* की संख्या बहुत कम हो गई (डा. वाई.एस.पी.यू.एच.एवं.एफ.)।

सब्जी फसलें

खीरा, तुरई तथा लौकी पर प्रयोगशाला में *डायाफानिया इंडीका* का बडे पैमाने पर पालन तकनीक का मानकीकरण किया गया। इमिडाक्लोप्रिड से अनावरण के 48 घंटे बाद *डोलीकोजेनिडे स्टेन्टोनी* की 20 प्रतिशत मृत्यु हुई जबकि परीक्षित कवकनाशी सुरक्षित पाए गए। *वर्टिसीलियम लेकानी* का छिडकाव ($1.0x10^{9}$ बीजाणु / मि.ली.) से *सिर्टोथ्रिप्स डोर्स्लस* का सभी अवस्थाओं में मृत्य संख्या अधिक रही (आई.आई.एच.आर.)।

टमाटर पर टी. किलोनिस 50,000/हे. के दर से चार विमोचन के साथ एच.ए.एन.पी.वी. ($1.5x10^{12}$ पी.ओ.बी./हे.) के दो छिडकाव को दूसरे तथा चौथे विमोचन के बाद प्रयोग करने से एच.अर्मिगेर का उतना ही प्रभवी नियंत्रण हुआ जितना कीटनाशकों से होता है (डा. वाई.एस.पी.यू.एच.एवं एफ)। टमाटर के फलों (तमिलनाडू कृषि विश्वविद्यालय) पर *एच. अर्मिजेरा* द्वारा होने वाले हानि को हे.एन.पी.वी. को $1.5x\ 10^{12}$ पी.ओ.बी./हे. के दर की पूरी खुराक से प्रभावकारी नियंत्रण किया जा सका। गांठ गोभी पर *बिवेरिया बासियाना, बी.थूरेन्जेनेसिस, एम. एनीसोफेलिया,* एच.इ.इंडिका तथा डाइक्लोर्फोस (0.05 प्रतिशत) का पेरिस ब्रासिक के प्रति मूल्यांकन किया गया है। डाइक्लोर्वोस को सबसे अधिक प्रभावी तथा *हेट्रोहेब्डीटिस इंडिका* का 2 बिलियन/हे. दर सबसे कम प्रभावी पाया गया (एस.के.यू.ए.एस.व टी.)।

खरपतवार

आसाम, केरला, पंजाब तथा गुजरात में विमोचित किए गए नियोकेटीना ईकोर्नियै तथा एन. ब्रूक स्थापित हो सके। नौनी में पार्थेनियम पर *ज़ाइगोग्रामा बायकोलोराटा* की सक्रियता बहुत कम रही और वह किसी भी तरह पादप विकास का दमन करने में प्रभावी न बन सका।

टर्फ घास

गोल्फ कोर्स की टर्फ घास से ग्रस्त ग्रब के लिए *बी. बेसियाना, बी.* ब्रोंगनियार्टि तथा *एम. एनीसोपीप्ले* के देशज पृथकों के $1x10^{8}$ बीजाणु / मि.ली. का मूल्यांकन किया गया। सभी कीट रोगजनकों का निष्पादन अच्छा रहा और *बी.बेसियाना* अधिक प्रभावकारी रहा जो शीघ्र मृत्यु प्रभावी बना सके (एस.के.यू.ए.एस.एवं टी.)।

3. EXECUTIVE SUMMARY

This report briefly highlights the salient findings of research conducted at PDBC, 10 SAUs and six ICAR-based centres and voluntary centres under the AICRP on biological control during 2004-05. In order to develop biocontrol technologies for the eco-friendly management of key pests, diseases and weeds, an extensive programme covering both basic and applied research was drawn. Emerging problems like the sugarcane woolly aphid, eco-friendly management of sucking pests on *Bt* cotton, and integration of biological control in organic farming, were included in the programme. Most of the experiments assigned under the technical programme drawn for the year 2004-05 have been carried out successfully.

Basic research

Project Directorate of Biological Control, Bangalore

Biosystematics

Two rare species, *Oenopia excellens* (Crotch) and *Protothea quadripunctata* (Mulsant), from the northeastern region and one new species of *Pseudoscymnus* from Bangalore, were recorded.

A website on the Coccinellidae of the Indian region featuring image galleries of common species and their natural enemies has been constructed and hosted. A computer-aided dichotomous key to 10 common Indian species of *Chilocorus* has been developed.

A host-parasitoid list for Indian Tachinidae, including 24 species from *Helicoverpa armigera*, has been compiled.

Introduction of natural enemies

Import permits have been obtained from the Plant Protection Advisor to the Government of India for the import of *Smicronyx lutulentus*, *Nephaspis bicolor*, *Ganaspidium nigrimanus* (=*G. utilis*), *Chrysocharis parksi*, *Delphastus pusillus*, *Telenomus triptus*, *T. laeviceps*, *T. ullyetti* and *Glabromicroplitis croceipes*. *Trichogramma* sp. nr. *mwanzai* Schulten & Feijen has been introduced from Kenya for evaluation against *Helicoverpa armigera*. The parasitization rate on *H. armigera* eggs glued on chickpea and pigeon pea ranged from 3.3 to 6.7 and 5.0 to 32.5, respectively. A shipment of *Eriborus trochanteratus* (adapted to *Opisina arenosella*) was received from Sri Lanka in February 2005 and a pure culture was raised using *Corcyra* larvae. Shipments of *Zygogramma bicolorata* and *Sturmiopsis inferens* were exported to Sri Lanka and ICIPE, Kenya, respectively.

Rearing and evaluation of natural enemies

Among the seven chickpea varieties (JG74, L550, JSC6, JG315, ICCV2, Black Channa and JG130) tested for ovipositional preference of *H. armigera*, egg laying was minimum on JG 130.

A technique for shipping *Telenomus* cards in ventilated plastic boxes fixed with polystyrene strips with slits has been standardized. The cost of one parasitized egg card of *Telenomus remus* with 10 egg patches was worked out to be Rs.4/-. The dosage / ha (50 cards) would cost Rs. 200/-.

Large cages measuring 1.7x1.7x 2.5' were utilized for multiplying *Campoletis chlorideae*. A temperature of 26-28°C and 70-80% relative humidity were optimum for production. The production was evaluated at three parasitoid densities per cage – 5-8, 10-13 and 20-23. The number of cocoons per cage was 72, 73.3 and 115, respectively and the number of cocoons/ female was 14.4, 5.2 and 6/female, respectively.

Progeny production in *Orius tantillus* was maximum at 24 and 28°C, the values being 28.8 and 26.2 per female, respectively.

Release of *Blaptostethus pallescens* nymphs on rice infested with *Sitotroga cerealella* eggs resulted in only 8% moth emergence. *Blaptostethus* also preyed on *H. armigera* eggs and larvae on chickpea.

Predators of *Ceratovacuna lanigera*

Micromus igorotus was recorded feeding on *Ceratovacuna lanigera*. Its biology was studied on *C. lanigera*, *Pseudoregma bambusicola*, *Aphis craccivora* and *Aphis spiraecola*. Adult longevity, pre-oviposition period and pupal periods were extended on other aphid species as compared to *C. lanigera*. *M. igorotus* larvae failed to thrive on the eggs of *Ferrisia virgata*, *Planococcus citri*, *Maconellicoccus hirsutus*, *Corcyra cephalonica* and *S. cerealella*. Other predators such as *Mallada boninensis*, *Spalgis epius*, *Cryptolaemus montrouzieri* and *Synonycha grandis* were also recorded in the sugarcane fields of Karnataka. Field evaluation of laboratory reared *Eupeodes confrater* indicated that the egg stage of the predator is susceptible to attack by soldier aphids.

Megalocaria dilatata (Coleoptera: Coccinellidae) and *Dipha aphidivora* (Lepidoptera: Pyralidae), predators of the sugarcane woolly aphid, were reared on *A. craccivora* as alternative prey. While *D. aphidivora* successfully completed its life cycle on *A. craccivora*, *M. dilatata* showed high mortality, particularly in the egg stage and the first instar. For oviposition, *D. aphidivora* preferred rough textured paper to polyethylene and cloth surfaces. *D. aphidivora* did not develop when fed exclusively on soldiers of *C. lanigera*.

Mass production of *Cryptolaemus montrouzieri*

Cryptolaemus montrouzieri was reared on *S. cerealella* eggs for five generations. The per cent pupation was 67.57% and adult emergence 84%. The mean larval and pupal periods were 13.69 and 7.36 days, respectively, and adult longevity was 52.02 days.

Use of insect viruses

Crocidolomia binotalis NPV (CbNPV) tested @ 10^5-10^9 POBs/ml against late second instar larvae resulted in 33.3-90.0% mortality as per the dose. A mean of 850 million POBs of *Cb*NPV was harvested/larva when inoculated at a low dose of 1x104 POBs/ml.

*Cb*NPV was not cross-infective to *Bombyx mori*, *H. armigera*, *Spodoptera litura*, *Plutella xylostella*, *Hellula undalis*, *Trichoplusia ni*, *S. exigua*, *Chilo partellus*, *Galleria mellonella*, *C. cephalonica*, and the predators, *Chrysoperla carnea* and *C. montrouzieri*.

Use of adjuvants, *viz.*, 1.0% starch + 10% crude sugar with the respective NPVs gave maximum mortality of *H. armigera* and *S. litura* larvae (87.55% and 94.33%, respectively) on the first day.

Entomofungal pathogens

Metarhizium anisopliae (isolate Ma-4) caused the highest per cent mycosis of *C. lanigera* (30.14), followed by *Beauveria bassiana* (Bb-5a) (20.46). Isolates Ma-4 and Bb-5a were also found pathogenic to *Dipha* (27.62 and 15.32% mycosis, respectively). *Verticillium lecanii* was not pathogenic to *C. lanigera*, but caused 7.62-33.48% mycosis of *Micromus*.

Isolation and characterization of indigenous *Bacillus thuringiensis* strains

Three isolates of *Bacillus thuringiensis*, two from Pantnagar and one from Anekal, were obtained. Pantnagar sample 2 exhibited the highest toxicity against *Plutella xylostella* in cabbage leaf bioassay.

Isolation of endophytic bacteria

Four new bacteria, *viz.*, *Bacillus megatherium* (MTCC 6533) (Plate1), *Bacillus* spp. (MTCC – 6534),

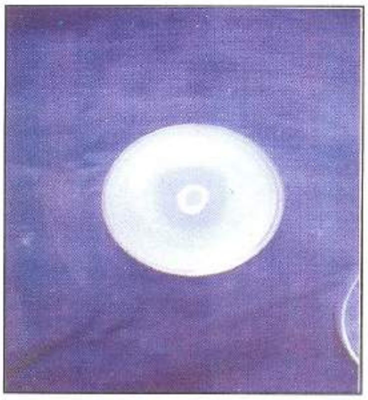


Plate1: Phosphate solubilization by *Bacillus megatherium* (PDBCENCH1), a chickpea endophyte

Enterobacter agglomerans (MTCC 6536), *Bacillus circulans* (MTCC 6535) and *Erwinia herbicola* (MTCC 6720), were isolated from the endosphere of plants. The cultures caused 8-16% enhanced growth in chickpea and pigeonpea and inhibitory activity against root rot pathogens.

Fungal antagonists

Among the PDBC isolates of *Trichoderma harzianum*, Th17 and Th7 were found to be very promising. Th P26 (from IISR, Calicut), Th7, Th8, and Th10 (from PDBC) were highly antagonistic to *Macrophomina phaseolina*. On colloidal chitin-amended medium (CCAM), growth of Th13, Th 14, Th 15, Th Varanasi, Th GTH7, Th Kudlu, Th Kallangai, Th ITCC, Th CPCRI, Th CICR and P26 was faster. Chitinase was detected in P26, Th10 and Th14 in *S. rolfsii* cell wall-amended broth. In colloidal chitin-amended broth, chitinase activity could be detected in P26 and Th-10. In potato-dextrose broth, chitinase activity could not be detected.

Talc formulations of *T. harzianum* and *T. viride* with 2 or 5% pure chitin had higher number of viable colony forming units (CFU) than those without chitin for up to three months of storage. Prawn shell powder as source of chitin reduced the number of viable CFUs, even after autoclaving due to the presence of anti-microbial compounds. Wider C:N ratios in production medium (10:1 and 15: 1) resulted in good sporulation and viable propagules in *T. harzianum* and *T. viride* during storage. Addition of glycerol in production medium at 3-9% also gave more CFU count during storage for up to 3 months. Heat shock at 40°C for 30 minutes or at 35°C for 45 minutes during stationary phase of growth in *T. viride* and *T. harzianum* increased the number of CFUs in storage for up to 2 months. Addition of colloidal chitin in production media at 0.2% increased the viable CFUs in *B. bassiana* and *M. anisopliae*. Addition of an osmoticant (PEG 6000) at 1.5% to the production medium of *B. bassiana* resulted in reduced sporulation.

Biological control of plant diseases

Cow dung was the best medium for the multiplication of *Pseudomonas fluorescens* at 32°C and 40% (w/w) moisture level. *Trichoderma harzianum* and/or *P. fluorescens* colonized FYM significantly increased seed germination and seedling growth of tomato and okra. Water soluble content of P, K, S, Zn, Cu and Fe and humic matter were higher in FYM-based antagonists. Biopriming of pea seeds with PBA 3 improved seedling stand and increased the yield of organically grown pea when applied as foliar spray. Seed treatment with different isolates of *Pseudomonas*, *T. harzianum* and *T. virens* resulted in 72.2, 52.3 and 41.3 percent suppression in sheath blight, respectively.

Entomopathogenic nematodes

Effect of initial inoculum of IJs on *in vivo* yields in *G. mellonella*, pathogenicity and time of emergence of *Steinernema carpocapsae* and *Heterorhabditis indica* were determined. Higher yields were obtained at 1000 Ijs of *S. carpocapsae* per larva within 6 days, whereas 300 Ijs of *H. indica* gave maximum yield within 10 days. The yield of *H. indica* was three-fold higher than the yield of *S. carpocapsae*. Persistence of *S. carpocapsae, S. abbasi, H. indica* and *H. bacteriophora* under shaded and open conditions in soil ranged from 60 to 90 days. Two isolates of *S. carpocapsae* and *H. indica* tested for shelf life were viable for up to 3 months. Talc-based formulation of *S. carpocapsae* was found suitable and stable for surface transport.

Pathogens for the biological suppression of phytophagous mites

Hirsutella thompsonii growth was excellent at 25°C. Conidial production of *H. thompsonii* was hindered at 37°C. *H. thompsonii* var. *synnematosa* also did not grow at 37°C and 40°C. When oatmeal agar (OMA) discs were used on the biomass of *H. thompsonii* in Sabouraud dextrose broth (SDB) as continuous shake culture, the inoculum load, the CFU, pellet number and wet and dry weights increased proportionately. A combination of OMA plugs and SDB medium was the best with maximum CFU numbers, wet and dry weights. The pellets of *H. thompsonii* and *H. thompsonii* var. *synnematosa* were able to grow well after 10 and 11 months of storage in sterile water under room conditions.

A simple magnetic stirrer technique for faster mass production of *H. thompsonii* has been developed. Exudates of *H. thompsonii* caused 77.8% mortality of *Tetranychus urticae* after seven days and the mortality decreased as exudate concentration was reduced. The metabolites of *H. thompsonii* collected from one-month-old shake culture were toxic to *T. urticae* (68.9% mortality after 7 days), but the mortality decreased with dilution.

Mycohit, a wettable powder formulation of *H. thompsonii* when sprayed twice at the rate of 50 g/l, reduced *T. urticae* population by up to 62.7% on okra in farmers' field in Coimbatore (Tamil Nadu).

Sequencing of β-tubulin gene in *Pochonia chlamydosporia*

Molecular identity of native isolates of *Pochonia chlamydosporia* at PDBC was established through sequencing the β-tubulin gene (1 to 233 bases) and registered in the Genebank, NCBI, Maryland, USA.

Biological suppression of plant parasitic nematodes

Pochonia chlamydosporia (PDBC PC59) isolated from the grapevine yards around Bangalore effectively controlled the reniform and root-knot nematodes. *Phytophthora*-root-knot nematode wilt complex in black pepper was effectively controlled by planting cuttings pre-treated with mancozeb 72 WP and akomin in combination with native isolates of *Trichoderma* sp. and *Paecilomyces lilacinus*.

Behavioural studies on natural enemies

Thirteen plant volatile compounds identified from maize, cotton, and tomato were evaluated through EAG studies for their cue to *Chrysoperla carnea*. The highest response of *C. carnea* was noticed towards linalool, followed by alpha-pinene and n-tetradecane. Combination of the three in equal proportion at full and half concentration received maximum response from *C. carnea* females.

Of the five volatile compounds tested against *Trichogramma chilonis* under dual choice, myrcene (58.66%) elicited maximum response, but was on par with methyl salicylate (48.66%). Similarly, of the 13 compounds evaluated for their cue to *T. chilonis*, maximum response was to a combination of α-Pinene+Linalool+α-terpinene (2:2:1) (50.00%). Highest net response of *T. chilonis* was observed towards linalool (27.50%), followed by myrcene (21.25%) under free-choice conditions. Among 18 varieties/hybrids of maize evaluated for the response of *T. chilonis* to volatiles released by their male and female flowers, the variety Deccan (94.87%) and ITC Adventa elicited the maximum response.

In a field experiment at Raichur, use of kairomones along with supplementary food as reinforcing agent for chrysopids increased their numbers. The recovery of *T. chilonis* was higher in the kairomone-treated plot compared to control.

Development and evaluation of improved methods of storage and release of *Trichogramma*

Releases of *Trichogramma embryophagum* and *T. chilonis* against *Opisina arenosella* @ 1000, 2000, 3000 and 4000 / palm reduced the larval population by 88.8, 75.0, 66.7 and 75.0% in *T. embryophagum* and 75.6, 60.0, 33.3 and 50.0% in *T. chilonis* during the 1st, 2nd, 3rd and 4th generations of the pest compared to untreated control.

Among eleven species of *Trichogramma*, four gave higher parasitism of *Earias vittella* in the initial laboratory testing. *T. brasiliense* and *T. chilonis* released @ 5 pairs each for 50 eggs caused 46.7 and 41.3 percent parasitism, respectively, indicating their potential use in the field.

A novel technique of modified atmosphere packing and storage of *Corcyra cephalonica* eggs was developed. This technique has enhanced the shelf life of *C. cephalonica* eggs by 3–4-fold over the traditional method.

The efficacy of the various release methods for *Trichogramma* spp. was determined in terms of time taken for release, adult emergence from various carriers and percentage egg parasitism. Mixing of eggs with carriers like talc (1:1) and agar solution (1%) recorded the least time taken for application. Agar solution was found to be the best aqueous carrier. The per cent emergence was lower in loose parasitized eggs with solid and aqueous carriers (40.5 to 57.1%) compared to 95-100% in tricho-bit, tricho-capsule and loose eggs without any carrier. Adult release, sprinkling of loose parasitized eggs mixed with vermiculite and semolina separately gave significantly higher parasitism compared to others.

Artificial diets for parasitoids and predators

Dipha aphidivora larvae were reared on two artificial diets with limited success. *Micromus igorotus* larvae survived for 2-13 days and did not reach pupal stage on three different semi-synthetic diets.

A combination of artificial diet with maize pollen and beans was effective for rearing *O. tantillus* in terms of nymphal development, survival, fecundity and female longevity. One-day-old larvae of *C. carnea* were reared on artificial diet for up to 38 generations and the mean per cent pupation and adult emergence were 87.0 and 84.8, respectively.

Artificial diets for host insects

Toddy palm leaf powder-based artificial diet was suitable for rearing *Opisina arenosella*. The pupation and adult emergence were 73.2 and 66.2%, respectively. The parasitoids, *Goniozus nephantidis*, *Brachymeria nosatoi* and *B. nephantidis*, successfully multiplied on *O. arenosella* reared on artificial diet.

The artificial diet with cabbage leaf powder and defatted soy for rearing *Plutella xylostella* gave 60.6 and 58.4% pupation and adult emergence, respectively.

Software development

A Pictorial Guide to Insect Bioagents (on CD) and a CD version of the software, "Helico-info" were developed.

Biological suppression of crop pests

Sugarcane

i. Woolly aphid

Encarsia flavoscutellum, a parasitoid of sugarcane woolly aphid (SWA), was observed at AAU, Jorhat (Assam) (Plate 2). The population of *E. flavoscutellum* peaked in the first week of January 2005 and gradually declined thereafter. *Encarsia* population was negatively correlated with maximum temperature, minimum temperature and rainfall (AAU).

Plate 2: *Encarsia flavoscutellum*, a parasitoid of sugarcane woolly aphid

Two peaks of SWA during June-August and November–January were noticed in Andhra Pradesh. Southern and northern Telengana zones recorded higher incidence than coastal districts. *D. aphidivora* was predominant in the areas where no insecticides were used and was noticed during November-January (ANGRAU).

Entomopathogenic fungi (*M. anisopliae, B. bassiana* and *V. lecanii*) under field conditions were not effective against SWA in Karnataka. Two releases of *M. igorotus* (100 pupae/ release) were successful in managing SWA within 45 days (UAS, Dharwad).

SWA infestation was noticed in five zones in Maharashtra. The infestation was higher in the western Maharashtra plain zone (41%) than in scarcity zone (27%) and central Maharashtra plateau zone (18%). The infestation was observed from the second fortnight of July to December and peaked during October-November, 2004. *Micromus* spp. population was high during July 2004 and *D. aphidivora* during December (MPKV).

The aphid incidence was initially noted in Vellore District (Tamil Nadu) during May 2004 and spread to other zones except high rainfall zone. The infestation intensity was initially 1.78 and reached 4.73 during March. The activity of predators was in the order *D. aphidivora* (1.83 / leaf) > syrphids (1.35 / leaf) > *M. igorotus* (0.4 / leaf) (TNAU). The activity of *Dipha* was noticed in December (SBI).

During October 2004, SWA was observed in the ratoon of CoS 767 and CoS88230 varieties with low to moderate population at Saharanpur (Uttar Pradesh). *D. aphidivora* was very active with more than 9 larvae/leaf (IISR).

ii. Tissue borers

Eight releases of *T. chilonis* @ 50,000/ha at 10 days interval during mid-April to end–June, six releases of *T. japonicum* during May-June @ 50,000/ha and 12-14 releases of *T. chilonis* at 7-10 days interval during July-October @ 50,000/ha proved effective against *Chilo infuscatellus, Scirpophaga excerptalis* and *Chilo auricilius*, respectively (PAU).

iii. White grubs

Application of *Heterorhabditis indica* @ 2.0 billion IJs per ha resulted in minimum population of white grubs (CCSHAU).

Cotton

i. Biocontrol in Bt cotton

The BIPM module consisting of seed treatment with *Trichoderma* and release of *Chrysoperla carnea* and need-based insecticide sprays was evaluated against sucking pests and *Spodoptera litura* in comparison with the farmers' package of practices (FPP) for Bt and non-Bt cotton. Bt cotton under BIPM and FPP performed better in reducing the bollworm damage and recorded higher seed cotton yield and natural enemy population than non-Bt cotton (TNAU). The sucking pest complex was comparatively lower in Bt cotton+BIPM than with Bt cotton + farmers' practice. *H. armigera* damage was also lower on Bt cotton in BIPM and FPP modules (ANGRAU). Bt cotton+BIPM package recorded significantly lower bud and boll damage, reduction in sucking pests and higher seed yield (GAU).

ii. Multiple-pesticide tolerant strain of *Trichogramma*

The multiple-pesticide tolerant strain of *T. chilonis* survived better than the laboratory strain in fields sprayed with chemicals and such fields recorded higher seed cotton yield (UAS (D)).

Tobacco

Nomuraea rileyi @ 10^{13} spores/ha effectively suppressed *H. armigera*. Sequential releases of *T. remus* and *Chelonus formosanus* resulted in higher parasitization of *Spodoptera exigua* and lowest seedling damage (CTRI).

Pulses

An IPM package employed in pigeonpea with *Trichoderma* seed treatment @ 4.0 g/kg seed, NSKE 5%, *Bt* @ 1.0 kg / ha for borer complex, *Ha*NPV @ 1.5 X 10^{12} POB/ha and intercrop of maize (10 % random planting) gave significant control of *H. armigera* and *Mylabris pustulata* and resulted in lower pod and seed damage and higher yield. *Heterorhabditis* sp. @ 1.5 billion nematodes/ha was superior to all the other treatments against *H. armigera* and blister beetle on pigeonpea (GAU).

Bt @ 1.0 kg/ha gave greater control of *H. armigera* larvae on lablab and the yield was superior to control and on par with *Ha*NPV @ 1.5x10^{12}/ha (GAU).

A BIPM package consisting of release of *T. remus* @ 100,000/ha and three sprays of *Sl*NPV @ 1.5 x 10^{12} POB/ha with 0.5% crude sugar as adjuvant against *S. litura* in soybean resulted in 17% higher yield than chemical control (CTRI).

Rice

Biointensive IPM consisting of the use of moderately resistant variety, *T. viride* as seed treatment, release of *Trichogramma japonicum* @ 50,000/ha/week (6 releases), spray of *Pseudomonas fluorescens*, need-based insecticidal application and use of bird perches (10/ha) for rice stem borer recorded only 2.9% of dead hearts, and higher yield and net profit (AAU, Jorhat).

In organically grown rice, *T. japonicum* (1 lakh/ha) was as effective as *T. chilonis* in controlling leaf folder. Significantly lower plant- and leafhopper count was recorded in chemical control followed by *M. anisopliae* and *B. bassiana* treatments. Maximum grain yield was recorded in *B. bassiana*-treated plot. Spider and coccinellid populations were higher in organic farming plot than in chemical control plot (KAU).

Seven combined releases of *T. chilonis* and *T. japonicum* each @ 1,00,000 per ha at weekly interval, starting at 30 DAT proved more effective against leaf folder and stem borer than individual releases on organically grown rice (PAU).

Oilseeds

Ischiodon scutellaris @ 1000 adults / ha (50,000 larvae / ha) reduced *Lipaphis erysimi* population on mustard and gave higher yield (GAU).

Coconut

There was no significant difference between trunk and crown release of *Goniozus nephantidis* against *O. arenosella*. Field release of *Cardiastethus exiguus* @ 50/palm reduced *Opisina* population significantly (KAU).

Tropical fruit crops

Metarhizium anisopliae at 1.0 x 10^9 spores/ml caused 77% mortality of mango hoppers after 72 hours. Release of *Cryptolaemus montrouzieri* @ 20/plant cleared the green shield scale on the medicinal plants *Mimusops elengi*, *Maduca longifolia* and *Wrighatia tinctoria*. *Leptomastix dactylopii* was recovered from *Planococcus citri* infesting custard apple fruits. Release of *C. montrouzieri* and *Cheilomenes sexmaculata* controlled *P.citri* and *Toxoptera aurantii*, respectively, on acid lime (IIHR).

Maximum percentage parasitism of spiralling whitefly on guava by *Encarsia* spp. was in February 2005 (39.88) (KAU). *E. guadeloupae* was recovered in guava orchards in Maharashtra two months after release, indicating its establishment (MPKV).

Bt formulations (Delfin, Biobit and Halt) reduced the fruit damage due to *Deudorix isocrates* on pomegranate (IIHR). *Telenomus* sp. parasitized 28.5-52% eggs of pomegranate fruit borer, *Deudorix epijarbas*, during July-August (Dr.YSPUH & F).

Temperate fruit crops

Parasitism of San Jose scale on apple was 4.73-15.42 % in different districts of Kashmir (SKUAST). The parasitization by *Aphytis* and *Encarsia perniciosi* was relatively lower at Nauni than at Mashobra. The woolly apple aphid was present during September-December. Emergence of *Aphelinus mali* was 60.7-68.5% from mummified aphids from trees treated with summer spray oils as against 82.9% from untreated trees. Summer oils tested were harmless to the predatory mites, *Amblyseius* spp., but brought down *Panonychus ulmi* and *Tetranychus urticae* significantly (Dr.YSPUH & F).

Vegetable crops

Laboratory mass rearing of *Diaphania indica* was standardized on cucumber, ridge gourd and bottle gourd. Imidacloprid caused 20% mortality of the parasitoid, *Dolichogenidea stantoni*, 48 h after exposure, while the fungicides tested were safe. *Verticillium lecanii* sprays (1.0x10^9 spores/ml) against *Scirtothrips dorsalis* caused high mortality to all stages (IIHR).

Four releases of *T. chilonis* @ 50000/ha and two sprays of *Ha*NPV at 1.5 x 10^{12} POB/ha applied after second and fourth release of the parasitoid checked *H. armigera* on tomato as effectively as insecticides (Dr.YSPUH & F). Fruit damage due to *H. armigera* was significantly lower when *Ha*NPV was applied at full dose @ 1.5 x 10^{12} POB/ha than at lower doses on tomato (TNAU).

Beauveria bassiana, *B. thuringiensis*, *M. anisopliae*, *H. indica* and dichlorvos (0.05%) were evaluated against

Pieris brassicae on knol-khol and dichlorvos proved to be the most effective and *Heterorhabditis indica* @ 2 billion/ ha the least effective (SKUAS & T).

Weeds

Neochetina eichhorniae and *N. bruchi* were found established at all the released spots in Assam, Kerala, Punjab and Gujarat. Activity of *Zygogramma bicolorata* was very low on parthenium at Nauni and had no suppressive effect on plant growth (Dr.YSPUH & F).

Turf grass

Indigenous isolates of *B. bassiana*, *B. brongniartii* and *M. anisopliae* were evaluated at 1x 10^8 spores/ml against white grubs infesting golf course. All the entomopathogens performed well and *B. bassiana* was the most effective, causing early mortality (SKUAS & T).

4. INTRODUCTION

Brief History

The All India Co-ordinated Research Project on Biological Control of Crop Pests and Weeds was initiated in 1977 under the aegis of Indian Council of Agricultural Research, New Delhi, with funds from the Department of Science and Technology, Government of India. Within two years (1979), ICAR included the project under its research activities with full financial support. Recognition of the importance of biological control came during the VIII plan with the upgradation of the centre to Project Directorate of Biological Control with headquarters at Bangalore. The Project Directorate started functioning on 19th October 1993. The AICRP started with 13 centres initially and has now increased to 16 centres, all functioning under the Project Directorate.

Past achievements

Basic Research

- Eighty-four exotic natural enemies (NEs) have been studied for utilization against alien pests, out of which 56 could be successfully multiplied in the laboratory, 50 species have been recovered from the field, four are providing partial control, five substantial control and six are providing economic benefits worth millions of rupees. Twelve are augmented in the same way as indigenous natural enemies.
- The encyrtid parasitoid, *Leptomastix dactylopii*, introduced from West Indies in 1983, has successfully established on mealybugs infesting citrus and many other crops in South India.
- Two aphelinid parasitoids of South American origin were fortuitously introduced against *Aleurodicus dispersus*. *Encarsia guadeloupae*, colonized in peninsular India from Lakshadweeps, has established, displacing the earlier introduced *E.* sp. nr. *meritoria*.
- *Curinus coeruleus* (origin: South America), the coccinellid predator introduced from Thailand in 1988, colonized successfully on subabul psyllid.
- *Cyrtobagous salviniae* (Origin: Argentina) was introduced in 1982 and colonized on water fern, *Salvinia molesta*, in 1983. Weevil releases have resulted in savings of Rs.68 lakhs / annum on labour alone in Kuttanad district, Kerala.
- The weevils, *Neochetina bruchi* and *N. eichhorniae*, and the hydrophilic mite, *Orthogalumma terebrantis* (Origin: Argentina), introduced in 1982 and colonized in 1983 on stands of water hyacinth, have established in 15 states. Savings on labour alone is Rs. 1120 per ha of weed mat.
- The chrysomelid beetle, *Zygogramma bicolorata* (Origin: Mexico), introduced and colonized in 1983 on stands of parthenium, has established in all the states and Union Territories.
- Biosystematic studies were carried out on 250 predatory coccinellids. A website on Indian Coccinellidae featuring image galleries of common species and their natural enemies has been constructed and hosted.
- A computer-aided dichotomous key to 10 common Indian species of *Chilocorus* is hosted on the internet.
- Biological control of sugarcane pyrilla has been achieved within the country by the redistribution of *Epiricania melanoleuca*, a parasite of *Pyrilla perpusilla*.
- Breeding techniques for 46 host insects standardized including rearing on semi-synthetic diet and cost of production has been worked out.
- Improved laboratory techniques developed for the multiplication of 26 egg parasitoids, seven egg-larval parasitoids, 39 larval/nymphal parasitoids, 25 predators and seven species of weed insects.
- A technique for shipping *Telenomus* cards in ventilated plastic boxes fixed with polystyrene strips (with slits) has been standardized.
- A beef liver-based semi-synthetic diet has been evolved for *Chrysoperla carnea* to facilitate its large-scale production and use.

- Toddy palm leaf powder-based artificial diet was developed for rearing *Opisina arenosella*
- Coccinellid predators, *Cryptolaemus montrouzieri*, *Cheilomenes sexmaculata* and *Chilocorus nigrita* successfully mass-produced on semi-synthetic diet.
- A new multi-cellular acrylic larval rearing unit devised for efficient and economic mass production of *Helicoverpa armigera* and *Spodoptera litura* for commercial production of host-specific parasitoids and NPV.
- The predators, *Micromus igorotus* and *Dipha aphidivora*, were identified for the management of sugarcane woolly aphid.
- A novel technique of modified atmosphere packing of *Corcyra cephalonica* eggs followed by low temperature storage at 8±1°C has been developed.
- Tritrophic relationships between natural enemies, their hosts and host plants have been determined.
- Tritrophic interaction studies between the egg parasitoid, *Trichogramma chilonis*, bollworm *H. armigera* and cotton, chickpea, pigeonpea, sunflower and tomato genotypes have helped in identifying biocontrol-friendly genotypes.
- Suitable low temperatures for short-term storage of trichogrammatids, *Eucelatoria bryani*, *Carcelia illota*, *Allorhogas pyralophagus*, *Copidosoma koehleri*, *Hyposoter didymator*, *Cotesia marginiventris*, *L. dactylopii*, *Sturmiopsis inferens*, and *Pareuchaetes pseudoinsulata* have been determined.
- An endosulfan-tolerant strain of *Trichogramma chilonis* (Endogram) developed for the first time in the world. Technology transferred to private sector for large-scale production.
- Strains of *Trichogramma chilonis* tolerant to multiple-insecticide and high temperature and a strain having high host searching ability have been developed for use against lepidopterous pests.
- Pesticide tolerant strain of *T. chilonis* had higher amount of glutathion-s-transferase activity than the susceptible strain.
- Different pesticides have been screened against 37 natural enemies for identifying the relatively safe ones to be used in a biological control-based integrated approach.
- Kairomones from scale extracts of *H. armigera* and *C. cephalonica* increased the predatory potential of chrysopids.
- Acid hydrolyzed L-tryptophan increased oviposition by *C. carnea* on cotton.
- Two fungal (*Trichoderma harzianum*-PDBCTH 10 and *T. viride*-PDBCTH 23), and two bacterial antagonists (*Pseudomonas fluorescens*-PDBCAB 2, 29 & 30 and *P. putida*-PDBCAB 19) of plant pathogens released for commercial production after intensive studies.
- Bacterial antagonists, particularly *Pseudomonas cepacia* (starin N 24), successfully suppressed *Sclerotium rolfsii* in sunflower rhizosphere as seed inocula.
- New species and strains of entomopathogenic nematodes (EPN), namely, *Steinernema abbasi*, *S. tami*, *S. carpocapsae*, *S.bicornutum* and *Heterorhabditis indica* have been recorded.
- Suitable media for mass multiplication of EPN identified. *S. carpocapsae* @ 1.25-5 billion/ha proved effective against brinjal borer, *Leucinodes orbonalis*. Talc-based and alginate-capsule formulations of *S. carpocapsae* and *H. indica* were effective against *S. litura* in tobacco.
- An easy and rapid technique to screen antagonistic fungi against plant parasitic nematodes has been devised to identify efficient strains. The antagonistic fungus, *Paecilomyces lilacinus* was found effective against *Meloidogyne incognita* and *Rotylenchulus reniformis* in red laterite soils and *Pochonia chlamydospora* was effective in sandy loam soil.

- Molecular identity of native isolates of *P. chlamydosporia* at PDBC was established through sequencing the β-tubulin gene (1 to 233 bases) and registered in the Genebank, NCBI, Maryland, USA.
- 'PDBC-INFOBASE' giving information about bioagents, their use and availability in public and private sector in the country; and 'BIOCOT", giving information about biocontrol measures for cotton pests and a CD version of the software "Helico-info" were developed.

Applied Research

- Eight releases of *T. chilonis* (@ 50,000/ha at 10 days interval) during April-June and six releases of *T. japonicum* (@ 50,000/ha at 10 days interval) during May-June have proved effective in suppressing sugarcane tissue borers.
- *Beauveria bassiana*, *B. brongniarti* and *Metarhizium anisopliae* were mass cultured and utilized effectively against sugarcane white grubs.
- *Encarsia flavoscutellum* and *Dipha aphidivora* were promising against the sugarcane woolly aphid.
- Application of *Heterorhabditis indica* @ 2.0 billion IJs/ha resulted in minimum population of white grubs in sugarcane.
- *Trichogramma chilonis* has proved effective against maize stem borer, *Chilo partellus*.
- Biocontrol-based IPM modules consisting of the use of moderately resistant variety, *T. viride* as seed treatment, release of *T. japonicum* @ 50,000/ha/week (6 releases), spray of *Pseudomonas fluorescens*, need-based insecticidal application and use of bird perches (10/ha) for rice stem borer recorded only 2.9% of dead hearts and resulted in higher yield and net profit.
- *Trichogramma japonicum* (1 lakh/ha) was as effective as *T. chilonis* in controlling the rice leaf folder.
- IPM modules for cotton crop have been formulated, comprising the use of oxydemeton methyl (0.03%), releases of *C. carnea*, *T. chilonis* and spray of *Ha*NPV. The module gave higher yields of seed cotton and conserved natural enemies better than insecticidal sprays alone.
- BIPM package recorded significantly lower bud and boll damage, lower population of sucking pests and higher seed yield than the package with chemical agents in Bt cotton.
- *Bt* and *Ha*NPV were important components of BIPM of pod borers in pigeonpea and chickpea resulting in increased grain yield.
- Release of *T. remus* @ 100,000/ha and three sprays of *S*NPV @ 1.5 x 10^{12} POBs/ha along with 0.5% crude sugar as adjuvant against *S. litura* in soybean resulted in 17% higher yield than in chemical control.
- Integration of *Telenomus remus* and NSKE for the management of *S. litura* and *C. carnea* and *Nomuraea rileyi* (@ 10^{13} spores/ha) for the management of *Helicoverpa armigera* on tobacco were effective. The cost-benefit ratio for BIPM was better (1:2.74) than that for chemical control (1:1.52).
- *Ischiodon scutellaris* @ 1000 adults/ha or 50,000 larvae/ha reduced *Lipaphis erysimi* population on mustard and gave higher yield.
- Inundative releases of parasitoids *Goniozus nephantidis* and *Brachymeria nosatoi*, against *Opisina arenosella* on coconut, coinciding the first release with the appearance of the pest, have proved effective.
- Adult release of *G. nephantidis* on trunks was as good as release on crown for the control of *O. arenosella* on coconut
- *Oryctes* baculovirus has been highly successful in reducing *Oryctes rhinoceros* populations in Kerala, Lakshadweep and Andaman Islands.
- *Cryptolaemus montrouzieri* has effectively suppressed *Planococcus citri* on citrus and grapes, *Pulvinaria psidii*, *Ferrisia virgata* on guava, *Maconellicoccus hirsutus* on grapes and *Rastrococcus iceryoides* on mango.

- Efficacy of *Trichogramma, Cryptolaemus, C. carnea,* *Ha*NPV and *Sl*NPV has been successfully demonstrated in Punjab, Andhra Pradesh, Karnataka, Maharashtra, Gujarat and Tamil Nadu.
- *Aphelinus mali* and several coccinellid predators were found effective against apple woolly aphid.
- San Jose scale parasitoids, *Encarsia perniciosi* and *Aphytis* sp., were well established in Jammu & Kashmir and Himachal Pradesh.
- *Trichogrammatoidea bactrae* and *Bt* were found effective against *Plutella xylostella*.
- Tomato fruit borer, *H. armigera* was effectively controlled by releases of *T. pretiosum* and *Ha*NPV.
- *Copidosoma koehleri* and *Bt* were found effective against potato tuber moth in country stores.

Mandate

Project Directorate of Biological Control, Bangalore

- Harness the natural resources to develop and promote biological control strategies for sustainable and eco-friendly pest management in agriculture and horticulture to enhance the profitability and welfare of the farming community.

AICRP on biological control of crop pests and weeds

- Promotion of biological control as a component of integrated pest and disease management in agricultural and horticultural crops for sustainable crop production
- Demonstration of usefulness of biocontrol in IPM in farmers' fields

Organisational set-up

With a view to fulfil the mandate effectively and efficiently, the Project Directorate is functioning with Biosystematics, Introduction and Quarantine Laboratory, Mass Production Laboratory, Pathology Laboratory, Entomophagous Insect Behaviour Laboratory, Biotechnology Laboratory and a Co-ordination, Documentation and Training Cell (Fig. 1).

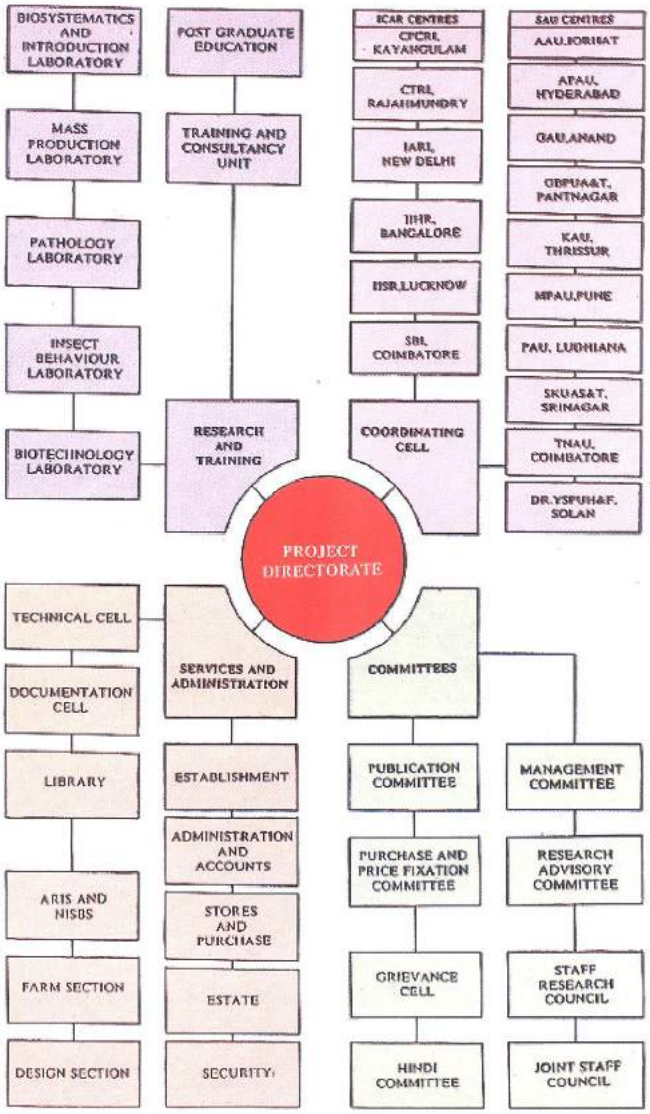
Financial statement (2004-05) (Rs.in lakhs)

Project Directorate of Biological Control, Bangalore

Head	Plan	Non-plan	Total
Pay & allowances	00.00	139.71	139.71
TA	03.00	02.40	05.40
Other charges including equipment	55.00	28.44	83.44
Information Technology	01.00	-	-
Works/petty works	131.00	21.10	152.10
Total	190.00	137.32	327.32

PROJECT DIRECTORATE OF BIOLOGICAL CONTROL
BANGALORE

Organisational Chart



AICRP Centres (ICAR share only)

Name of the centre	Amount sanctioned and expenditure (Rs.)
AAU, Jorhat	10,39,839
ANGRAU, Hyderabad	13,10,333
GAU, Anand	31,92,293
KAU, Thrissur`	08,53,000
MPKV, Pune	14,28,754
PAU, Ludhiana	21,55,372
SKUAS&T, Srinagar	21,19,231
TNAU, Coimbatore	13,16,441
YSPUH&F, Nauni, Solan	09,72,504
GBPUA&T, Pantnagar	02,92,000
Total	1,46,79,767

ICAR Institute-based centres (CPCRI, Kayangulam; CTRI, Rajahmundry; IARI, New Delhi; IIHR, Bangalore; IISR, Lucknow and SBI, Coimbatore) did not maintain separate budget accounts since the Project has been merged with Non-Plan.

Staff position

Category	Posts sanctioned up to 31-03-2004 *	Posts filled up to 31-03-2005	Vacant positions
PDBC, Bangalore			
Research Management	01	01	-
Scientific	25	22	3
Technical	18	18	-
Administrative	07	06	1
Supporting	06	6	-
Subtotal (a)	57	53	4
SAU-based Centres			
Scientific	21	21	-
Technical	31	31	-
Administrative	1	1	-
Subtotal (b)	53	53	-
ICAR Institute-based Centres			
Scientific	-	-	-
Technical	-	-	-
Subtotal (c)	-	-	-
Grand total (a+b+c)	110	106	4

5. RESEARCH ACHIEVEMENTS

BASIC RESEARCH

Project Directorate of Biological Control, Bangalore

(i) Biosystematic studies on predatory Coccinellidae

Two rare species, *Oenopia excellens* (Crotch) and *Protothea quadripunctata* (Mulsant), were recorded from northeastern India. Seventeen new synonymies were established.

Web site on the Coccinellidae of the Indian region

A web site on the Coccinellidae of the Indian subcontinent was developed (URL: www.angelfire.com/bug2/j_poorani/index.html). The site provides a checklist of the coccinellid fauna of the Indian subcontinent and features image galleries of common species encountered in the agroecosystems of the Indian region, their natural enemies and other assorted images and links to relevant sites.

Using the software Lucid Phoenix, a web-based dichotomous key to 10 common species of *Chilocorus* of the Indian region was constructed. The key is hosted at the following site:

http://www.lucidcentral.org/keys/phoenix/ChilocorusSpeciesOfIndia/IndianChilocorusSpecies.html

Fact sheets on common coccinellid species of the Indian Region

Fact sheets have been produced for 125 species of common coccinellids of the Indian region in html. The fact sheets provide information on nomenclature, diagnosis, geographic distribution, prey/associated habitat, seasonal occurrence, and selected references along with photographs and other illustrations.

(ii) Pictorial Guide to Insect Bioagents on CD

A CD entitled "A Pictorial Guide to Insect Natural Enemies in Biological Control" has been prepared for use by economic entomologists and students.

(iii) Introduction and studies on the exotic natural enemies of some crop pests and weeds

Import permits for natural enemies

Import permits for *Smicronyx lutulentus, Nephaspis bicolor, Ganaspidium nigrimanus* (=*G. utilis*), *Chrysocharis parksi, Delphastus pusillus, Telenomus triptus, T. ullyetti* and *Glabromicroplitis croceipes* were obtained from the Plant Protection Advisor to the Government of India.

Export of natural enemies

A shipment of *Zygogramma bicolorata* was sent to Sri Lanka for the biological suppression of parthenium. A shipment of *Sturmiopsis inferens* was exported to ICIPE, Nairobi, Kenya, for trials against *Chilo partellus.*

Monitoring the population of parasitoids of spiralling whitefly

The population of *Aleurodicus dispersus* and its parasitoids was monitored on guava, *Michelia* sp., *Cassia siamea* and *Bauhinea*. Parasitization by *Encarsia guadeloupae* was negligible from April to July. The parasitoid was more active from August till January and reduced thereafter. Highest per cent parasitisation (above 92.9 %) was recorded on *Cassia* during August, 2004.

Studies on *Trichogramma mwanzai*

A consignment of *Trichogramma* sp. nr. *mwanzai* Schulten & Feijen was received during April, 2004 and a pure culture was raised from these parasitised eggs. Till 31st March, 2005, the parasitioid had undergone more than thirty generations. The extent of parasitization of *Helicoverpa armigera* eggs glued to chickpea and pigeonpea leaves ranged from 3.3 to 6.7 and 5.0 to 32.5, respectively, with higher parasitism noticed on pigeonpea.

Studies on *Trichogramma brassicae*

A shipment of *Trichogramma brassicae* was received on 29-01-2005 and a pure culture was raised on the eggs of *Corcyra cephalonica*. The parasitoid has completed five generations. A part of the culture is maintained on the eggs of *Plutella xylostella*. The per cent parasitisation was 47.4 – 93.4 on *P. xylostella*.

Studies on *Eriborus trochanteratus*

A shipment of *Eriborus trochanteratus* adapted to *Opisina arenosella* was received from Sri Lanka on 4th February 2005. A pure culture raised on *Corcyra* larvae has established well in the laboratory and has to be tested on *O. arenosella*.

(iv) Rearing and evaluation of natural enemies with special reference to scelionid, braconid, ichneumonid and anthocorid groups

Rearing of *Spodoptera exigua*

Spodoptera exigua was successfully reared in the laboratory on a semi-synthetic diet developed for *S. litura* (Nagarkatti and Satyaprakash, 1972) for 7 generations. Each female laid 348-411 eggs (Mean - 384/female) with 8-50% hatching (mean - 27%). The per cent pupation was 71.8%, 62.0% and 15% during July-August, September-October and November-December, respectively. Incubation period was 3-4 days, larval period 13-14 days and pupal period 4-5 days. From December, there was a drastic reduction in hatching and pupation due to very low humidity. The fecundity ranged from 3 to 28 egg masses per 5 pairs. Egg laying ranged from 50 to 107.3 during the first five days of oviposition and a drastic reduction was observed from the 6th day (Fig. 1). The per cent hatching ranged 17-28 during the first 6 days and declined later.

Ovipositional preference of *H. armigera* on different chickpea varieties

The ovipositional preference of *H. armigera* on seven varieties of chickpea, *viz.*, JG74, L550, JSC6, JG315, ICCV2, Black Channa and JG130 was studied in free choice tests. The per cent egg laying was maximum on JSC6 and JG315 (19.14 and 17.86, respectively) (Fig. 2), but the values were not significantly different.

Shipping technique for *Telenomus remus*

A method was standardised for the shipment of parasitised cards of *Telenomus remus*. Polystyrene strips with slits were fixed to the sides of ventilated plastic boxes and the ends of each card were inserted into the slits. These boxes were used for shipments. Seven consignments of parasitised eggs of *Telenomus* (of different age and stored batches) were sent by courier to Kerala and the feedback indicated that the egg masses were intact upon receipt.

The parasitised egg cards of *Telenomus* were sent two, four and eight days after exposure. Another set of *Telenomus* cards was shipped after 2, 4, 6 and 8 days of storage. Except for two consignments, which reached after 5 days from the date of shipment, all the other consignments reached in 1-2 days. From the unstored cards, emergence occurred after the cards reached the

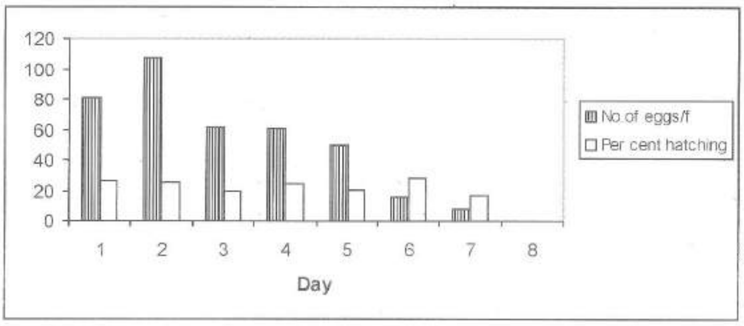


Fig. 1. Day-wise fecundity of *Spodoptera exigua*

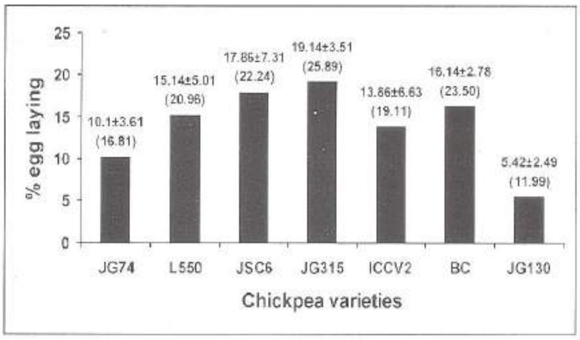


Fig. 2. Ovipositional preference of *H. armigera* on different chickpea varieties
(Figures in parentheses are angular transformed values (df=6,42; F=1.24; P=0.31; Non-significant)

destination in 9-10 days from the date of exposure as in the control. In the case of the stored batches, emergence occurred in 9-10 days, 11 days, 11-13 days and 16 days from the date of exposure in 2, 4, 6 and 8 day storage batches, respectively. These were also comparable to the control batches.

Production protocol for *Telenomus remus* (10 lakhs/month)

- Each *Spodoptera litura* egg mass has approximately 200 eggs
- Sex ratio of *T. remus* is generally balanced- 1:1.
- Two days before the due date of emergence of *T. remus*, segregate 5 patches of parasitised eggs per tube.
- 24 h after emergence of adults, expose 10 patches of eggs (0-1-day- old) into each tube.
- Allow to parasitise for 48 h, remove the exposed egg patch and again separate into 5 parasitised patches per tube.
- In 10-12 days, adults emerge from the parasitised egg patches.
- From one exposure, 2000 adults or 1000 females are expected to emerge.
- In order to obtain 10 lakh *Telenomus* per month, 500 exposures per month to be made, @ 125 per week and 20 per day.
- To reach this level of production, the host culture (*S. litura*) to be scaled up to obtain at least 220 egg patches per day.
- Optimum parasitoid: host egg ratio has been found to be 1:2, hence adults from one parasitised egg patch to be released for each egg mass of *Spodoptera* found in the field.

Cost of production of *T. remus*

Cost of production of one pupa of *S. litura* = Rs.0.79

100 pupae = Rs.79/-

58 female moths = Rs.79/-

Each female moth can lay approximately 1000 eggs or 5 good patches with 200 eggs in each patch.

For 250 egg patches (from 50 moths) = Rs.79/-

Cost of one egg patch = Rs.0.32

Cost of 100 egg patches = Rs.32/-

Ten egg patches for each exposure

Additional cost involved in making cards, feeding adults with honey, etc. for 10 exposures = Rs.5/-

Cost of 100 parasitised egg patches = Rs.37/-

Cost of 1 egg card of *Telenomus* with 10 parasitised egg patches = Rs.3.70

This does not include the cost of infrastructure & manpower. For the release of one lakh parasitised eggs per ha, 50 such cards are required, which would cost Rs. 200/-.

Production of *Campoletis chlorideae*

Production details for *Campoletis chlorideae* were worked out by utilizing large cages measuring 1.7 x 1.7 x 2.5'. The production details were worked out for two years, 2003-04 and 2004-05. The number of cocoons per female ranged from 2 to 8.5 during 2003-04 and 6.1 to 19.9 in 2004-05. The cocoon production was higher during September-January (Fig. 3).

Per cent parasitism ranged from 10.32 to 35.2 in the first year and 19.4 to 42.4 in the second year. In the first year, per cent parasitism was higher from September to December (23.98 to 35.2) and in the second year parasitism was more than 30% from November.

Per cent adult emergence ranged from 50 to 77.94 in the first year with a drastic reduction during February-March. In the second year, more than 50% emergence was observed almost round the year.

A humidity of 70-80% and temperature of 26-28°C were found optimum for increasing the production.

The production details at three parasitoid densities per cage – 5-8, 10-13 and 20-23 - are summarized in Table 1.

Performance of *Campoletis chlorideae* on *Bt* and non-*Bt* cotton

The per cent parasitism of *S. litura* larvae obtained on *Bt* and non-*Bt* cotton (var. MECH-162) was 29.27 and 17.04, respectively, and that of *Helicoverpa armigera* larvae, 4.31 and 3.22, respectively, indicating that the performance of *C. chlorideae* on *Bt* and non-*Bt* cotton was on par.

Biological parameters of *Orius tantillus* at different temperature regimes

Orius tantillus adults were maintained at four temperature regimes and their biological parameters studied (Table 3). Male and female longevity was maximum at 24°C and minimum at 30°C. Though the developmental time was shortest at 30°C, the adult longevity was reduced. Developmental time was prolonged at 20°C. The maximum progeny production was at 24° and 28°C, while it was drastically reduced at 20 and 30°C. Considering longevity and progeny production, 24°C was the optimum temperature (Table 2).

Evaluation of *Blaptostethus pallescens* on *Sitotroga cerealella*

In preliminary trials to evaluate the efficacy of *Blaptostethus pallescens* nymphs against *Sitotroga cerealella* eggs infesting rice, *Sitotroga* adult emergence in the treatment batches was 8% as compared to 52.3% in the control. The predator could move up to a depth of 13 cm.

Evaluation of *Blaptostethus pallescens* on *H. armigera* eggs and larvae

The feeding potential of *B. pallescens* nymph, adult male and adult female on *H. armigera* eggs was 2.7, 8.1 and 14 per day, respectively. When the anthocorids were released, only 26.7% hatching was observed compared to 79.4% hatching in control. At a ratio of 50 eggs: 5 nymphs, after 4 days, only 7.5% hatching was observed in treatment and 60% in control. The predator could also feed on young larvae of *H. armigera*.

(v) Development of novel mass production, storage and packing techniques for *Cryptolaemus montrouzieri*

A novel method of mass production of *Cryptolaemus montrouzieri* using *Sitotroga cerealella* eggs is being developed.

Biology of *Sitotroga cerealella* on different grain media

Biology of *S. cerealella* was studied on paddy, unhusked wheat, barley and maize. The egg, larval and pupal periods were 5.0-8.1, 15.5-24.0, 7.5-10 days, respectively, on these media. Total average life cycle

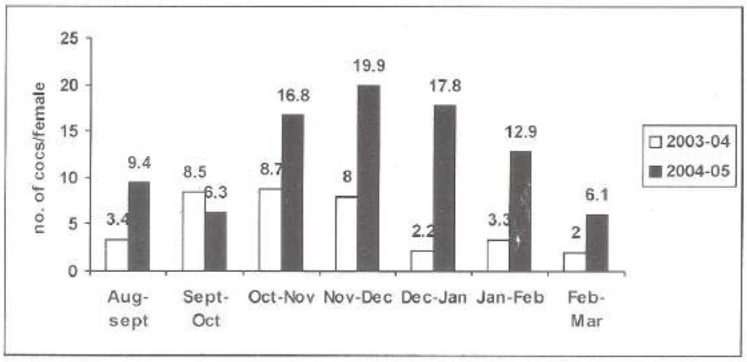


Fig. 3. Number of cocoons/female of *Campoletis chlorideae* in different months

ranged from 36.66 to 37.00 days. Maximum average fecundity was obtained on maize (138.8 eggs/female), followed by paddy (122.68 egg/female). The average total life cycle was completed faster in October (32.58 days), and greatly plolonged in January (41.4 days).

Mass multiplication of *Sitotroga cerealella* on unhusked wheat

Sitotroga cerealella was reared on a large scale on unhusked wheat in the laboratory for 9 generations. The moths started emerging after 30 days of infestation. The life cycle of the female was shorter than male. The weight of the female pupa was 4.54 mg and that of the male was 3.09 mg. The adult longevity ranged from 6.32 to 7.87 days. Fecundity was 108-115 eggs per female. About 10 cc eggs/week was obtained (3 cc on alternate days) by infesting 1kg grains with 1cc of eggs on alternate days. The egg, larval and pupal mortality was 19.35-26.20, 53.22-54.50 and 8.65-10.17%, respectively. A culture started with 100 eggs is likely to yield 30-35 adults.

Oviposition preference of *S. cerealella* on different substrates

Absorbent cotton, black muslin cloth and black paper (smooth and rough) were evaluated as substrates for the oviposition of *S. cerealella*. Maximum eggs were laid on cotton pad followed by black paper. Eggs laid on black muslin cloth folds were sparse and there was heavy scale accumulation. The problem of egg entanglement in cotton and scale removal on rough black paper was eliminated in smooth black paper accordion, which is a good oviposition substrate for *S. cerealella*.

Table 1. Cocoon and female progeny production at different parasitoid densities per cage

No. of female parasitoids per cage	Cocoon harvest per cage	Cocoons/ female	No. of females per cage	No. of females/ female
5-8	72.0	14.4	15	5
10-13	73.3	5.2	20	2
20-23	115.0	6.0	33	2

Table 2. Biological parameters of *Orius tantillus* at different temperature regimes

Temp. (°C)	Male Longevity	Female Longevity (days)	Male Devpt. (days)	Female Devpt. (days)	Progeny/ female (days)
20	14.7	23.3	27.1	29.9	13.2
28.8	24	32.3	36.2	21.0	20.3
28	19.0	24.1	18.0	17.9	26.2
30	9.7	16.5	14.2	13.6	13.8

Biology of *Cryptolaemus montrouzieri* on *Sitotroga cerealella* eggs

Seven generations of *C. montrouzieri* were reared on *S. cerealella* eggs. Three cc eggs of *S. cerealella* were used for rearing 10 larvae of *C. montrouzieri* up to pupal stage. A total of 185 larvae was reared in the first five generations. The pupation was 67.57% and adult emergence from these pupae was 84%. The average total survival in the first five generations was 56.75%. The average larval and pupal periods were 13.69 and 7.36 days, respectively, whereas adult longevity was 52.02 days. Average adult weight was 8.66 mg while female population was 35.61%.

(vi) Mass production and evaluation of *Micromus* sp.

Weekly surveys were conducted in sugarcane growing areas of Karnataka during 2004-2005, besides a few surveys in Andhra Pradesh, Tamil Nadu and Maharashtra. Several immature stages of hemerobiids were collected from these areas. The species was identified as *Micromus igorotus* Banks.

Studies on the biology of *Micromus igorotus*

The biology of *M. igorotus* was studied on *C. lanigera*, *Pseudoregma bambusicola*, *Aphis craccivora* and *A. spiraecola*. Adult longevity, pre-oviposition and pupal periods were extended when the adults and larvae of *M. igorotus* were reared on the laboratory host, *A. craccivora* (Table 3).

The larvae of *M. igorotus* could not survive on the eggs of *C. cephalonica* and *S. cerealella* and the nymphs of *Maconellicoccus hirsutus*, *Planococcus citri* and *Ferrisia virgata*.

Field evaluation of lab-reared *Micromus igorotus*

Laboratory reared *M. igorotus* was evaluated in the field at Deshahalli, Maddur, in a 0.25 ha sugarcane plot. One thousand eggs of *M. igorotus* were released in two instalments at weekly intervals. First release was made in the first week of December, when the initial population density was 62.5 aphids/clump. The aphid population came down to 45.6 per clump a week after release. However it increased and reached its initial density (60.1 aphids/clump) in the following week, when the second release was made. The population remained low in the following two weeks (43.2 and 38.8 aphids/ clump). However, the aphid population had its second peak in the next week (59.9 aphids/clump) (Fig. 4). Even after the release the average population of the predator never reached even up to one larva/clump, apparently due to the presence of soldier aphids.

Survey for the natural enemies of *Ceratovacuna lanigera*

In weekly surveys in 12 villages of Maddur taluk of Mandya district (Karnataka), *Dipha aphidivora*, *Micromus*

Table 3. Biology of *Micromus igorotus* on various aphid species

Aphid species	Biological parameters (days)				
	Adult longevity	Pre-oviposition period	Egg period	Larval period	Pupal period
A. craccivora	25.72	5.21	4.00	6.83	8.06
P. bambusicola	28.50	4.81	3.55	7.23	6.46
A. spiraecola	19.83	6.28	4.00	7.50	7.16
C. lanigera	29.51	4.12	3.67	6.78	5.76

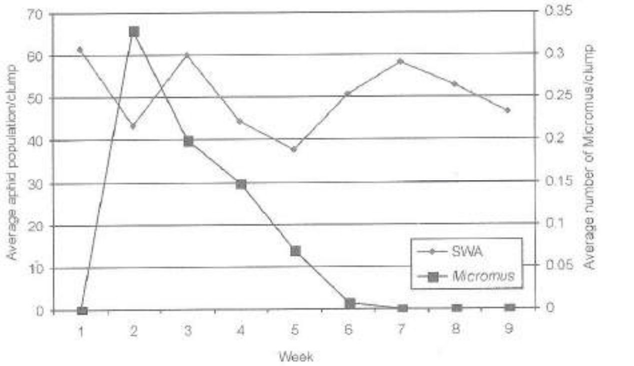


Fig. 4. Field evaluation of laboratory reared *Micromus igorotus* at Maddur

sp., *Mallada desjardinsi* (= *Mallada boninensis*), *Spalgis epeus*, *C. montrouzieri* and *Synonycha grandis* were recorded. These predators occurred in small numbers and only once in the crop season (January, 2005).

Adults emerging from the field-collected pupae of *M. desjardinsi* were released inside a cloth-walled cage (30x30x30cm) on a bouquet of sugarcane leaves infested with *C. lanigera*. The fecundity was 154.75 eggs/female. The larvae, however, could not survive on *C. lanigera* in the laboratory.

In and around Mandya district, *C. lanigera* populations peaked in October-December, 2004. The populations of *D. aphidivora* did not always peak with *C. lanigera* populations. *Synonycha grandis* was noticed occurring naturally, though in very low numbers.

In Tahttiguppe area of Bangalore rural, two syrphids, *Episyrphus balteatus* and *Dideopsis aegrota*, were recorded. *Eupeodes confrater* was collected in large numbers. Efforts made to rear this species failed.

Rearing of *Anisolemnia dilatata* and *Dipha aphidivora* on *Aphis craccivora*

Attempts were made to rear *A. dilatata* and *D. aphidivora* on alternative prey. These could be reared on laboratory reared *A. craccivora*. High mortality was noticed in *A. dilatata*, particularly during the egg (57.6%) and first instar (23.0%). *D. aphidivora*, however, developed successfully (Table 4), though adult longevity and the rate of multiplication were much lower on *A. craccivora*.

Table 4. Developmental time of *Dipha aphidivora* on *Ceratovacuna lanigera* and *Aphis craccivora*

Stage	*C .lanigera* (days)	*A. craccivora* (days)
Egg	3.4	5.1
Larva	11.4	12.3
Pupa	7.1	8.2
Adult	6.2	3.8
Total	28.1	29.4

Oviposition and feeding preference of *Dipha aphidivora*

Dipha aphidivora laid more eggs on paper of rough texture (507) compared to polyethylene (122) or cloth (39). When fed solely on a diet of nymphs, alates or sterile soldiers of *C. lanigera*, *D. aphidivora* failed to develop on the soldiers (Table 5). The developmental period was fastest on nymphs. Adult longevity was also higher when larvae were fed on nymphs (Plate 3).

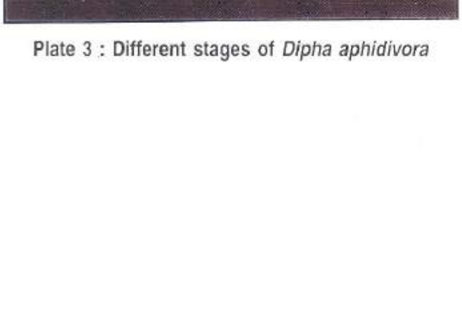


Plate 3 : Different stages of *Dipha aphidivora*

Table 5. Development of *Dipha aphidivora* on different castes of *Ceratovacuna lanigera*

Castes	Period surviving (days) as		
	Larvae	Pupae	Adults
Alates	13	8	2
Soldiers	1	-	-
Nymphs	9	8	3

(viii) Herbivore Induced Plant Synomones and their utilization in enhancement of the efficiency of natural enemies

Volatile profile of *Bt* and non-*Bt* cotton with and without imidacloprid treatment

The volatiles trapped from the bolls of *Bt* and non-*Bt* cotton with and without imidacloprid treatment were identified using GCMS system. Maximum compounds (20) were identified from non-*Bt* cotton, followed by *Bt* with imidacloprid and non-*Bt* with imidacloprid (14 each). Minimum compounds (11) were identified from *Bt* cotton. Non-*Bt* cotton contained Alpha-pinene, undecane, decane and eicosane, which were absent in Bt cotton and other combinations. Octadecane was found only in *Bt* cotton. However, quantitative changes were observed in some compounds like dodecane, limonene and linalool.

Volatile profile of male flowers of different varieties/hybrids of maize

The volatiles from fifteen varieties/ hybrids of maize, namely, FLDK-973, Kesari King, Deccan corn, Ganga Kaveri 3014, FLDK-984, Shubham Aditya, Seedtek-740, Seedtek-Suraj, Seedtek Kanak, ITC Advanta 9714, American Seed Popcorn, Pioneer Hybrid corn, PMH-2255, Godavari Shubham and Sumitra seeds were trapped, concentrated and identified using GCMS. Linalool–L was present in all the 15 varieties/hybrids (4.23 to 78.44%, highest from Variety Godavari Shubham). Limonene was identified from 14 varieties (0.05% to 87.61%, the highest from American Seed Popcorn).

Pentanol was found in 12 varieties (0.01 to 64.24%, the highest in Kesari King). Maximum volatile diversity was found in American Popcorn (19), followed by Seedtek Suraj (18).

Green leaf volatiles of different varieties/hybrids of maize

Green leaf volatiles trapped from different varieties/ hybrids of maize were identified. Maximum compounds were identified from the green leaves of variety Deccan (17), followed by ITC Advanta (10) and Pioneer (9). The most common compounds were 1,2-Benzenedicarboxylic acid, heptadecane, pentadecane, dodecane and phenol, 2,4-bis.

Volatiles trapped from buds of *Tagetes erecta*

Seventeen volatile compounds were identified from marigold buds. The most common compounds were cis-ocimene, beta-ocimene, cis-bisabolene, beta-bisabolene, sabinene, myrcene, methyl chavicol, alpha-terpiniole and phenol 2, 4-bis.

EAG response of *Chrysoperla carnea* to plant volatiles

Thirteen plant volatile compounds identified from maize, cotton, and tomato were evaluated through EAG studies for their cue to *C. carnea*. Highest response of *C. carnea* was noticed towards linalool (-1.306mv), followed by alpha-pinene (-1.214mv), n-tetradecane (-1.091), methyl salicylate (-1.032mv) and alpha-terpinene (-0.937mv). The best two compounds, namely, linalool and alpha-pinene, along with myrcene and their combination in 1:1:1 ratio were re-evaluated in two concentrations. Combination of these in equal proportion at full and half concentration of myrcene received maximum response from *C. carnea* females.

Olfactometric response of *T. chilonis* to plant volatiles under dual choice condition

Olfactometric response of *T. chilonis* to linalool, limonene, alpha-pinene, myrcene, methyle salicylate and combination of linalool+ limonene + M. salicylate was evaluated under dual-choice condition. Maximum response was recorded towards myrcene (58.66%), which was on par with methyl salicylate (48.66%), alpha-pinene (47.99%), and limonene (43.33%).

Olfactometric response of *T. chilonis* to linalool, myrcene and alpha-pinene and their combination in equal proportions was studied in a Y-tube olfactometer under dual choice condition. Significantly highest net response was observed towards linalool (27.50%), followed by myrcene (21.25%), which was on par with their combination (17.50).

Thirteen plant volatile compounds and some combinations were evaluated for their cue to *T.chilonis*. Maximum response was given to a combination of α-Pinene+linalool + a-terpinene (2:2:1) (40.00%), followed by α-Pinene+linalool+ α-terpinene (1:1:1) (40.00%) and linalool alone.

Olfactometric response of *T. chilonis* to plant volatiles under multiple choice condition

Under multiple choice-olfactometeric study, *T. chilonis* gave maximum relative response to linalool (18.66%), followed by limonene, alpha-pinene and myrcene. Combination of linalool, limonene and methyl salicylate was less attractive. In another bioassay on the response of *T. chilonis* to alpha-pinene, linalool, myrcene and their combination, maximum response was to linalool (67.70%), followed by myrcene (60.00%).

Olfactometric response of *T. chilonis* to volatiles of male and female flowers of maize

Eighteen varieties/hybrids of maize were evaluated for the response of *T. chilonis* to the volatiles released by their male and female flowers in a Y-tube olfactometer. *T. chilonis* gave maximum response to the female flowers of Deccan (94.87%), followed by ITC Advanta, Pioneer hybrid (77.76%) and Ganga Kaveri 3014 (73.84%). Among male flowers, maximum response was to Pioneer hybrid (71.41%), followed by ITC Advanta (61.08%) and Ganga Kaveri (46.15%).

Olfactometric net response of *C. carnea* females to plant volatiles

Chrysoperla carnea females were given chemical cues of fourteen plant volatiles in a Y-tube olfactometer and evaluated for their net response. Mean net response was maximum to linalool (23.33%), followed by alpha-pinene (16.66%), (IS)-(-)α-pinene (16.66%), n-heneicosane (16.66%) and n-decyl aldehyde (13.33%). However, statistically all these cues were on par. There was no response to hexacosane.

The best treatments (volatiles), *viz.*, alpha-pinene, linalool, myrcene and their combination in 1:1:1 ratio, were re-evaluated on *C. carnea* females in a dual test. Again linalool was found most attractive (net response value 66.66%), followed by alpha-pinene (50.00%). Myrcene alone was the least attractive (36.33) and on par with combination (37.58).

Response of *C. carnea* to different volatiles under multiple choice

Five plant volatiles, *viz.*, linalool, limonene, α-pinene, myrcene, methyl salicylate and linalool + limonene + m. salicylate (1:1:1) were evaluated against *C. carnea* females under multiple-choice condition. Maximum relative response was shown towards linalool (18.66%), followed by limonene (15.99%), and α-Pinene (15.99%). Methyl salicylate (9.33) and combinations (9.99) were the least attractive and on par.

(ix) Host-derived kairomones to enhance the efficiency of natural enemies

In a field trial at Raichur (Karnataka), the per cent damaged bolls in the kairomone treated plants was less compared to treated control (natural released enemies without kairomone treatment) and untreated control plots. Higher number of good open bolls (22.1) and least number of bad opened bolls (8.2) were recorded in kairomone treated plots. Highest yield was recorded in the kairomone treated plots (22.44 q/ha) (Table 6).

Field evaluation of kairomones as reinforcing agents for trichogrammatids on cotton

A field trial was conducted at Raichur (UAS-D) on the use of kairomones as reinforcing agents for *T. chilonis*. There was a definite increase in parasitization in the treated plot over the treated control. However, the recovery was found to decrease over a period of time (Table 7).

Table. 7. Recovery of *Trichogramma chilonis* from kairomone-treated experimental plot

Recovery	Per cent eggs parasitized	
	Treated plot	Treated control
1	34	23
2	37	28
3	24	16
4	18	11

The pest incidence was lower in the kairomone-treated plot compared to treated control and untreated plots. The number of good open bolls (20.12) and yield were higher in the treated plot (18.6 q/ha) compared to treated control (16.9 q/ha) and untreated plots (12.2 q/ha). The number of bad open bolls per plant was higher in the untreated plot (28.2) followed by treated control (10.3). The kairomone-treated plot recorded the lowest number of bad opened bolls (6.84).

Table 6. Incidence of bollworms and yield in kairomone-treated cotton

Parameter	Treated Plot	Treated control	Untreated
Fruiting bodies damaged (%)	21.34	26.84	48.44
Good open bolls per plant	22.12	18.12	11.44
Bad open bolls per plant	8.2	12.22	26.48
Yield (Q/ha)	22.44	20.12	13.15

Mass priming of *T. chilonis* with kairomones

Among the unsaturated hydrocarbons tested as mass priming agents to increase the searching efficiency of *T. chilonis*, nonacosane recorded higher parasitization (16.8 %), followed by hexacosane (13.6 %). The control recorded lowest parasitization (3.8 %).

Development of kairomonal formulations with combination of linalool and unsaturated hydrocarbons

Linalool, a compound from cotton plants, was found to be attractive to most of the entomophages, recording higher parasitization at 0.1 and 0.2%. Nonacosane in combination with 0.2% linalool recorded highest parasitization compared to other compounds (Table 8).

Table 8. Parasitization by *T. chilonis* in different combinations of linalool and unsaturated hydrocarbons (0.1%)

Compound	Per cent parasitization by *T. chilonis* at different concentrations (%) of linalool		
	0.1	0.2	0.3
Tricosane	25.0	27.2	0.0
Pentacosane	28.0	24.4	0.0
Docosane	27.6	24.8	0.0
Nonacosane	25.6	31.6	2.0
Hexacosane	23.2	24.0	0.8
Control	14.0	16.4	0.0
CD (P=0.05)	4.6		

(x) Development and evaluation of improved strains of trichogrammatids

Evaluation of *Trichogramma chilonis* and *Trichogramma embryophagum* against *Opisina arenosella* on coconut

Release of either *T. chilonis* or *T. embryophagum* at 1000 wasps/palm effectively suppressed *O. arenosella* on coconut palms. The mean per cent reduction in larval population was 75.6% in *T. chilonis* and 88.8% in *T. embryophagum* (Table 9).

Testing of trichogrammatids against *Earias vittella* on okra

Based on per cent parasitism and emergence from *E. vittella* eggs, *T. achaeae* (47.6 and 38.4%), *T. chilonis* (43.5 and 40.2%), *T. embryophagum* (33.9 and 39.6%) and *T. brasiliense* (40.1 and 30.3%), respectively, were the most suitable species. Though

Table 9. Efficacy of *Trichogramma* spp. against *Opisina arenosella* larval population on coconut in Bangalore

Treatments	1st generation				Mean(T)*
	Release rate @ parasitised eggs / palm				
	1000	2000	3000	4000	
T. chilonis	0.30	0.10	0.30	0.20	0.22c
T. embryophagum	0.10	0.10	0.10	0.10	0.10b
Untreated control	0.90	0.90	0.90	0.90	0.90a
Mean (RR)	0.43	0.36	0.43	0.43	
	T	RR	T x RR		
CD (P=0.05)	0.16	NS	NS		

T. dendrolimi parasitised 47.6% eggs, adult emergence was very poor (1.3%). In general, sex ratio was female-biased.

Effect of photoperiod on parasitizing efficiency of trichogrammatids

The data on effect of photoperiod (14L: 10D, 12L: 12D and 8L: 16D) and temperature of 25±1°C on the parasitizing efficiency of certain trichogrammatids revealed that *T. chilonis* exhibited greater response to changing photoperiod (Table 10).

Table 10. Effect of photoperiod on the efficiency of parasitization of trichogrammatids

Species	Per cent parasitization in		
	14L:10D	12L:12D	8L:16D
T. japonicum	76.0	69.0	5.0
T. chilonis	66.0	64.0	84.0
Tr. bactrae	55.0	64.0	54.0
T. pretiosum	3.0	56.0	5.0

Storage studies with *Corcyra cephalonica* eggs and *T. chilonis* parasitised eggs at low temperature

A modified atmosphere packing enhancing the storability of *Corcyra* eggs parasitized by *Trichogramma* to 42 days has been developed. This technique enhanced the shelf life of *C. cephalonica* eggs by 3-4 fold as compared to the traditional method (Table 11).

Efficacy of various release methods on parasitising efficiency of *T. chilonis*

The efficacy of various release methods on the parasitising efficiency of *T. chilonis* was studied in terms of time taken for release and per cent emergence (Table 12). The per cent emergence from various treatments was significantly higher in traditional techniques like adult and Tricho-bit releases, and also in some of the newer techniques like Tricho capsule and loose eggs without carrier (95.0 to 100.0%). However, when loose eggs were mixed with a solid carrier or aqueous solution, the emergence was reduced (40.5 to 57.1%).

Maximum parasitisation was obtained when loose eggs mixed with vermiculite were used (76.7%) and it

Table 11. Effect of storage of *Corcyra* eggs on parasitization by *Trichogramma* and its emergence

Storage (days)	% parasitism		% emergence	
	New method	Old method	New method	Old method
7	100.0	100.0	95.0	95.0
14	100.0	50.0	95.0	95.0
21	95.0	40.0	95.0	75.0
28	90.0	5.0	90.0	75.0
35	90.0	0.0	90.0	75.0
42	70.0	0.0	85.0	75.0
49	30.0	0.0	70.0	50.0
56	30.0	0.0	24.7	16.0
63	20.0	0.0	11.6	-
70	10.0	0.0	6.4	-

Table 12. Comparative efficacy of different techniques of release of *Trichogramma chilonis*

Release of	Time taken (in minutes)	Emergence (%)
Adults	5.0[b]	100.0[a]
Tricho bits	2.3[d]	95.0[a]
Tricho capsules	6.4[a]	95.7[a]
Loose eggs	3.2[c]	95.0[a]
Loose eggs in water	1.5[e]	50.0[c]
Loose eggs in Tween 80 (0.1%)	3.4[c]	52.4[c]
Loose eggs in agar solution (1%)	1.0[f]	46.9[d]
Loose eggs with talc	1.0[f]	40.5[e]
Loose eggs with semolina	1.1[f]	57.1[b]
Loose eggs with vermiculite	1.3[e]	57.1[b]

Means followed by similar letters are not different statistically (P=0.05).

was on par with adult release (65.9%) and loose eggs mixed with semolina (61.3%), but significantly higher than other treatments (P = 0.05%). Amongst the treatments with aqueous carriers, spraying of loose parasitised eggs in agar solution recorded high parasitisation (55.3%) compared to other treatments where loose eggs were mixed with soap solution (46.7%) or water (33.4%). The results indicate that it is possible to develop better alternative methods of *Trichogramma* release both in solid and aqueous carriers.

Biochemical characterization of *Trichogramma* strains

Protein content was higher in the heat tolerant *Trichogramma* strain (24.8 mg) compared to laboratory strain (17.8 mg/100 ml of sample) (Table 13), indicating that more protein accumulation occurred due to heat treatment, making them survive at a higher temperature. Glutathion S-transferase activity of various insecticide-tolerant strains (without exposure to respective insecticides) was greater compared to the laboratory strain.

(xi) Development and formulation of artificial diets for anthocorids

Development of *Orius tantillus* on artificial diet, prey insects and plant materials

Development of *Orius tantillus* nymphs (2-day-old) was studied on ten different diets comprising beef liver-based lyophilized artificial diets, prey insects, maize pollen and cut beans in various combinations. Total developmental time from egg to adult averaged 10.0-15.3

Table 13. Protein content and GST activity of various strains

Strains	Protein content (mg / 100 ml of sample)	Specific activity of GST (i mol CDNB conjated / mg of protein / minute)			
		Parent generation	3rd generation	5th generation	7th generation
Heat tolerant	24.8	-	-	-	-
Laboratory strain	17.8	130.2	-	-	-
Endosulfan tolerant	-	230.8	365	236.5	378.6
Monocrotophos tolerant	-	245.5	264.	239.9	248.5
Fenvalerate tolerant	-	215.3	235.5	223.3	304.8
Multiple-insecticide tolerant	-	239.2	185.6	373.0	-

Table 14. Developmental time, survival and per cent female progeny of *O. tantillus* on different diets

Diet	Duration of nymphal stage (Days)	Survival (%)	Female (%)
Diet 1 (Maize pollen)	11.6^{a}	58.2^{b}	20.0^{b}
Diet 2 (Bean alone)	15.3^{c}	14.3^{d}	0^{c}
Diet 3 (Artificial diet alone)	12.0^{b}	31.1^{c}	0^{c}
Diet 4 (Maize pollen + beans)	11.0^{a}	62.3^{b}	18.0^{c}
Diet 5 (Artificial diet + beans)	11.1^{a}	69.0^{a}	23.0^{b}
Diet 6 (Artificial diet + maize pollen + beans)	10.5^{a}	74.0^{a}	26.0^{b}
Diet 7 (*Corcyra* eggs + beans)	10.8^{a}	75.0^{a}	38.0^{a}
Diet 8 (*Sitotroga* eggs + beans)	10.0^{a}	76.6^{a}	43.0^{a}
Diet 9 (Thrips + beans)	11.3^{a}	65.5^{b}	35.0^{a}
Diet 10 (Water alone)	0	0^{e}0^{c}	

Means followed by similar letters are not different statistically (P=0.05).

days (Table 14). Rearing on beans alone (Diet 2) significantly extended the developmental period compared to that on other diets. Survival on lepidopteran eggs (Diet 7 & Diet 8) was similar but was higher on the natural prey *Thrips palmi* (Diet 9). Among the diet combinations, artificial diet + maize pollen + beans was found to be effective for rearing *O. tantillus* (Fig. 5). Natural and artificial diets when offered individually resulted in comparatively lower nymphal survival and per cent female emergence, than when offered in combination with maize pollen and beans. On beef liver-based artificial diet enriched with cholesterol+maize pollen+beans, the nymphal period, adult formation and longevity were 15.6 days, 67 % and 16.9 days, respectively. Artificial diet-reared predators could lay eggs.

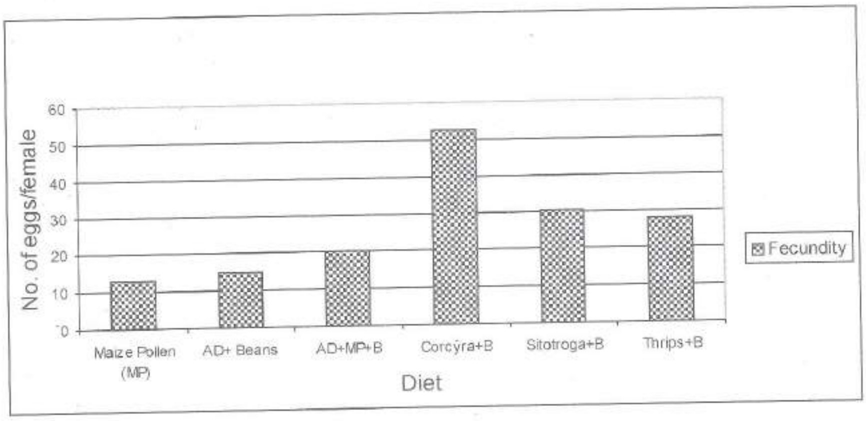


Fig. 5. Fecundity of *O. tantillus* reared on different diets

Development of artificial diets for the rearing of *Dipha aphidivora* and *M. igorotus*

An attempt was made to develop an artificial diet for the rearing of *D. aphidivora*. Three-to-four-day-old *D. aphidivora* larvae were reared on artificial diets (AD I and II). On AD I, 45% of the larvae reached the pupal stage, with 40% adult emergence. The adult moth lived for 7 days and laid fertile eggs. Mean pupal and adult weight was 1.32mg and 0.58mg, respectively. The mean survival and adult emergence on AD II was 45%. The pupal and adult weight and longevity of the adult moths were 1.32mg, 0.64mg and 7 days, respectively. The females could lay eggs. These two artificial diets were found to be promising.

Larvae of *Micromus* sp. were not able to complete the development on artificial diets.

Rearing of *Chrysoperla carnea* using artificial diet

One-day-old larvae of *C carnea* were reared on artificial diet from F32 to F38 generations and the mean per cent pupation and adult emergence were 87.0% and 84.8%, respectively. Fecundity was 337 eggs/female. Newly hatched larvae were reared on artificial diet from F29 to F35 generations and the pupation, adult emergence and fecundity were 86.5%, 84.5% & and 324.8 eggs/female, respectively. The same parameters when reared on *Corcyra* were 87.0%, 85% and 348.8 eggs/female (F28 to F34 generations), respectively. There were no significant differences in the biological attributes of *C. carnea* when reared on diet and on *Corcyra* (Fig. 6). A patent has been filed for this artificial diet.

(xii) Development and evaluation of artificial diets for *Opisina arenosella* and *Plutella xylostella* and studies on host-parasitoid relationship

Evaluation of artificial diets for *Opisina arenosella*

The diet with toddy palm leaf powder in combination with defatted soya and kabuligram was most suitable for the development of *O. arenosella* among the diets evaluated. The artificial diet was refined to improve the larval survival, per cent pupation and fecundity. Significant differences were observed between *O. arenosella* reared on natural (coconut leaves) and artificial diets with respect to the above attributes (Table 15). The shelf life of the artificial diet at room temperature (25-27°C) was 20-22 days. The cost of rearing a pupa on the artificial diet based on per cent pupation (73.2) was Rs. 0.80, while on the natural diet, the cost was Rs. 0.71 (89.2% pupation). Artificial diet stored at 5°C for 20 days provided 58.6 % pupation.

The parasitoids, *Goniozus nephantidis*, *Brachymeria nosatoi* and *B. nephantidis* successfully multiplied on artificial - diet reared on *O. arenosella* (Table - 16)

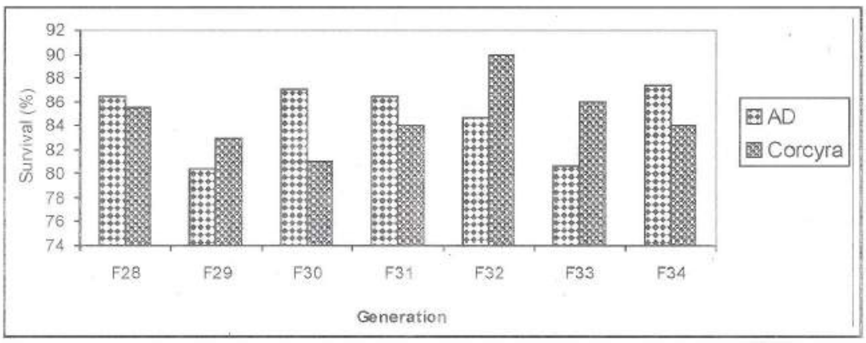


Fig. 6. Comparative survival of *C. carnea* reared *in vitro* and *in vivo*

Table 15. Development of *Opisina arenosella* on artificial and natural diets

Biological attributes	Tp +Ds + Kbg	Toddy palm leaf	Coconut leaf
Larval period (days)*	38.2	36.4	38.2
Pupal period (days)*	9.6	8.4	8.62
Pupation (%)	73.2[b]	89.2[a]	87.6[a]
Adult emergence (%)	66.2[b]	85.6[a]	83.4[a]
Fecundity (number of eggs per female)	102.2[a]	128.2[c]	114.2[b]

Means (n=26 generations) followed by the same letters in horizontal columns are not significantly different.

* Differences between the means are not significant statistically (P=0.01).

TP + Ds + Kbg = Toddy palm leaf powder + defatted soya + Kabuligram

Table 16. Development of *Goniozus nephantidis* and *Brachymeria nephantidis /B. nosatoi* on *O. arenosella* reared on artificial and natural diet

Biological attributes	Artificial diet reared host larvae	Host plant reared larvae
G. nephantidis		
Total developmental period (days)	14.2	12.2
Number emerged/larva	6.1	8.4
Adult longevity (days)	52.2	60.2
Number of larvae parasitised during life time	12.2	15.4
B. nephantidis (*B. nosatoi*)		
Total developmental period (days)	16.1 16.0)	15.6 (16.2)
Adult longevity (days)	45.4 (49.4)	60 (62.0)
Per cent parasitization	85.2 (81.4)	93.0 (88.4)

Figures in parentheses correspond to *B. nosatoi*. Mean of 23 generations

Ovipositional response

When old larval galleries of *O. arenosella* with frass were used as a substrate for oviposition, the fecundity, per cent hatch and larval survival were significantly higher (128.6, 94.0 and 92.0, respectively) than those on coconut leaf wrapped with cotton (102.4, 89.2 and 76.6, respectively).

Evaluation of artificial diet for *Plutella xylostella*

Defatted soya with cabbage leaf powder was more suitable than the other diets evaluated. The soya-based diet was further refined to improve the biological parametres. On the artificial diet, an adult emergence of 68.4 per cent and fecundity of 78.2 were recorded (Table 17), while on natural diet (mustard seedlings) 90.2 and 112 per cent, respectively, were recorded. The developmental period was prolonged on artificial diet and significant differences were observed between the artificial and natural diet reared hosts.

The shelf life of the soya-based diet at room temperature (25-27°C) was 18 days. The cost of rearing a pupa on the artificial diet excluding the cost of labour and permanent items was Re. 0.24 based on the average per cent pupation of 60.6. On mustard seedlings, it was

Table 17. Development of *Plutella xylostella* on artificial diet and natural host

Diet	Biological parameters				
	Larval period (days)	Pupal period(days)	Pupation(%)	Adult emergence(%)	Fecundity
Soya based diet	10.8	7.6	60.6	58.4	78.2
Control (Mustard seedlings)	8.8	5.2	88.6	82.2	112.4

Means (n=27 generations) are not significantly different (P=0.05).

Re. 0.17 per pupa considering 88.6 per cent pupation. When reared on artificial diet stored at 5°C for 15 days, 54.2 % pupation of *P. xylostella* was recorded.

Ovipositional response of *P. xylostella*

Aluminium foil dipped in cabbage leaf extract when used as a substrate for oviposition resulted in lower fecundity (89.6), but higher egg hatching (86.6%) and larval survival (89.2%) compared to cabbage leaf (126.4, 92.0 and 94.2, respectively).

Development of *Cotesia plutellae* on host reared on artificial diet

The developmental period of the parasitoid did not differ on natural and artificial diet-reared hosts. However, significant differences were observed in the per centage parasitisation and adult longevity of the parasitoids reared on artificial diet (78.4% and 8.12 days, respectively) and natural diet reared hosts (92.6 % and 12.4 days, respectively).

(xiii) Development and use of insect viruses for the management of major pest complex of cruciferous crops

Host-pathogen relationship

Crocidolomia binotalis NPV at varying concentrations (10^5 to 10^9 POBs/ml) could cause 33.3 to 90% mortality of late second instar larvae and 70 to 80% mortality of third and fourth instar larvae, when incubated for 4-6 days.

CbNPV was not found infective to *Helicoverpa armigera, Spodoptera litura, Spodoptera exigua, P. xylostella, Hellula undalis, Trichoplusia ni, Chilo partellus, Galleria mellonella* and *Corcyra cephalonica* at 1×10^6 POBs.

Safety of *C. binotalis* NPV

Crocidolomia binotalis NPV at 1×10^6 POBs /ml was found safe to *C. carnea* and *C. montrouzieri*. It was also found to be safe to the 2nd instar larvae of mulberry silkworm.

(xiv) Evaluation of adjuvants for NPV for management of *Helicoverpa armigera* in tomato

Pot culture experiments were conducted to study the effect of different adjuvants such as starch and crude sugar in different combinations on the persistence of *Ha*NPV tomato plants (Table 18). Starch (1%) along with crude sugar (10%) gave a maximum mortality of 87.55 per cent on the day of commencement of the experiment (zero day). This treatment was significantly superior to other treatments on the first three days. This was followed by the treatments '0.5 % starch + 10% crude sugar' and '10 % crude sugar only' where the larval mortalities were 75.00 and 73 per cent, respectively. On the fourth day there was no significant difference in larval mortality between the treatments.

(xv) Identification and evaluation of entomofungal pathogens for the management of sugarcane woolly aphid, *Ceratovacuna lanigera*

Pathogenicity of fungal pathogens to sugarcane woolly aphid (SWA) and its predators

Among the isolates of *M. anisopliae* (Ma-1, 2, 3, 4, 5, 6, 7), *B. bassiana* (Bb-3, 4, 5a, 6) and *V. lecanii* (Vl-1, 2a, 3a, 5, 7) tested on *C. lanigera* at Kanakapura, Ma-4 isolate caused the highest mycosis (30.14%), followed by Bb-5a (20.46%). These two isolates were also pathogenic to

Table 18. Persistence of *Ha*NPV on tomato plants when applied with different combinations of adjuvants against II instar larvae of *H. armigera*

Treatments	Mean larval mortality (%)	
	0 Day	3 Days
0.5 % starch + 10 % crude sugar	75.00^{bc}	35.71^{b}(66.32)
1 % starch + 10 % crude sugar	87.55^{a}	46.66^{a}(71.55)
Only 10 % crude sugar	73.00^{bcd}	34.48^{b}(64.54)
Only 0.5 % starch	62.50^{e}	27.58^{b}(75.13)
Only 1 % starch	69.56^{de}	31.03^{b}(73.28)
Control (only virus in distilled water)	61.53^{e}	20.68^{c}(70.58)

Figures in parentheses represent per cent original activity remaining

Dipha (27.62 and 15.32%, respectively). Ma-4 isolate caused 29.14% mycosis of *Micromus*. The isolates of *V. lecanii* were not pathogenic to SWA, but caused 7.62-33.48% mycosis of *Micromus*.

Development and field evaluation of formulations

Four formulations of Ma-4 isolate of *M. anisopliae* tested on SWA at Kanakapura caused 30.14-37.4 per cent mycosis and were statistically on par.

Effect of serial passage of Ma-4 and Bb-5a on their virulence to SWA

The isolates Ma-4 and Bb-5a were passed through *C. lanigera* for five generations and after each passage, virulence of the re-isolated culture was tested on *C. lanigera*. Slight increase in the per cent mycosis of *C. lanigera* was observed with the re-isolated cultures after 5th passage.

(xvi) Studies on the pathogens of phytophagous mites and assessment of their potential in microbial control

Effect of temperature on *H. thompsonii* and *Hirsutella thompsonii* var. *synnematosa*

Temperature had a significant effect on the growth of *H. thompsonii* and *H. thompsonii* var. *synnematosa*. Both did not record mycelial growth at 37°C and above, however, when shifted to 25°C, the mycelia recovered and recorded excellent growth compared to the growth at other temperatures (27, 35 and 36°C). Temperature did not have any significant effect on the micromorphology of the two fungi.

Effect of different inoculum loads (OMA/ PDA mycelial discs) on *H. thompsonii* in liquid culture (SDB)

In continuous shake culture (Sabouraud dextrose broth (SDB), 150 RPM), when Oat Meal Agar (OMA) discs were used, the colony forming units (CFU), pellet number and wet and dry weights increased proportionately with the number of mycelial discs per flask. The size of the pellet, however, decreased with increasing number of discs. The CFU obtained with 6 discs was 6.4 times more than that produced by one disc. Similar trend was recorded with Potao Dextrose Agar (PDA) discs.

In alternating shake-stationary culture, the number of colonies, pellet number, wet and dry weights increased with increase in the inoculum load (OMA and PDA discs). However, the pellet size was maximum at an inoculum level of 4 discs of *H. thompsonii* indicating that pellet formation was affected by inoculum load.

Studies on the storage of *H. thompsonii* and *H. thompsonii* var. *synnematosa*

Storage of *H. thompsonii* and *H. thompsonii* var. *synnematosa* pellets in sterile water was found to be

Table 20. Comparison of the magnetic stirrer (MS) and shake culture methods of mass production of *H. thompsonii*

Plugs from/ Medium	CFU/ml ($x10^4$)		Wet weight (g/100 ml)		Dry weight (mg/100 ml)	
	MS	Shaker	MS	Shaker	MS	Shaker
PDA/PDB	12.72^a	6.66^a	13.49^a	13.455^a	608^a	561^a
PDA/SDB	18.03^c	8.22^b	14.94^a	14.680^a	668^a	688^{bc}
OMA/PDB	17.33^b	7.17^c	14.10^a	13.878^b	753^b	639^c
OMA/SDB	43.20^d	10.62^d	17.52^b	17.230^c	880^c	788^d

Means followed by similar letters are not different significantly (P=0.01)

better under refrigerated conditions. Although the pellets after 10 and 11 months of storage under room conditions showed growth, dark colouration and reduction in fluffiness were observed in the culture. All replicates were contaminated after 15 days of growth in 10-month storage and after 3 days of growth in 11-month storage.

Mass production technology for *H. thompsonii*

A simple magnetic stirrer technique for faster mass production of *H. thompsonii* has been developed with two media (PDB and SDB) and two different mycelial plugs (PDA and OMA). A combination of OMA plugs and SDB medium recorded maximum CFU numbers and wet and dry weights (Table 20) in both magnetic stirrer technique and shake cultures (Plate 4) .

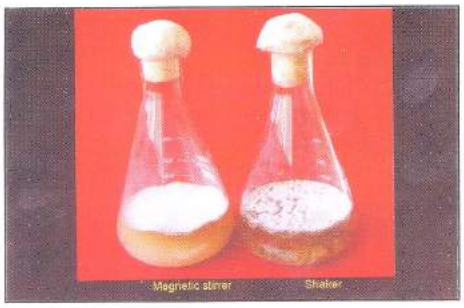


Plate 4: Sporulating biomass of *Hirsutella thompsonii*

Rearing of *Tetranychus urticae* on three different host plant leaves

Detached leaves of tomato, cowpea and bhendi were studied for their suitability for rearing mites. Tomato and bhendi leaves were able to sustain the mites for about 20 days with the number of mites being the highest on bhendi (Table 21).

Table 21. Production of *T. urticae* on detached leaves of three different host plants

Host plant	Mean number of mites days after release		
	10	15	20
Tomato	73.4	34.3	28.0
Cowpea	18.8	51.3	-
Okra	46.4	48.0	79.5

Effect of time of exposure on number of conidia on adult *T. urticae*

The number of conidia attached to the body surface of *T. urticae* adults was found to be directly proportional to the time of exposure/crawling of the mites on the fungus culture. An average of 32.10 conidia were observed attached to the mites after 60 minutes of crawling on the culture.

Effect of *H. thompsonii* exudates and metabolites on *T. urticae* adults

Exudates of *H. thompsonii* (5 ml) caused maximum mortality of *T. urticae* adults at 100% concentration (77.78%) and the minimum in control (36.66%) at the end of 7th day of incubation. The mortality decreased as the concentration of exudates was reduced.

The metabolites from one-month-old shake culture of *H. thompsonii* caused the maximum mortality when undiluted (68.89 %) at the end of 7th day, while mortality in control was 36.66 % (Table 22). Mortality decreased with the increase in dilution of the metabolites. Similar observations were recorded with different concentrations of metabolites from six-month-old stationary cultures.

Table 22. Effect of *H. thompsonii* metabolites from shake-stationary liquid culture on *T. urticae* adults

Concentration of metabolites (%)	Mortality (%) after days treatment	
	5	7
100	27.78	68.89^{a}
80	32.22	66.67^{ab}
60	14.45	42.22^{c}
40	10.00	46.67^{abc}
Control	18.89	36.66^{c}

Means followed by similar letters are not different statistically (P=0.05).

Effect of *H. thompsonii* on *T. urticae* adults

When the biomass of three-month-old stationary liquid culture of *H. thompsonii* was sprayed on mite-infested brinjal, bhendi and tomato in glasshouse, maximum mortality of mites was observed on bhendi, followed by brinjal and tomato.

Field evaluation of *H. thompsonii* in comparison with two other entomofungal pathogens and chemicals

Two field experiments were conducted at Singanallore and Vellalore in Coimbatore district of Tamil Nadu through the Department of Agricultural Entomology, Tamil Nadu Agricultural University, Coimbatore, during September 2004 and February, 2005 to evaluate the efficacy of *H. thompsonii* formulation (Mycohit) at 25 and 50 g/l; unformulated *Beauveria bassiana* (1x10^7 conidia/ml); *Metarhizium anisopliae* (1x 10^7 conidia/ml); wettable sulphur (3.2 g/l) and dicofol (2.5 ml/l) against *T. urticae* on bhendi (cv. Mahyco No. 10 hybrid). Per cent reduction in mites was maximum in plants treated with Mycohit at 50g/l followed by *B. bassiana* at both locations. At Singanallore, Mycohit (50 g/ litre) at 14 days after first and second sprays reduced the mite population by 58.09 and 45.65 %, respectively. At Vellalore, the mite population reduction was 62.72 and 48.83 %, respectively.

(xvii) Identification of *Trichoderma* isolates with enhanced biocontrol potential

Twenty *T. harzianum* cultures from PDBC collections and 8 cultures from other institutes were screened *in vitro* by dual plating against *Sclerotium rolfsii* and *Macrophomina phaseolina*. The isolates Th-15, Th17, Th7 and Th14 had better mycelial growth (8.39, 8.31, 8.21 and 8.02 cm colony diameter, respectively) compared to other cultures. Per cent reduction in growth of *S. rolfsii* in dual plate over control plate was higher with Th7, Th6, Th14 and ThCPCRI. Th15, Th17 and Th7 among PDBC isolates and Th-Kallangai and Th-ITCC among other isolates were found to be superior. Th P26 (from IISR, Calicut) and Th 7, Th 8 and Th 10 (from PDBC) were more antagonistic to *M. phaseolina* compared to other isolates.

Screening for chitin utilization by *T. harzianum* isolates

On solid media, all 28 tested isolates exhibited growth on the media amended with chitin (0.2%) on par with PDA, indicating that the isolates were capable of utilizing chitin. However there was variability in their colony characters.

On liquid media, Th (CPCRI) recorded highest growth (mycelial dry weight) in PDB (0.593 g/100ml) five days after growth in shake culture, followed by Th 6, Th 18, Th G, TH 7, Th 10 and Th 14. Though the growth of Th 9 was poor in PDB, its growth on colloidal chitin, amended broth was better (0.443 g/ml). In general, growth of fungal isolates on Colloidal Chitin Amended Medium (CCAM) was less compared to that on PDB. On *S. rolfsii* cell wall - amended broth, Th P 26 was best in growth five days after inoculation (0.433 g/ml).

Assay of chitinases in liquid culture

Twenty-eight isolates of *T. harzianum* were tested for their ability to produce chitinases in liquid culture with or without chitin amendment. The chitinase activity was detected in P26, Th10 and Th14 in *S. rolfsii* cell wall-amended broth and P26 and Th-10 in colloidal chitin-amended broth, but not in PDB.

(xviii) Efficient formulations of *Trichoderma* sp. and entomofungal pathogens with prolonged shelf life

Addition of pure chitin to formulation of *T. harzianum* and *T. viride*

Addition of pure chitin (commercial grade) to the talc formulations of *T. harzianum* and *T. viride* (8% moisture level) at 0, 1, 2, 5 per cent level initially, increased the *Trichoderma* population after one month. In control where there was no chitin addition, the population of *Trichoderma* was reduced from 11.33 X 10^6 to 2.66 X 10^6. However, the population was not reduced up to 3 months in chitin-amended formulation (Fig. 7a). In chitin-amended formulations of *T. viride*, compared to control, there was higher spore count. The highest number of CFUs (14.53 X 10^6) was recorded in 2% chitin added formulation followed by 5% (10.33 X 10^6) after 3 months of storage (Fig. 7b).

Effect of time of addition of chitin in formulation

Addition of chitin at the time of mixing the culture with talc increased the chances of contamination and the cfu/g reduced drastically compared to its addition to the formulation dried to 8% moisture level (Fig. 8).

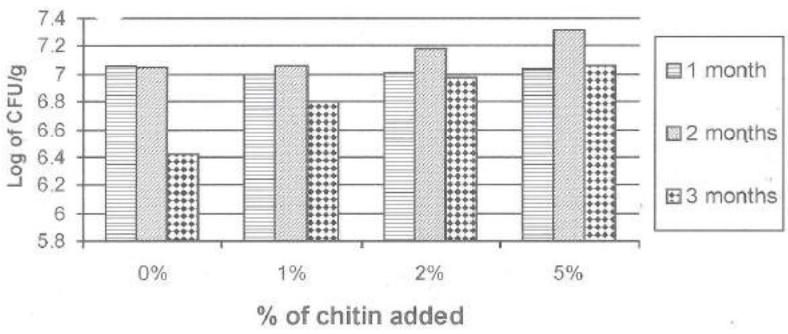


Fig. 7a. Effect of addition of pure chitin in formulation of *T. harzianum* (Th10).
Initial population of *T. harzianum*: 1.4 X 10^7 cfu/g of sample

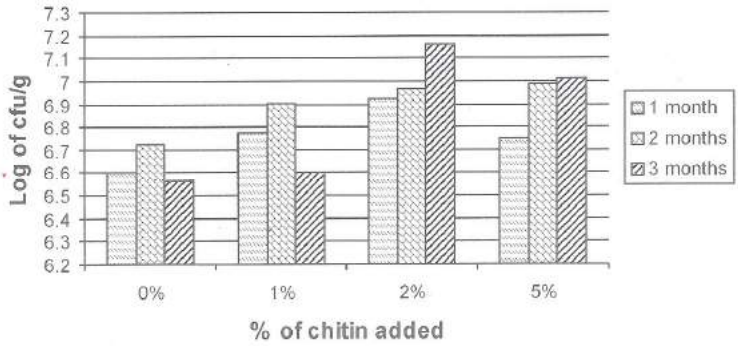


Fig. 7b. Effect of addition of pure chitin in formulation of *T. viride* (Tv23).
Initial population of *T. viride*: 5.3 X 10^6 cfu/g of sample

Effect of addition of colloidal chitin in media on shelf life of *T. viride* and *T. harzianum*

Addition of colloidal chitin to the formulations of *T. viride* and *T. harzianum* increased their CFU count for up to 2 months of storage (Table 23).

Addition of colloidal chitin to molasses-yeast extract medium did not reduce the CFUs of *T. harzianum* while it decreased the CFUs when added to *Trichoderma* special medium.

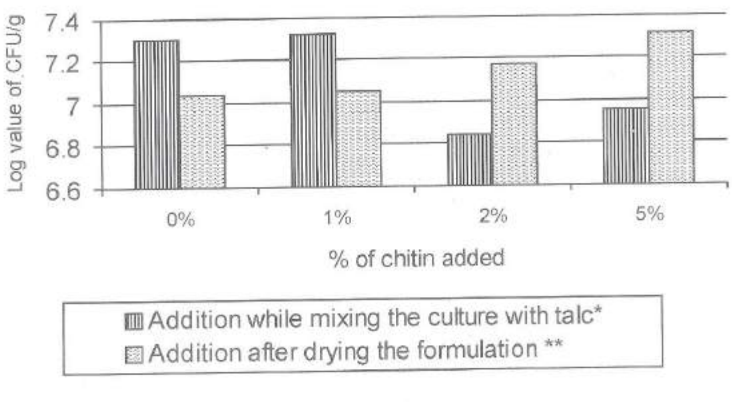


Fig. 8. Effect of time of chitin addition on CFUs
* Initial population 2.2 (X 10^7), ** Initial population 1.4 (X 10^7)

Table 23. Effect of addition of colloidal chitin (0.2%) to production medium of *Trichoderma harzianum* (Th10) on shelf life (CFU/g X 10^6)

Time(months)	*T. harzianum*		*T. viride*	
	Control	Chitin	Control	Chitin
1	3.66	5.33	14.33	22.33
2	3.33	17.00	15.33	24.00
3	0.33	27.33	-	-

Effect of C: N ratio of the production media on the shelf life of *T. viride* (Tv 23) and *T. harzianum* (Th-10)

Media with wide C:N ratios (15:1 and 10:1) yielded higher CFUs and supported the spores of both *T. viride* and *T. harzianum* for up to four months compared to the media with narrow C: N ratios of 1:5 and 1:1.

Effect of addition of glycerol on the shelf life of *T. harzianum* (Th-10)

Addition of glycerol (3 or 6%) in the production media increased the population of *T. harzianum* in formulation till one month and then it stabilized. For up to 3 months, the CFU in formulations from glycerol added cultures was higher compared to the control.

Effect of heat shock on shelf life

Heat shock to *T. harzianum* at the end of fermentation (just before harvest) at 40°C for 30 min increased the initial CFU of the formulation after one month (12.0) compared to control or heat shock at 40°C for one hour (8.0).

Addition of chitin on shelf life of *Beauveria bassiana* and *Metarhizium anisopliae*

Addition of colloidal chitin in the production media at 0.2% (w/v) retained higher numbers of viable propagules of *B. bassiana* for up to 3 months followed by the addition of colloidal chitin at 0.5%. Similarly, addition of colloidal chitin in production media at 0.2% or 0.3% increased the spore production of *M. anisopliae* in shake culture.

A combination of 0.2% colloidal chitin and 2% pure chitin in production medium increased the initial population of *B. bassiana* and *M. anisopliae* in both shake and stationary cultures compared to their individual addition (Table 24).

Addition of polyethylene glycol PEG 6000, to the production medium of *B. bassiana* at 1-5% concentration resulted in reduced sporulation of *B. bassiana* at

Table 24. Effect of addition of colloidal chitin and pure chitin on the shelf life of *B. bassiana* and *M. anisopliae*

Treatment	*B. bassiana* (CFU/g x 10^9)		*M. anisopliae* (CFU/g x 10^9)	
	Shake	Stationary	Shake	Stationary
0.2 % Colloidal chitin in medium	73.0	11.0	100.0	11.5
2.0 % chitin in formulation	63.0	6.5	26.5	10.5
0.2 % Colloidal chitin in medium + 2.0 % chitin in formulation	76.0	12.0	107.0	13.5
Control	60.5	7.5	25.5	9.5

production stage itself in both shake and stationary cultures.

(xix) Mass Production, Formulation and Field Testing of entomopathogenic nematodes (EPNs) against important lepidopteran pests

In vivo mass production of *Steinernema carpocapsae* and *Heterorhabditis indica*

A positive correlation was observed between the dosage of *S. carpocapsae* and *H. indica* and mortality of *G. mellonella* and a negative correlation between the dosage and the time of mortality. The optimum dosage level differed for *H. indica* and *S. carpocapsae*.

Maximum progeny production was observed at the highest dosage of 1000 Ijs/larva followed by 300 Ijs/larva and the emergence was completed in four days after placing on white trap for harvesting. IJs emerged earlier (6-10 days after infection) in *S. carpocapsae* compared to *H. indica* (10-12 days) (Table 25).

Bioefficacy

The median lethal concentration (LC_{50}) of *S. carpocapsae* at 48h post-exposure was 29 Ijs (Y= -6.12 + 4.18 X), 49 Ijs (Y = - 1.4 + 0.87 X), 99 Ijs (Y = -3.74 + 1.87 X) and 147 Ijs/larva (Y = -6.81 + 3.14 X) for final instar larvae of *G. mellonella*, *P.xylostella*, *S. litura* and *H. armigera*, respectively.

Persistence of EPN in open and shaded conditions

When native isolates of *S. carpocapsae*, *S. abbasi*, *H. indica* and *H. bacteriophora* were artificially inoculated into the soil under open and shaded conditions at PDBC, all the isolates persisted for longer periods under covered conditions. *Steinernema* spp. persisted better under both conditions and the maximum was found to be 90 and 75 days and 75 and 60 days in shaded and open conditions for *Steinernema* spp. and *Heterorhabditis* spp., respectively (Fig. 9).

Table 25. Progeny production of *S. carpocapsae* as influenced by initial inoculum level in *G. mellonella* larvae

Dosage (Ijs/larva)	Final yield in lakhs (IJs/larva)	
	S. carpocapsae	*H. indica*
10	-	180095
40	1,57,600	220257
80	1,71,200	188714
300	2,05,200	647285
1000	2,49,000	195771

Formulation, storage and bulk transport

A new formulation using diatomaceous earth and talc was tested for *S. carpocapsae* and *H. indica* and found suitable for nematode formulation and application.

Talc-based formulations of nematode isolates were found effective against the larvae of *G. mellonella* after

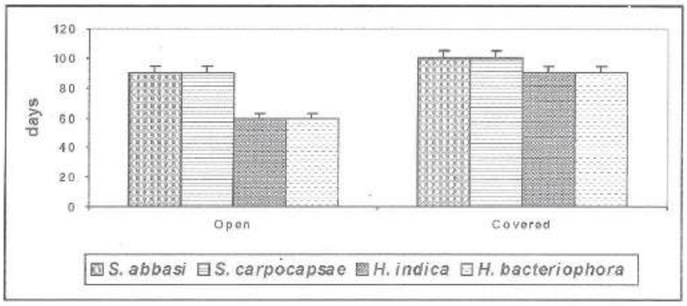


Fig. 9. Persistence of nematode isolates in open and shaded conditions

10 days of transport. *Steinernema carpocapsae* and *S. abbasi* caused 100% mortality of *G. mellonella* larvae after 48 h, whereas *H. indica* and *H. bacteriophora* caused the same mortality in 96 h. The progeny production (infective juveniles/dead cadaver) was 5.63 lakhs in *H. bacteriophora*, followed by *H. indica* (5.45 lakhs), *S. abbasi* (4.16 lakhs) and *S. carpocapsae* (3.64 lakhs).

Field efficacy of talc formulations against white grubs on turf in Srinagar

Field efficacy of talc-based formulations of *S. carpocapsae*, *S. abbasi*, *H. bacteriophora* and *H. indica* against white grubs in turfgrass was evaluated at Srinagar. All the species tested significantly reduced the grub population in 30 days after application. However, *Steinernema* spp. were more effective compared to *Heterorhabditis* spp. The highest mortality (42.0%) was recorded with *S. abbasi*, followed by *S. carpocapsae* (38.4%).

(xx) Biological suppression of plant parasitic nematodes exploiting antagonistic fungi and bacteria in specific cropping systems

Field surveys for antagonistic agents against plant parasitic nematodes

Pochonia chlamydosporia (PDBC PC59) was isolated from the soil samples from reniform nematode-infested fields in Yelahanka (Bangalore) and Doddaballapura. The genomic DNA of this native isolate was extracted and processed by PCR for beta-tubulin gene. The amplicons at 270 bp from 1% agarose gels were used for gene sequencing and the sequence was matched with that of our previous isolates in collection and on NCBI Genbank (BLAST).

Evaluation of formulations of *Paceilomyces lilacinus* against reniform and root-knot nematodes in chickpea and eggplant under glasshouse conditions

Under glasshouse conditions, application of talc formulation of *P. lilacinus* at 4g (10^8 spores/g) per 2kg soil resulted in 52% infection of egg masses of reniform nematodes in chickpea, and a reduction of 46% of nematode populations in soil and 44% in roots of chickpea. In case of eggplants inoculated with root-knot nematodes, although there was 72% egg mass infection by *P. lilacinus*, root infection by nematodes was as high as 60% and reduction in root-gall formation was 34%.

Evaluation of formulations of *P. lilacinus* and *P. chlamydosporia* against golden cyst nematodes in potato (Multilocation trial, CPRS, Ooty)

In trials in potato cyst nematode-infested fields of CPRS, Ooty (Plate 5), incorporation of talc formulation of *P. lilacinus* or *P. chlamydosporia* at 30 kg/ha and their combinations with carbofuran (2kg a.i./ha) resulted in 20-30 % reduction of cyst nematode infection in roots, 38-54% infection of cysts (Plate 6) and reduced the

Plate 5 : Biological control of potato cyst nematodes using tale formulation of *Pochonia chlamydosporia* and *Paecilomyces lilacinus* under AICRP-field tria at CPRS, Ooty

Plate 6 : Parasitised cysts of golden nematodes

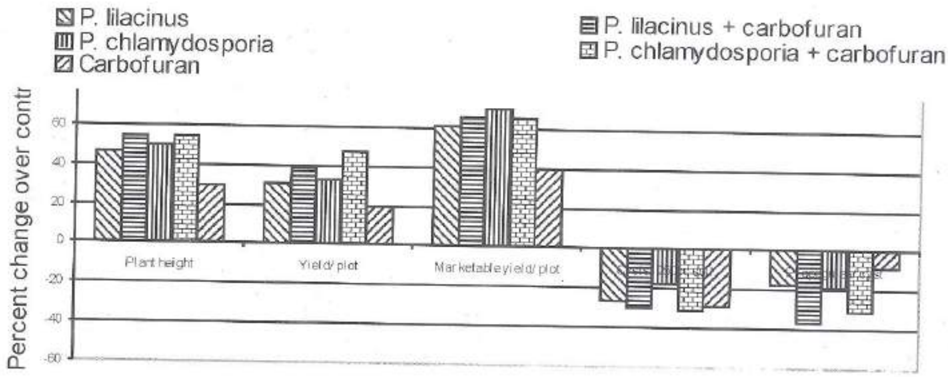


Fig. 10. Effect of talc formulations of *P. lilacinus* and *P. chlamydosporia* on growth and yield of potato cyst nematodes under field conditions

nematode population by 8-10% in soil at the end of the season (Fig. 10). There was a 40-70 per cent increase in marketable yield in treated plots over untreated plots (Plate 7).

Plate 7: Potatoes free of cyst nematodes in treated plots.

Biological control of *Fusarium*-root-knot nematode complex in brinjal

Incorporation of *P. lilacinus* first, followed by *T. harzianum* 10 days later, to the naturally nematode and Fusarium-sick soil in pots and then transplanting the brinjal seedlings reduced the incidence of wilt in brinjal by 70% and their combined incorporation reduced the wilt incidence by 50%.

Rhizospheric competence of *P. lilacinus* isolates on tomato under pot conditions against reniform and root-knot nematodes

Rhizospheric competence of three isolates of *P. lilacinus* (PDBC PL55, PL56, PL57) against root-knot and reniform nematodes on tomato under glasshouse conditions was studied. During the first 45 days of pot studies, *P. lilacinus* survived better in autoclaved soil amended with 500 cc of FYM (organic manure) than in non-autoclaved soil amended with organic manure. PDBC PL55 exhibited higher amount of root colonization although the infection of egg masses of reniform and root-knot nematodes was more or less similar in autoclaved and un-autoclaved soil.

Influence of plant root pattern on nematode infection and behaviour of bioagents

Plant root pattern and volume exhibited a direct relationship with the establishment of *P. lilacinus* and *P. chlamydosporia* in tomato, brinjal and cotton rhizospheres under pot conditions. The higher the root density and volume, the higher was the root-knot nematode infection, egg masses and the fungal parasitization of the egg masses. Brinjal exhibited higher root volume and root hair, followed by tomato and cotton at 45 days in 9" earthen pots.

Table 26. Effect of talc formulation of *P. lilacinus* (PL) in combination with organic amendments against root-knot nematode in tomato

Treatments	Plant		Root-knot nematode	
	RKI (0-5 scale)	Healthy root (%)	Egg mass parasitized (%)	Increase/ Reduction in nematode populations (%)
PL in talc	3.8[b]	41[d]	28[c]	(-) 18
Farm compost	3.9[b]	32[b]	12[a,b]	(-) 6
Pelletised organic manure	4.0[b]	30[b]	3[a]	(+) 10
Neem cake	3.7[a,b]	37[c]	3[a]	(-) 12
Vermicompost	3.8[b]	36[c]	8[a]	(-) 14
PL+ Farm compost	3.2[a,b]	49[e]	34[c,d]	(-) 35
PL+Pelletised organic manure	3.4[a,b]	48[e]	26[c]	(-) 29
PL + Neem cake	2.8[a]	54[f]	28[c]	(-) 40
PL+ Vermicompost	2.8[a]	54[f]	38[d]	(-) 42
Untreated check	4.1	22[a]	3[a]	(+) 94

Means followed by similar letters are not different statistically (P=0.05).

Field evaluation of talc formulation of *P. lilacinus* in combination with commercial and local organic amendments against root-knot nematode in tomato

Microplot experiments were carried out in root-knot nematode infested farmer's field to evaluate the combinations of talc formulation of *P. lilacinus* and organic amendments, *viz.*, farm compost, pelletized organic manure, vermicompost and neem cake (300Kg/acre or 750Kg/ha) with respective checks on tomato (Cv. Avinash). Egg mass parasitization and reduction in nematode populations were highest in PL + vermicompost, followed by PL + neem cake, farm compost and pelletized organic manure (Table 26).

Root-knot nematode management in carnations in polyhouses

An experiment was carried out on root-knot nematode infested carnation in a commercial polyhouse using Dazomet as pre-plant soil sterilant (25 g/m^2); antagonistic fungus, *Pochonia chlamydosporia* (2x10^9 spores/m^2); neem cake (1.0 kg/ m^2) and their combinations. A combination of Dazomet followed by soil amendment with *P. chlamydosporia* and neem cake recorded maximum healthy roots (98%) and flower yield (29.6%) and plant recovery (6% mortality) compared to other combinations (Table 27). The fungus established better in Dazomet-treated and neem cake-amended beds. Dazomet reduced not only nematode populations but also other soil-borne pathogens, thus reducing the competition from native soil flora and fauna.

Studies on Fusarium-root-knot nematode disease complex in tomato under glasshouse conditions

Glasshouse studies were carried out on tomato in two sets of 9" earthen pots, one set containing autoclaved soil and another inoculated with *M. incognita* (MI) juveniles (@ 2000 ljs), to study the effect of integration of *P. lilacinus* (PL) and *T. harzianum* (TH) on the nematode-wilt disease complex and the plant.

Table 27. Effect of treatments on root galls, healthy roots and plant mortality at different stages of crop growth in carnation (one year post treatments)

Treatment	Root gall index (RGI)(0-5 scale)	Nematode multiplication rate (NMR)	Healthy roots (%)	Plant mortality (%)	Per cent increase in flower yield/ bed over control
Dazomet	0.5^b	0.4^c	74.0	14.0^b	17.5
Neem cake + *P. chlamydosporia*	1.0^c	1.0^d	48.0^b	22.0^c	16.0
Dazomet + *P. chlamydosporia*	1.0^c	0.2^b	84.0^c	12.0^b	23.0
Dazomet + neem cake + *P. chlamydosporia*	0.2^a	0.0^a	98.0^d	6.0^a	29.6
Control	3.4^d	2.4^d	32.0^a	44.0^d	-

Means followed by similar letters are not different statistically (P=0.05).

Table 28. Progress of Fusarium wilt in tomato in the presence of *M. incognita* (MI) bioagents and neem cake cómbinations

Treatment	Dose/plant	Wilt index at weekly interval 15 days after transplantation							
		1	2	3	4	5	6	7	8
M. incognita	2000J_2	0	0	0	0	0	0	0	0
Fusarium	5g PDA (1.2x10^8 spores/g)	0	0	+	++	++	-	-	-
MI+ Fusarium	2000 J_2	0	+	+	++	++	-	-	-
MI + Fusarium + PL	2g PDA (2.3x10^9 spores/g)	0	0	0	+	+	++	++	-
MI + Fusarium + TH	2g PDA (2.8x10^8spores/g)	0	0	0	+	+	+	++	-
MI + Fusarium + neem cake	8.8x10^{10}spores	0	+	+	++	++	-	-	-
MI + Fusarium + PL+ Neem cake	20g	0	0	0	0	0	+	++	++
MI + Fusarium + TH+ Neem cake	½ dose each	0	0	0	0	+	+	+	0
MI + Fusarium PL+ TH+ Neem cake	½ dose each	0	0	0	0	0	0	+	0

Wilt Index : (0) - No wilting; (+) - wilting of young leaves; (++) - wilting of whole plant; (-) - Dead plant.

PL and TH individually checked *Fusarium* wilt in tomato in the presence of *M. incognita* for 7 weeks but plant mortality occurred due to wilt after 7 weeks (Table 28). A combination of PL+TH+ neem cake completely checked wilt and 80% plants were free from wilt. Tomato root colonization and egg mass parasitization were highest with TH + PL+ neem cake.

(xxii) Software development

A software on biological control measures for major pests of sugarcane has been prepared and is available on CD-ROM.

In the National Information System on Biological Suppression of Crop Pests under preparation, information on 35 crops, their important pests and natural enemies has been included.

A database on microbial biocontrol agents is under construction.

BIOLOGICAL CONTROL OF PLANT DISEASES USING ANTAGONISTIC ORGANISMS

(i) Evaluation of seed biopriming with *Trichoderma harzianum* (TH) and *Pseudomonas fluorescens* (PsF) and TH enriched FYM technologies

GBPUA & T

Effect of seed biopriming and sprays with biocontrol agents on disease incidence and yield of organically grown lentil

Foliar application of *Trichoderma harzianum* (PBAT-43), *Pseudomonas fluorescens* (PBAP-27) and *T. harzianum* (PBAT-43) + *P. fluorescens* (PBAP-27) and seed biopriming significantly increased, plant stand as compared to control and mancozeb was equally effective. Foliar application of only PBAP-27 significantly reduced rust incidence over control. In other treatments, difference with control was not significant. All the treatments significantly increased yield over control, the mixed formulation being the most effective (Table 29).

In organically grown pea, biopriming of pea seeds with bioagents improved the seedling stand significantly over control and PBAT 43 + PBAP 27 was most effective. Foliar application of bioagents significantly reduced powdery mildew, however, effect on rust was not significant. Application of PBAP 27 + PBAT 43 through seed and foliar spray was most effective in increasing the yield of organically grown pea (Table 30).

Table 29. Effect of seed biopriming and foliar application of different biocontrol agents on rust and yield of organically grown lentil

Treatments	Seedlings/m^2	Rust intensity (%)	Grain yield (kg/ha)
Seed biopriming + PBAT 43 spray	532	28	866
Seed biopriming + PBAP 27 spray	548	22	861
Seed biopriming + PBAT 43 spray + PBAP 27 spray	545	28	888
Seed treatment (@2.5g/ha) + 4 sprays (@2.5g/l) mancozeb	531	30	861
Control	445	33	802
CD (P=0.05)	61	9	57

Table 30. Effect of different biocontrol agents applied through seed, FYM and/or foliar application on foliar diseases and yield of pea

Treatments	Seedling stand (m^2)	Powdery mildew incidence (%)	Rust Intensity (%)	Grain yield (kg/ha)
Seed biopriming with PBAT 43 + Sprays with PBAP 27 (with non-colonized FYM)	56	13	29	355
FYM colonized with PBAT 43+ Sprays with PBAP 27	63	16	33	352
Seed biopriming + Colonized FYM+ Sprays with PBA-3	69	12	30	388
Control	52	36	37	301
CD (P=0.05)	6	10	8	53

Table 31. Evaluation of seed biopriming with *T. harzianum* (TH) and *P. fluorescens* (PsF) and TH enriched FYM technologies at PAU, Ludhiana on chickpea

Treatment	Per cent seed germination 10 days after sowing	December 2004	April 2005
Seed treatment with TH	81.7	39.30	39.92 [a]
Seed treatment with PsF	91.7	44.65	37.15 [a]
Seed biopriming with TH	83.9	43.77	32.35 [bc]
Seed biopriming with PsF	80.4	40.80	28.52 [c]
TH enriched FYM	88.6	43.87	32.90 [bc]
Seed biopriming with PsF + TH enriched FYM	80.9	41.95	32.55 [bc]
Seed treatment with mancozeb (0.3%)	83.7	38.15	29.17 [c]
Control	89.7	45.05	35.12 [b]
CD (P=0.05)	-	NS	(0.52)

Means followed by similar letters are not different statistically (P=0.05).
*Based on three blocks/replication

Table 32. Evaluation of *Trichoderma* spp. against soil borne diseases in chickpea at PAU, Ludhiana, during 2004-05

Treatments	Per cent germination 10 days after sowing	Initial plant stand/ m^{2*}	Final plant stand per m^{2*}
Seed treatment with *Trichoderma* spp. @ 4g/kg seed	91.2	55.95	40.47 [a]
Biopriming seeds with *Trichoderma*	83.0	50.45	38.30 [a]
Trichoderma enriched FYM (100kg/plot)	84.5	51.47	39.57 [a]
Seed treatment with mancozeb	87.6	53.22	38.95 [a]
Control	84.8	51.47	31.37 [b]

Means followed by similar letters are not different statistically (P=0.05)
*Based on three blocks/replication

PAU, Ludhiana

Evaluation of seed biopriming with *Trichoderma harzianum* (TH) and *Pseudomonas fluorescens* (PsF) and TH enriched FYM technologies on chickpea

At PAU, Ludhiana, population per seed at 0 h and 48 h after biopriming was 2.45 x10^7 and 3.75 x10^7, respectively, in case of *T. harzianum* and 2.59 x10^7 and 2.75 x 10^7, respectively, in case of *P. fluorescens*. There was no significant difference in plant population during December-March in different treatments (Table 31). However, during April, lowest population (28.52 per m^2) was observed in seed biopriming with PsF and it was significantly lower than seed treatment with TH, PsF and control. There was no significant difference in number of *H. armigera* larvae and the pod infestation among different treatments. The total number of pods in different treatments was higher than that in control, but the differences were not significant. The grain yield in all the treatments was significantly higher than that in control. The highest yield (11.35 q/ha) was given by seed biopriming with PsF +TH enriched FYM and it was significantly better than all other treatments.

(ii) Evaluation of *Trichoderma* spp. against soil borne diseases in chickpea (PAU)

At PAU, Ludhiana, the germination in seed treatment with *Trichoderma* spp. was higher (91.2 per cent) as compared to other treatments (Table 32). There was no significant difference in initial plant stand in different treatments. The final plant stand in all treatments was significantly higher than in control. The incidence of wilt was in general low and significantly lower in all the treatments ((0.11 to 0.18%) than control (2.36 per cent). The incidence of *H. armigera* in pods was not significant in different treatments. The number of pods in seed treatment with *Trichoderma* (572.5) and *Trichoderma* enriched FYM (575.75) was higher than in all other treatments, but the differences were not significant. The differences in grain yield between the treatments were not significant.

Table 33. Effect of foliar application of different biocontrol agents on brown spot intensity and yield of organically cultivated scented rice cv. Kalanamak 3119

Treatments	Brown spot intensity	Grain yield (q/ha)
PBAT 43	41.7	33.0
PBAP 27	22.4	39.4
PBAT 43 + PBAP 27	23.2	43.6
Mancozeb	56.0	28.7
Control	91.3	22.4
CD (P=0.05)	11.8	6.3

(iii) Management of foliar diseases using *Trichoderma harzianum* and/or *Pseudomonas fluorescens*

GBPUA&T, Pantnagar

Foliar application of all biocontrol agents significantly reduced the brown spot incidence and increased the yield of scented rice cv. Kalanamak 3119 under organic cultivation (Table 33). PBAP 27 and PBAP 27 + PBAT 43 were more effective.

PAU, Ludhiana

In a field trial on the management of foliar diseases of rice using *Trichoderma harzianum* and Psf at village Uggi (Distt. Jalandhar), after one week of spray the severity of the disease was non-significant. However, after 15 and 21 days of spray, all the treatments were better than control. The lowest severity of infection was recorded with PsF, which was on par with mancozeb 0.3%. The yield was not significantly different.

(iv) Shelf-life of *Trichoderma* and/or *Pseudomonas* formulations with different moisture levels (PDBC)

In talc formulations, at 15% moisture level, *T. harzianum* propagules were viable ($7.5X10^6$cfu/g) even after storage for 180 days at room temperature (17-37°C). In sorghum grain flour formulations, no significant differences were observed in the populations of the viable propagules ($1.8X10^7$ to $5.32X10^8$) when stored at room temperature for 180 days and 5,8,10,15% moisture levels.

BIOLOGICAL SUPPRESSION OF SUGARCANE PESTS

A. Studies on sugarcane woolly aphid, *Ceratovacuna lanigera*

(i) Survey for sugarcane woolly aphid (SWA) and its natural enemies

IISR, Lucknow

Surveys were conducted in nine locations in Saharanpur, Haridwar and Muzaffarnagar areas of Uttar Pradesh. Ratoon crops of CoS88230 and CoS767 were found moderately affected by sugarcane wooly aphid during July-October, 2004 in a few villages of Saharanpur district and the predator, *Dipha aphidivora* was also active. In Haridwar and Muzaffarnagar, moderate to severe infestation was seen mostly in ratoon crop in varieties CoPt 84212, CoS767, CoS8432, CoS 95255 and CoJ 64 with low populations of *D. aphidivora*. In a few places, *Eupeodes confrater*, chrysopids, coccinellids and spiders were also found feeding on SWA.

SBI, Coimbatore

The survey conducted during November 04 - March 05 at monthly intervals in a single field at Coimbatore revealed that the mean aphid rating reached a peak in January 2005 (Table 34) and decreased to a low level in March 2005. Predation by *Dipha, Micromus* and syrphids was recorded.

College of Agriculture (MPKV), Pune

Survey for SWA and its natural enemies was carried out in July and September, 2004 in plain and scarcity zones, and in November-December, 2004 in submontane zone, Western Ghat zone, western Maharashtra plain zone, scarcity zone and central Maharashtra plateau zone. The incidence of SWA was noticed on 6 to 10 months old crop in Pune and Nasik districts from first week of July, 2004 and in Satara and Ahmednagar districts during September, 2004. *Micromus* spp. (2-25 grubs/leaf in July, 2004) and *D. aphidivora* (1-2 larvae/ leaf in September, 2004) were observed in Pune and Ahmednagar districts. During November-December, 2004, 10-75 % SWA infestation was noticed, with an intensity rating of 1.0-3.4. *Micromus* sp. (1-3 grubs / leaf) was noticed on 3-4 month-old crop, whereas *D. aphidivora* (2-7 larvae / leaf) was recorded on 8 to 12-month-old crop at most of the locations surveyed.

The aphid colonies along with the larvae of *D. aphidivora* were also noticed on the leaves of wild sorghum (*Sorghum halepense*) and wild maize (*Coix lacryma*), which were present inside the sugarcane fields at Pawananagar, Tal- Mawal, Dist-Pune in the last week of October, 2004.

AAU, Jorhat

Surveys were carried out in the district of Golaghat, Nagaon, Darrang and Sonitpur. In Golaghat district, the pest was first observed in the II fortnight of June (35.4/3 sq. cm.). The number of SWA in 3 cm²/leaf was maximum

Table 34. Seasonal fluctuations of SWA and its predators on sugarcane at Coimbatore

Month/year	Mean aphid rating	Per cent leaves colonized by predators		
		Dipha	*Micromus*	Syrphid
November 2004	2.35	-	-	-
December 2004	2.15	90.2	-	8.20
January 2005	3.47	57.3	-	6.67
February 2005	1.69	25.6	-	-
March 2005	1.49	27.1	2.43	-

Table 35. Population of sugarcane wooly aphid and *Dipha aphidivora* at Jorhat

Months	Mean number of woolly aphid/ 2.5m²	Mean no. of *D. aphidivora*/ leaf	Temperature (°C)		Total rainfall (mm)
			Max.	Min.	
June 2004	35.4	4.4	31.3	24.9	211.6
July	47.2	8.6	30.1	24.7	295.5
August	45.9	9.0	32.3	25.4	281.0
September	30.4	8.1	30.3	24.4	208.2
October	69.2	11.8	28.7	21.1	146.9
November	119.4	5.4	27.1	15.6	35.7
December	35.5	3.6	24.4	11.6	12.5
January 2005	20.6	0	21.4	10.4	78.8
February	8.5	0	24.1	13.3	81.8
Correlation of pest& predator population with weather parameters	(r) for SWA	-	0.2397	0.1034	- 0.1493
	(r) for *D. aphidivora*	-	0.7655*	0.7595*	0.6171

(119.4) in November 2004 and minimum (8.5) in February 2005. *Dipha aphidivora* was observed in maximum numbers (11.8/leaf) in October 2004 and was not recorded after January (Table 35). The coccinellid, *Micraspis* sp. was also found to be associated with SWA. In Darrang and Sonitpur districts during October 2004, the average number of woolly aphids varied from 20 to 30/3 sq. cm, whereas *D. aphidivora* varied from 2.8 to 3.4/leaf. The population of *D. aphidivora* showed a significant positive correlation with temperature.

The parasitoid, *Encarsia flavoscutellum*, was first recorded on 19th December 2004 in ICR Farm, AAU, Jorhat. In subsequent weekly observations on this parasitoid till the end of February 2005, the maximum average number was recorded in January (159.0) and February (130.0/leaf).

ANGRAU, Hyderabad

Incidence of SWA and its natural enemies was recorded in four agroclimatic zones of Andhra Pradesh. In the southern Telangana zone, *Dipha* was observed only from November 2004-January 2005 (1-5/25 plants), while pest incidence was recorded during July-August and November 2004-January 2005. In the northern Telangana zone, coccinellids and syrphids were noticed in a few spots and the pest intensity ranged from 2 to 6. In the Krishna-Godavari zone, the pest intensity ranged from 1-3 and only coccinellids and syrphids were noticed in a few spots.

Surveys indicated two peaks of populations, the first during June–August and the second during November–January. The natural enemies consisted mainly of *D. aphidivora* and coccinellids and syrphids in certain places. *Micromus* incidence was noticed in certain pockets of southern Telangana zone.

PAU, Ludhiana

The SWA was not recorded in any of the surveys carried out at Behram (Distt. Nawanshehar), Jandiala (Jalandhar District) and various sugar mill areas.

TNAU, Coimbatore

The incidence of the aphid was initially noticed in Vellore District of Tamil Nadu during May 2004. Surveys in different districts during 26-30 October 2004 indicated the prevalence of the aphid in most of the agroecological zones of Tamil Nadu except parts of the southern and high rainfall zones. The infestation on clump basis ranged from 20 to 100% and the intensity ranged from 1 to 5. *Dipha aphidivora*, *Micromus* sp. and syrphids were recorded in the aphid-infested tracts during October-November 2004.

In Telungupalayam village, Coimbatore district, observations during September 2004-March 2005 on planted cane (5-month-old) showed that the mean intensity of infestation was initially 1.78 and reached 4.73 during March. The mean number of predators recorded/leaf over the period was in the order *D. aphidivora* (1.83) > syrphids (1.35) > *M. igorotus* (0.4).

(ii) Evaluation of potential natural enemies of sugarcane woolly aphid

a. *Dipha aphidivora*

ANGRAU, Hyderabad

Three situations, *viz.*, initial infestation of SWA and *Dipha*, II. Initial infestation of SWA and no *Dipha* and III. Initial infestation of SWA without *Dipha* + inoculative releases of *Dipha* (@100 larvae from other experimental plots) were assessed.

The aphid population/cm^2 ranged from 39.4 to 53.9 in pre-count in SI, 46.2-69.0 in SII and 49.4-89.4 in SIII. The population of SWA decreased in SI (20.0 to 40.6) & SIII (41.4 to 63.8) seven days after first release. There was not much difference in pre- and post-counts in SII. Similar trends were noticed in the population levels of SWA after 2nd release of *Dipha* also. The population of SWA was least when *Dipha* was released the second time (21.0). It is apparent that *Dipha* either occurring naturally or on its release was capable of suppressing the aphid population.

TNAU, Coimbatore

In Coimbatore, *Dipha* collected locally from infested fields during December was released in a field without *Dipha* (two releases @ 400/treatment at 10 days interval). This accretive release of *Dipha* was effective in the management of the aphid.

b. *Micromus igorotus*

UAS, Dharwad

The impact of *M. igorotus* releases at different intensities of SWA was studied in the field at five locations with the following situations:

1: High incidence of SWA without *M. igorotus* (SI); 2. initial incidence of SWA without *M. igorotus* (SII), 3. high incidence of SWA with *M. igorotus* (SIII), 4. initial incidence of SWA with (SIV) two releases @100 pupae/ha, 5. high incidence of SWA without *M. igorotus* (SV), chemical spray (chlorpyriphos @ 2 ml/l). Observations on initial population of SWA and the predators (*M. igorotus* and *D. aphidivora*) on 15, 30 and 45 days after release were made.

The data revealed that either natural colonization or artificial releases of *M. igorotus* could reduce the population of the SWA very significantly. Chlorpyriphos controlled the aphids initially, but it destroyed the predators and 45 days after treatment, the aphid population reestablished (Table 36).

(iii) Methods of mass production of *Dipha* and *Micromus*

College of Agriculture (MPKV), Pune

Shade nets of 40 and 50% mesh were used by preparing temporary structures with bamboo frame. The crop (Co 86032) (5, 6, 7 and 8 months old) was covered with shade net at the first appearance of SWA. Thereafter, inoculative release of *D. aphidivora* @ 100 larvae was made in each shade net on sugarcane leaves covered with SWA to an extent of 75%.

The covering of 7-month-old sugarcane crop with 50% shade net resulted in enhanced growth of the SWA and yielded 2700 larvae or pupae of *D. aphidivora* within two months (Table 37). Mass rearing of *D. aphidivora* in 50% shade net was more efficient than 40% shade net conditions. The cost of one shade net (5 x 5 m) was Rs.3000/-.

Table 36. Effect of field release of the predator *Micromus igorotus* at different intensity levels of SWA at Dharwad

Treatment	SWA grade and predator (days after release)											
	Before release			15			30			45		
	SWA grade	Predator / leaf		SWA grade	Predator/leaf		SWA grade	Predator/leaf		SWA grade	Predator/leaf	
		M	D		M	D		M	D		M	D
S I	5.6 a	0.0c	0.0b	4.8a	1.6b	0.2b	4.0a	3.0b	0.,6a	2.2a	4.4a	0.40a
S II	2.6 b	0.0c	0.0b	2.2c	1.4b	0.0b	1.6c	2.0c	0.0c	1.2b	1.0b	0.0b
S III	5.0a	1.6a	0.6a	3.0b	3.4a	1.0a	2.2b	4.2a	0.6a	1.2b	0.40bc	04 a
S IV	2.8b	1.0b	0.2b	2.0c	3.2a	0.2b	1.4c	1.4c	0.2b	1.0b	0.0c	0.0b
S V	5.6a	0.0c	0.2b	1.0d	0.0c	0.0b	1.4c	0.0d	0.0c	2.6 a	0.0c	0.0b

S I -High intensity of SWA with no *M. igorotus*; S II -Initial intensity of SWA with no *M. igorotus*; S III -High intensity of SWA with *M. igorotus*; S IV -Initial intensity of SWA with *M. igorotus*; S V- M: *M. igorotus*; D: *D. aphidivora*; DAR= Days after release

Table 37. Multiplication of *D. aphidivora* in shade nets during 2004-05 at MPKV, College of Agriculture, Pune

Age of crop**	40% shade net				50% shade net			
	Av. No. of SWA / 2.5 cm^2 /leaf / plant*		Av. No. of *Dipha* larvae / leaf / plant**		Av. No. of SWA / 2.5 cm^2 /leaf / plant*		Av. No. of *Dipha* larvae / leaf / plant**	
	Initial population	Population 30 days after cover	30 days after release of *Dipha*	Total production of *Dipha#*	Initial Population	Population 30 days after cover	30 days after release of *Dipha*	Total production of *Dipha*
05-11-2004	-	-	-	-	15	88	3.2	1521
06-12-2004	32	82	3.4	1600	30	90	3.7	2360
07-01-2005	40	85	3.5	2160	42	65	3.75	2700
08-03-2005	-	-	-	-	20	-	-	-
Control (Uncovered)	25 (Initial population of SWA)					47	1.8	720

(iv) Bio-intensive pest management practices for sugarcane scales

Regional Station (CCSHAU), Karnal

The experiment was laid out in 0.2 ha field planted with cultivar Co 7717 in scale endemic area of Co-operative Sugar Mills, Palwal, Faridabad district. The IPM module comprising of use of healthy seed, dipping of seed setts in malathion 0.075%, detrashing of dried leaves and release of coccinellids, *Chilocorus nigrita* and *Pharoscymnus horni* (@ 2000 adults/ha three times during September-October) was compared with farmers' practice and an untreated check. The farmers' practice included seed and sett treatment with chlorpyriphos @ 1.25 kg a.i./ha for control of top shoot borer in first week of July. The incidence and intensity of scale was measured from September 2004 to February 2005. The scale incidence rose from zero (at the time of sowing) to a maximum of 28 per cent in untreated check during September after one month of stripping of lower leaves and just before the first release of *C. nigrita* and *P. horni*. In IPM module and the farmers' practice plots, the incidence at this interval was 17.3 and 23.4 per cent, respectively. After the second release of the predators, the IPM plot recorded the lowest incidence and intensity of the scale. At harvest, the IPM plot recorded 21.6 and 29.3 per cent less scale incidence and intensity than the untreated check. However, the infestation in farmers' practice plot was not much different from untreated check at the time of harvest.

(v) Field evaluation of *Trichogramma chilonis* against *Chilo tumidicostalis* / *C. infuscatellus*

AAU, Jorhat

Trichogramma chilonis was field evaluated against *Chilo tumidicostalis* at the Sugarcane Research Station, Buralikson, on var. Dhansiri (CoBLN 9605). Nine releases of *T. chilonis* were made at 50,000/ha/release at 10 days interval, the first release at 55 days after planting. Post-release observations indicated that *T. chilonis* had a good impact in reducing the borer population with the mean incidence of *C. tumidicostalis* in the released plot being 13.3 % as against 18.2 % in the farmers' plot and parasitism being 36.2 % in the *Trichogramma*-released plot against 13.8 % in the farmers' practice plot. The released plot registered a higher yield (80 t/ha) than the farmers' practice plot (57 t/ha).

PAU, Ludhiana

Trichogramma chilonis was evaluated against the early shoot borer, *C. infuscatellus* on variety COJ 64. The parasitoid was released eight times at 10 days interval during mid-April to end-June @ 50,000/ha. In the chemical control plot, Sevidol 4.4G (carbaryl+BHC) was applied @ 18.75 kg/ha at planting. The incidence of early shoot borer in control (12.60%) was significantly higher than that in the *Trichogramma* released field (6%) and chemical control (5.76%) fields, the reduction in damage over control being 52.38 and 53.52 per cent, respectively. The yield in released field (602.3 q/ha) was on par with chemical control (604.5 q/ha), both being significantly higher than control (540.7 q/ha).

The release of high temperature-tolerant strain of *T. chilonis* developed by PDBC was compared with the local strain of *T. chilonis*, chemical control and untreated control for managing the early shoot borer. Both strains were released 8 times, during mid-April-June, at 10 days interval @ 50,000/ha. In chemical control, cartap hydrochloride (Padan 4G) was applied @ 25 kg/ha, after 45 days of planting.

The pest incidence in control was significantly higher than all other treatments (13.48 %), while the treatment with high temperature-tolerant strain of *T. chilonis* (6.12%) was on par with chemical control (6.08%) and local strain (6.68%) treatments. The yield in all the treatments (612-617q/ha) was significantly higher than control (515.0q/ha).

(vi) Field evaluation of *Trichogramma japonicum* against *Scirpophaga excerptalis*

IISR, Lucknow

Field evaluation of high temperature-tolerant strain of *Trichogramma japonicum* and the pupal parasitoid, *Tetrastichus howardi* against top borer, *Scirpophaga excerptalis*, was carried out at IISR farm (var. CoLk 8102).

Table 38. Field evaluation of high temperature-tolerant strain of *T. japonicum* and *Tetrastichus howardi* against sugarcane top borer, *Scirpophaga excerptalis*

Treatment	Incidence of top borer (%) in brood				Cane yield(t/ha)
	II	III	IV	V	
T. japonicum (Tj)	11.81	16.64[b]	7.46[ab]	13.05[b]	52.94[b]
Tetrastichus howardi (Th)	13.13	20.37[c]	6.26[a]	12.75[ab]	53.07[b]
Tj + Th	11.31	19.83[c]	5.78[a]	10.12[a]	54.16[b]
Carbofuran 3G	13.65	12.77[a]	6.22[a]	11.04[a]	60.82[a]
Control	14.93	22.23[d]	8.63[b]	13.70[b]	37.77[c]

Means followed by the same letters are not different statistically (P=0.05) by L. S. D.

Table 39. Field evaluation of *Trichogramma japonicum* against *Scirpophaga excerptalis*

Treatment	Incidence of *S. excerptalis* Post release	Per cent parasitism	Yield (q/ha)
T. japonicum @ 50,000/ha (6 releases)	7.52[a]	19.35	740.5[a]
Phorate 10G @ 30kg/ha	7.28[a]	3.60	743.3[a]
Control	15.72[b]	4.60	620.6[b]

Means followed by the same letters are not different statistically (P=0.05)

Trichogramma japonicum was released @ 100000 adults /ha at weekly interval (at start of egg laying in each brood *i.e.* 3 releases in each brood) and *T. howardi* @ 5,000adults/ha once at pupal stage in each brood and Furadan 3G @ 1kg.a.i/ha was applied against III brood of top borer only in synchronization with pest activity (last week of June).

The incidence of the top borer (II brood) in the treatment ranged from 11.3 to 14.9%, which was on par with control (Table 38). The incidence of III brood ranged from 12.8 to 22.2%. The suppressive role of bioagents was significant in IV and V brood. Significantly higher cane yield was obtained in bioagent & chemical treatments in comparison to control. Only *T. japonicum* could be recovered from released plots.

PAU, Ludhiana

Trichogramma japonicum was evaluated against *S. excerptalis* and the results were compared with chemical control and untreated control. The parasitoid was released 6 times at 10 days interval during May-June @ 50,000/ha. In chemical control, phorate (Thimet 10G) @ 30kg/ha was applied during last week of June.

The incidence of top borer in control (15.72%) was significantly higher than in parasitoid released (7.52) and chemical control (7.28) plots (Table 39). The yield in control (620.6q/ha) was significantly lower than in released fields (740.5q/ha) and chemical control (743.3q/ha).

(vii) Efficacy of EPN (*Heterorhabditis indica*) in controlling white grub in sugarcane

Regional Centre (CCSHAU), Karnal

Heterorhabditis indica @ 0.5, 1.0, 1.5 and 2.0 billion IJs per ha was applied along the furrows coinciding with the first instar of the grub. The standard recommended insecticide Phorate @ 2 kg a.i. per ha was used for comparison.

The pre-treatment mean population of grubs per meter row length ranged from 0.69 to 1.2. At 30 days after application, *H. indica* treated plots recorded a mean number of 0.3 to 1.33 grubs in a meter row length, the value being minimum in the plot receiving the highest number of infective juveniles. The grubs infected with EPN increased from 4.7 % to 15.9 % as the dosage increased. The insecticide-treated plot registered 63.7 per cent reduction in infestation.

BIOLOGICAL CONTROL OF COTTON PESTS

(i) Biointensive Pest Management (BIPM) for *Bt* Cotton

Four modules, *viz.*, *Bt* cotton+BIPM, non-*Bt*+BIPM, *Bt* cotton+farmers' practice and non-*Bt* cotton+farmers' practice, were evaluated in the field in ANGRAU, TNAU, GAU, and PAU.

ANGRAU, Hyderabad

The sucking pest population was in general higher on *Bt* cotton grown under BIPM. Square and boll damage was less in *Bt* cotton+BIPM and highest in non-*Bt* cotton+farmers' practices. The square damage was 8.01% in *Bt* cotton+BIPM, while it was 39.83 % in non-*Bt* cotton+farmers' practice. Least boll damage of 7.01 per cent was recorded in *Bt* cotton + BIPM package. However, boll damage was 9.89 per cent in *Bt* cotton+farmers' practice. Non-Bt cotton+BIPM registered 35.72 % damage. Non-*Bt* cotton+farmers' practice recorded maximum damage (42.01%).

Egg parasitism was 6.9 per cent in *Bt* cotton + BIPM package and 3.2 per cent in non-*Bt* cotton with BIPM package. The parasitization was, however, found to be less in both *Bt* cotton and non-*Bt* cotton grown under Farmer's practice. Non *Bt* cotton with BIPM module recorded more number of coccinellid predators (32.78/50 plants) while in *Bt* cotton with BIPM, it was 8.17/50 plants. In Farmer's practice module, both *Bt* and non-*Bt* varieties recorded negligible number of coccinellid beetles. Spider fauna was also higher in BIPM package in both *Bt* cotton and non-*Bt* cotton (29.79 and 23.50/50 plants, respectively) while it was less than 3.0/50 plants in Farmer's practice both in *Bt* and non *Bt* cotton. Maximum yield (1872 kg/ha) was recorded in *Bt* cotton + BIPM followed by *Bt* cotton + Farmer's practice (1103 kg/ha). Non-*Bt* cotton with BIPM package recorded 891 kg/ha. Non-*Bt* cotton with farmer's practices recorded least yield of 726 kg/ha.

AAU, Anand

There was significant reduction in the population of aphid, jassid and whitefly in case of *Bt* cotton + BIPM as compared to non-*Bt* cotton. *Bt* cotton + BIPM package also recorded significantly lower bud and boll damage (0.42 % and 0.41%) compared to non-*Bt* cotton + BIPM (6.20 and 13.17%), while non-*Bt* cotton + GAU schedule recorded 7.23 and 15.65 % bud and boll damage, respectively. *Bt* cotton + BIPM package also recorded lower locule damage (0.82 and 0.79 %) by *E. vittella* and *P. gossypiella*, whereas it was 12.63 % and 23.28 % in case of non-*Bt* cotton + GAU schedule, respectively. *Bt* cotton + existing practice recorded 0.56 and 0.63 % bud and boll damage respectively, and low locule damage (1.13 and 0.94 %) due to *E. vittella* and *P. gossypiella*. The seed cotton yield was also higher in *Bt* cotton + BIPM (2653 kg/ ha) as compared to non-*Bt* cotton + BIPM and non-*Bt* cotton+GAU schedule (2014 kg / ha and 1734 kg / ha), respectively (Table 40). Observations also revealed that the population of various natural enemies like chrysopids, *C. sexmaculata*, *Geocoris*, staphylinids, *Rogas* and *T. chilonis* were higher in case of *Bt* cotton+BIPM and non-*Bt* cotton+BIPM package.

TNAU, Coimbatore

The incidence of *Amrasca biguttula biguttula* in different modules ranged from 2.54 to 5.36 and from 3.00 to 8.40 per plant (three leaves) at Thondamuthur and Singanallur, respectively. The increasing order of incidence of leafhoppers in different modules was Farmers' Package of practies (FPP), MECH 162 *Bt* > BIPM, MECH 162 *Bt* > BIPM, MECH 162 N *Bt* > FPP, MECH 162 N *Bt*. The incidence of aphids was less in the FPP MECH 162 *Bt* module. The mean number of thrips per plant at Thondamuthur was 1.25, 1.60, 1.00 and 3.10 in BIPM MECH *Bt* 162, BIPM, MECH 162 N *Bt*, FPP, MECH 162 *Bt* and FPP, MECH 162 N *Bt*, respectively.

Table 40. Efficacy of biointesive pest management (BIPM) for *Bt* Cotton in Anand

Treatment	Sucking pests / 15 leaves			% Damage by boll worms				Yield(Kg/ ha.)
	Aphid	Jassid	Whitefly	Bud	Boll	Locules		
						E. v.	*P. g.*	
Bt Cotton +BIPM package	3.09^{a}	1.71^{a}	1.72^{a}	3.72^{a}	3.67^{a}	5.19^{a}	5.11^{a}	2653^{a}
Non-*Bt* Cotton +BIPM package	7.91^{c}	2.09^{c}	2.13^{c}	14.42^{b}	21.28^{b}	19.94^{b}	27.84^{b}	2014^{b}
Bt Cotton + existing package of practices	3.54^{b}	1.94^{b}	1.86^{b}	4.29^{a}	4.54^{a}	6.11^{a}	5.56^{a}	2625^{a}
Non-*Bt* Cotton + GAU schedule	8.54^{d}	2.43^{d}	2.39^{d}	15.60^{c}	23.30^{c}	19.94^{b}	28.85^{c}	1734^{b}

Table 41. Incidence of bollworms, their damage and seed cotton yield in different BIPM modules at Thondamuthur

Modules	Mean larval population / Plant		Bollworm damage (%)				Seed cotton yield (kg ha^{-1})
	H. armigera	*E. vittella*	Fruiting bodies	Open boll	Locule	Interlocule	
BIPM - MECH 162 *Bt*	0.40^{a}	0.09^{a}	1.30^{a}	1.95^{a}	0.90^{a}	1.05^{a}	2040^{d}
BIPM - MECH 162 Non *Bt*	0.91^{c}	0.19^{c}	2.45^{c}	3.50^{c}	1.85^{c}	2.25^{c}	1680^{d}
FPP - MECH 162 *Bt*	0.47^{b}	0.10^{b}	1.80^{b}	2.50^{b}	1.40^{b}	1.50^{b}	1740^{d}
FPP - MECH 162 Non *Bt*	1.40^{d}	0.71^{d}	6.02^{d}	7.30^{d}	3.40^{d}	4.10^{d}	1480^{d}

*Mean of ten observations over the season; Means followed by different letters within a column indicate significant differences (P=0.05).

The mean number of whiteflies at both the locations ranged 1.04-2.50 and 1.20-2.96, respectively. Lower incidence of sucking pests was recorded in FPP+ MECH 162 *Bt* module plots.

Bt cotton recorded lower *H. armigera* population than MECH 162 N *Bt*. There was no significant difference in the incidence of *H. armigera* between BIPM MECH 162 *Bt* (0.40) and FPP MECH 162 *Bt* (0.47) module at Thondamuthur (Table 41). In the field trials at Singanallur MECH 162 N *Bt* recorded higher *H. armigera* incidence (2.60). Similar trend was noticed in the spotted bollworm incidence. *Bt* cotton recorded significantly lower population (0.25) than non-*Bt* (0.57). The order of occurrence of *E. vittella* in different modules was BIPM MECH 162 *Bt* > FPP MECH 162 *Bt* > BIPM MECH 162 N *Bt* > FPP MECH 162 N *Bt*.

The per cent fruiting body damage in different modules was in the order, BIPM MECH 162 *Bt* > FPP MECH 162 *Bt* > BIPM MECH 162 N *Bt* > FPP MECH 162 N *Bt* at Thondamuthur. The per cent bollworm damage in both locations showed the same trend.

MECH 162 *Bt* protected with BIPM recorded a yield of 2040 kg ha^{-1}, whereas FPP module recorded 1740 kg ha^{-1} (Table 66). In Singanallur trial, the yield was 2110 kg ha^{1} in BIPM MECH 162 *Bt*, and 1780 kg ha^{-1} in FPP MECH 162 *Bt*. *Bt* cotton under BIPM or FPP performed better in reducing the bollworm damage and gave higher seed cotton yield compared to non-*Bt*. The BIPM modules recorded significantly higher number of natural enemies such as chrysopids, coccinellids and spiders than the FPP modules (Table 42).

Table 42. Incidence of natural enemies in different modules at Thondamuthur (T) and Singanallur (S)

Modules	Mean number of insects (per leaf) over the season *			
	Green lacewings		Coccinellids	
	T	S	T	S
BIPM MECH 162 *Bt*	0.45[a]	0.45[d]	1.84[a]	2.14[a]
BIPM MECH 162 N *Bt*	0.41[b]	0.41[c]	1.38[b]	1.14[b]
FPP MECH 162 *Bt*	0.28[c]	0.26[b]	1.34[c]	1.08[c]
FPP MECH 162 N *Bt*	0.32[d]	0.10[a]	1.20[d]	0.80[d]

*Mean of ten observations

Means followed by different letters within a column indicate significant differences (P=0.05)

(ii) Evaluation of pesticide-tolerant strain of *Trichogramma chilonis* on cotton

The pesticide-tolerant strain of *T. chilonis* developed by PDBC, Bangalore, was compared with local strain and local recommended spray schedule at PAU, GAU and UAS, Dharwad.

PAU, Ludhiana

The incidence of spotted bollworm and *H. armigera*, among the intact fruiting bodies was the lowest with PAU strain (4.70%), followed by pesticide-tolerant strain (4.84%) of *T. chilonis* and significantly lower than PAU spray schedule (6.82%) and control (38.12%). The incidence of bollworms among green bolls was lowest in treatment with pesticide-tolerant strain (4.08%) and it was significantly lower in PAU strain (6.70%) than in PAU spray schedule (8.94%) and control (32.04%) (Table 43).

The parasitisation of *H. armigera* eggs was higher (11.20%) when pesticide-tolerant strain was released and it was significantly higher than treatment with PAU strain (9.32%), control (0.92%) and PAU spray schedule (0%). Highest yield (18.40q/ha) was obtained with releases of pesticide-tolerant strain of *T. chilonis* which was on par with PAU strain release (17.90q/ha), which in turn was on par with PAU spray schedule (17.16q/ha). Significantly lowest yield (5.52q/ha) was obtained in control.

UAS, Dharwad

The experiment was laid out using the variety NCS-145 (Bunny hybrid). The plots where multiple-insecticide resistant strain (MRS) of *Trichogramma chilonis* was released had less fruiting body damage (30.4%) as compared to laboratory strain and control (39.46 and 47.65 per cent, respectively) (Table 44). The good opened bolls were also higher (12.20/plant) in *T. chilonis* (MRS) released plots as compared to lab strain released plots (8.30 bolls per plant) and control plots (5.22 bolls/plant). Lab strain released plots recorded relatively higher number of bad opened bolls (8.20 bolls/plant) as compared to MRS released blocks (5.60 bolls/plant). MRS plots recorded higher seed cotton yield (7.95 q/ha) than lab strain plots and control (5.85 and 2.12 q/ha, respectively).

The recovery of field released *T. chilonis* was evaluated to understand their capacity to survive under sprayed field conditions. The recovery was higher (24.00%) in multiple resistant strain treatment and low in laboratory strain treatment (8.00%). A similar trend was noticed in all four recoveries. In general, the multiple resistant strain survived better than laboratory strain under sprayed field conditions.

AAU, Anand

Insecticide-tolerant and local strains of *T. chilonis* were equally effective in reducing bud and boll damage

Table 43. Evaluation of pesticide tolerant strain of *Trichogramma chilonis* on cotton (var. Ankur 651) in Punjab

Parameters	Release of *T. chilonis*		PAU spray schedule	Control
	PT strain	PAU strain		
Incidence among fruiting bodies (%)				
SBW	0.58[a]	0.76[ab]	0.96[b]	4.86[c]
Ha	4.26[a]	3.94[a]	5.86[b]	33.26[c]
SBW+Ha	4.84[a]	4.70[a]	6.82[b]	38.12[c]
Incidence among green bolls (%)				
SBW	0.26[a]	0.94[b]	1.76[c]	3.26[d]
Ha	3.82[a]	5.76[b]	7.18[c]	28.78[d]
SBW+Ha	4.08[a]	6.70[b]	8.94[c]	32.04[d]
Parasitization of *H. armigera* eggs	11.20[d]	9.32[c]	0.00[a]	0.92[b]
Yield (q/ha)	18.40[a]	17.90[a]	17.16[a]	5.52[b]

SBW = Spotted bollworm, Ha = *Helicoverpa armigera*, PT= Pesticide tolerant strain

Table 44. Evaluation of multiple-insecticide tolerant strain of *Trichogramma chilonis* at Dharwad

Parameters	*T. chilonis* (MRS)	*T. chilonis* (lab strain)	Control
Per cent fruiting bodies damage	30.40	39.76	47.65
GOB per plant	12.20	8.30	5.22
BOB per plant	5.60	8.20	11.25
Yield (Quintal/ha)	7.95	5.85	2.12

GOB: Good opened bolls; BOB: Bad opened bolls

due to bollworms on Hybrid Cotton 10. The bud and boll damage was 7.26 per cent and 10.97 per cent, respectively, in case of insecticide tolerant strain whereas it was 7.68 and 11.31 per cent, respectively, in case of local strain. The bud and boll damage in untreated plot was 16.10 and 23.12 per cent, respectively. The locule damage due to *E. vittella* was also significantly lower in plots that received insecticide-tolerant strain (12.51%) and local strain (13.14%), compared to untreated control (32.11%). Similarly, the damage due to *P. gossypiella* in the above treatments was 14.13, 14.67 and 31.45 %, respectively. The per cent parasitism by *T. chilonis* was found to be 33.17, 30.67 14.17 and 7.83 % in case of insecticide tolerant strain treated , local strain treated, check and farmer's practice plots, respectively.

The seed cotton yield in insecticide tolerant and local strain treated plots was 2028 kg/ha and 1958 kg/ha, respectively. The control plot recorded 1305 kg/ha seed cotton yield.

Field results at Nagpur

Effectiveness of the two strains, *viz.* MITS and high temperature tolerant strain (HTTS) of *T. chilonis* was assessed in a field experiment at Nagpur. The mean levels

Table 45. Parasitisation of *H. armigera* eggs by *T. chilonis* strains

Observation	No. of eggs collected	Parasitisation (% mean) by *T. chilonis* strains	
		Heat-tolerant	Insecticide-tolerant
1st	25	16.3	26.6
2nd	25	33.3	33.3
3rd	10	6.6	10
4th	10	50	40
Mean	17.5	26.6	27.5

of parasitisation assessed by collection of *H. armigera* eggs from *Trichogramma* released plots are furnished in Table 45.

Cotton (NCS-145 – Bunny cotton hybrid) was sown in three treatments separately and the recovery of egg parasitoids was higher in MITS (24.0%) as compared to lab strain (8.0%) in all four recoveries. The mean egg parasitism in MITS block was 17.1% as compared to 5.1% in the lab strain released plots.

In the treatments where MITS was released, less damage to fruiting bodies (30.4%) was recorded as compared to lab strain released treatments (39.8%) and untreated control (47.7%), respectively. The good opened bolls (GOB) were also more (12.2 / plant) in MITS plots as compared to 8.3 bolls/plant in lab strain treatment and 5.2 bolls/plant in untreated control. Similarly bad opened bolls (BOB) were significantly lower in MITS plots as compared to lab strain released plots and untreated control.

(iii) Standardization of release points for *Trichogramma chilonis*

Studies were carried out at Anand and Ludhiana. The treatments comprised releases at 100 points/ha (100 bits of egg card/ha, each bit containing 1500 parasitised eggs), 150 points/ha (150 bits of egg card/ha, each bit containing 1000 parasitised eggs) and 200 points/ha (200 bits of egg card/ha, each bit containing 750 parasitised eggs). The releases were made @1,50,000/ week.

AAU, Anand

Trichogramma chilonis releases on Hybrid 10 at 200 points proved significantly more effective than releases at 150 points and 100 points. The extent of bud and boll damage was 5.58 and 11.87 per cent, respectively. The locule damage due to *E. vittella* was also significantly lower and seed cotton yield higher (1829 kg/ha) when *Trichogramma* was released at 200 points compared to 100 points (1611 kg/ha).

PAU, Ludhiana

The trial was carried out on cotton hybrid Ankur-651. The parasitoids were released 11 times at weekly interval from July to September @ 1,50, 000 per ha. The incidence of bollworm complex among the intact fruiting bodies in control (35.48 %) was significantly higher than releases of *T. chilonis* at different number of points (16.79 to 23.10 per cent) (Table 46). The lowest incidence (16.79%) was recorded in adult releases and it was significantly lower than releases in the form of tricho-cards. The total bollworm incidence in control among green bolls (37 %) was significantly higher than releases of *T. chilonis* (14.14-25.16%). The lowest incidence (14.14%) was recorded in adult releases, significantly lower than releases as tricho-cards. The parasitisation of *H. armigera* eggs in control (1.14%) was significantly lower than that in releases of *T. chilonis*. The highest parasitisation (19.64%) was recorded in adult releases and it was significantly higher than releases through trichocards (11.72 to 14.98%). The seed cotton yield in *T. chilonis* releases (6.00 to 9.26q/ha) was

Table 46. Standardization of release points for *Trichogramma chilonis* on cotton in Punjab

Parameters	100 points/ ha	150 points/ ha	200 points/ ha	Adults	Control
Incidence among fruiting bodies (%)					
SBW	3.78^{a}	3.00^{a}	2.41^{a}	1.98^{a}	5.76^{a}
Ha	19.32^{a}	16.96^{a}	16.00^{a}	14.81^{a}	29.72^{a}
SBW & Ha	23.10^{c}	19.96^{bc}	18.41^{c}	16.79^{b}	35.48^{d}
Incidence among green bolls (%)					
SBW	6.24^{d}	5.71^{c}	5.22^{b}	3.96^{a}	6.76^{e}
Ha	18.92^{d}	16.26^{c}	14.78^{b}	10.18^{a}	30.24^{e}
SBW & Ha	25.16^{d}	21.97^{c}	20.00^{b}	14.14^{a}	37.00^{e}
Parasitization of *H. armigera* eggs	11.72^{b}	13.20^{c}	14.98^{d}	19.64^{e}	1.14^{a}
Yield (q/ha)	6.00^{c}	7.12^{b}	7.86^{b}	9.26^{a}	5.08^{c}

SBW = Spotted bollworm, Ha = *Helicoverpa armigera*

significantly higher than control (5.08q/ha). The highest yield (9.26q/ha) was recorded in adult releases and was significantly higher than releases in the form of tricho-cards. Releases of *T. chilonis* as adults proved better than releases in the form of tricho-cards for the control of bollworm complex, increasing egg parasitisation and seed cotton yield.

(iv) Influence of cotton cultivars/hybrids on the parasitisation efficiency of *Trichogramma chilonis*

AAU, Anand

The influence of the release of *Trichogramma chilonis* (@ 1,50,000/ha/week (6–8 releases) and five tricho bits/treatment with each bit containing 600 parasitised eggs) on the cultivars G.Cot Hy.6, G.Cot Hy.8, G.Cot Hy.10, G.Cot 10 (Desi) and G.Cot 16 was studied. Parasitism by *T.chilonis* ranged from 15.67 in G.Cot10 to 29.33% in G.Cot Hy.10. Considering the per cent parasitism (29.33) and yield (1972 kg/ha), G.Cot Hy.10 appeared to be more conducive to *T. chilonis* releases (Plate 8).

PAU, Ludhiana

Seventeen cultivars/hybrids of cotton were evaluated. There were significant differences in parasitisation of *H. armigera* eggs among different cultivars/ hybrids (Table 47). The highest parasitisation was observed on RCH 138 *Bt* (23.24%), followed by RCH 317 *Bt* (22.32%) and RCH 134 *Bt* (21.36%) and it was significantly higher than all other cultivars/ hybrids. The highest seed cotton yield was obtained in RCH 134 *Bt* (32.19q/ha), which was significantly higher than all other cultivars.

Plate 8 : Maize and *Cassia occidentalis* for conservation of natural enemies in cotton ecosystem

(v) Field trial on the use of kairomones to increase the efficiency of chrysopids in cotton ecosystem

UAS, Dharwad

The trial was laid out on variety NCS–145 (Bunny

Table 47. Influence of cotton cultivars/ hybrids on the parasitisation efficiency of *T. chilonis* at Ludhiana

Varieties/hybrids	Parasitization of *H. armigera* eggs	Seed cotton Yield(q/ha)
Ganga kaveri 151	18.20^{c}	20.26^{e}
Dhawal 2	17.10^{bc}	21.04^{de}
Ankur 651	18.80^{c}	22.20^{d}
LHH 144	17.80^{bc}	21.40^{de}
RCH 134	19.20^{c}	24.42^{c}
RCH 138	18.30^{c}	23.60^{c}
White gold	19.60^{cd}	19.90^{ef}
RCH 134 *BT*	21.36^{d}	32.19^{a}
RCH 138 *BT*	23.24^{d}	29.08^{b}
RCH 317 *BT*	22.32^{d}	28.43^{b}
LD 694	16.20^{b}	18.20^{fg}
LD 327	17.10^{bc}	15.70^{h}
F 846	15.30^{ab}	17.04^{gh}
F 1861	14.20^{a}	17.42^{g}
F 1370	16.10^{b}	19.42^{ef}
LH 1556	17.00^{bc}	18.96^{ef}
Moti	18.10^{c}	18.80^{f}

Table 48. Effect of L-tryptophan (Kairomone) on boll damage and yield in cotton

Parameters	Treated plot	Treated control	Untreated control
Per cent fruiting bodies damaged	21.34	26.84	48.44
GOB per plant	22.12	18.12	11.44
BOB per plant	8.2	12.22	26.48
Yield q/ha	22.44	20.12	13.15

hybrid) and kairomone-treated and chrysopid released plots were compared with chrysopid released plots alone and untreated control.

After the first spray of L-tryptophan, there was a slight increase in the population of chrysopids. The population of chrysopid eggs, larvae, adults and cocoons was 0.38, 0.28, 0.38 and 0.08 per plant, respectively, in the treated plot as compared to treated control where the population was 0.32, 0.20, 0.18 and 0.02 per plant, respectively. Untreated control recorded very low population of chrysopids.

The kairomone-treated plot recorded minimum damage to fruiting bodies (21.34 %) as compared to treated control and untreated control (26.84 and 48.44

Table 49. Efficacy of microbial insecticides against *H. armigera* on lablab

Treatments	*H. armigera* (Larva/plant)*	Pod damage (%)**	Seed damage (%)	Yield(kg/ha)
Bt @ 1.0 kg / ha	1.40^{a}	4.15^{a}	3.40^{a}	2140^{a}
Ha NPV @1.5 x10^{12} POBs / ha	2.23^{d}	8.45^{b}	7.92^{c}	1970^{ab}
Ha NPV @0.75x10^{12} POBs/ ha	1.61^{b}	4.61^{a}	4.87^{a}	1830^{bc}
Ha NPV @ 0.375x 10^{12} POBs /ha	1.84^{c}	7.28^{b}	6.97^{ab}	1690^{c}
N. rileyi @ 1x10^{13} conidia / ha	2.49^{e}	10.27^{c}	9.47^{c}	1380^{d}
Insecticidal check	2.27^{d}	10.34^{c}	9.49^{c}	1170de
Control	3.15^{f}	14.79^{d}	13.84^{d}	970^{e}

Means followed by different letters within a column indicate significant differences (P=0.05)

%, respectively). Similarly, maximum good open bolls (GOB) and minimum bad open bolls (BOB) were recorded in treated plot. Maximum seed cotton yield (22.44 q/ha) was recorded in treated plot as compared to treated control and untreated control (20.12 and 13.15 q/ha, respectively) (Table 48).

BIOLOGICAL CONTROL OF TOBACCO PESTS

(i) Biological control of *Helicoverpa armigera* in tobacco

CTRI, Rajahmundry

Field trials were conducted to evaluate *Nomuraea rileyi* (10^{12} spores/ha and 10^{13} spores/ha), *B.t. kurstaki* (1 kg/ha), and *Ha* NPV (1.5 x 10^{12} POB/ha) against *H. armigera* on tobacco with a control (water spray).

All the treatments were superior to untreated control in terms of larval count per panicle, per cent capsules damaged per plant, and seed yield per ha in the order *N. rileyi* @10^{13} spores/ha > *N. rileyi* 10^{12} spores / ha> *Btk* >*Ha* NPV.

BIOLOGICAL CONTROL OF PULSE CROP PESTS

(i) Evaluation of BIPM package in soybean

CTRI, Rajahmundry

The study comprised of BIPM Package (release of *Telenomus remus* against *Spodotera litura* @ 100,000/ ha coinciding with egg laying and spraying of *Sl*NPV 3 times @ 1.5 x 10^{12} POB/ha along with 0.5% crude sugar as adjuvant) and chemical control (two sprays of monocrotophos and chlorypyrifos each against leaf webber and *Spodoptera litura* @ 1.5 and 2.5 ml per litre, respectively).

BIPM package was better with the mean larval population of *S. litura* per plant significantly lower (10.42) than in chemical control (14.53). The mean plant damage was 4.58 % in BIPM and 6.68 % in chemical control. The yields were 10.25 q/ha in BIPM and 8.75 q/ha in chemical control.

(ii) Microbial control of *H. armigera* and *Adisura atkinsoni* on lablab

AAU, Anand

Application of *Bt* @ 1.0 kg / ha provided greater control of the larval population of *H. armigera* (0.96) with lowest per cent pod damage (0.52) and per cent seed damage (0.35), which were on par with higher dose of *Ha*NPV @ 1.5X10^{12} POB / ha. The yield from *Bt*-treated plots (2140 kg / ha) was significantly higher than control (970 kg / ha) and statistically on par with *Ha*NPV @ 1.5 X 10^{12}POBs / ha (1970 kg / ha) (Table 49).

(iii) Evaluation of *Heterorhabditis* sp. against *Mylabris pustulata* and lepidopteran pod borers in pigeonpea

AAU, Anand

Release of EPN @ 1.5 billion/ha was significantly

Table 50. Evaluation of *Heterorhabditis* sp. against *H. armigera* and blister beetle on pigeon pea

Treatment	H. armigera larvae (No./5 terminal shoots/plant)				Blister beetle (No./5 terminal shoots/plant)				Pod damage (%)	Seed damage (%)	Yield (kg/ha)
	Before spray	After spray			Before spray	After spray					
		3 days	7 days	10 days		3 days	7 days	10 days			
EPN@0.5b/ha	3.80^{a}	3.46^{a}	3.31^{a}	3.31^{a}	3.28^{a}	3.19^{a}	3.00^{ab}	2.79^{b}	17.69^{b}	16.51^{b}	845^{b}
EPN@1.0b/ha	4.00^{a}	3.87^{c}	3.74^{c}	3.60^{b}	3.32^{a}	3.19^{a}	3.03^{b}	2.83^{c}	16.61^{b}	15.81^{b}	870^{ab}
EPN@1.5b/ha	3.74^{a}	3.60^{b}	3.46^{b}	3.31^{a}	3.46^{a}	3.25^{a}	3.03^{b}	2.72^{a}	13.55^{a}	13.82^{a}	925^{a}
Untreated check	4.12^{a}	3.92^{d}	3.79^{d}	3.79^{c}	3.40^{a}	3.40^{b}	3.31^{c}	3.28^{d}	23.12^{c}	18.35^{c}	813^{c}

better than all the other treatments and untreated control for the management of *H. armigera* and blister beetle. The treatment proved effective for the control of *H. armigera* from the third day onwards while for blister beetle after seven days (Table 50). Treatments of 0.5 and 1.0 billion nematodes/ha were on par with control. Similar trends were observed in per cent seed damage, pod damage and yield.

3.7. BIOLOGICAL CONTROL OF RICE PESTS

(i) Isolation of fungal pathogens from rice ecosystem

AAU, Jorhat

Entomofungal pathogens, *Fusarium* sp., *Penicillium, Aspergillus, Beauveria bassiana* and *Alternaria* sp. from leaf folder, and *B. bassiana* and *M. anisopliae* from leafhoppers, were isolated.

(ii) Evaluation of biointensive IPM for rice stem borer and disease management

AAU, Jorhat

The IPM module (comprising the use of moderately resistant variety, *Trichoderma viride* as seed treatment, releases six of *Trichogramma japonicum* @ 50,000/ha/week, spray of *Pseudomonas fluorescens*, need-based insecticidal application and use of bird perches @10/ha) was compared with chemical control and farmers' practice.

The pre-treatment dead heart incidence ranged 4.61-4.94 %. At 58 days after transplantation, significant reduction of dead heart in IPM (2.23 %) and chemical control (3.41 %) was observed as against farmers' practice (10.27 %) (Table 51). The white ear head (WEH) population was also significantly lower in the IPM (2.90 %) and chemical control plots (4.15 %) than in farmers' practice (11.41 %). The yield was significantly higher in the IPM plot (4707 kg/ha) and insecticide-treated plot (3676 kg/ha) than in farmer's practice (3002 kg/ha). The cost-benefit ratio was highest in BIPM (1:2.40) as compared to farmer's practice (1: 1.59) and chemical control (1:1.58).

(iii) Evaluation of *Trichogramma japonicum* against rice leaf folder and stem borer

AAU, Jorhat

Trichogramma japonicum and *T. chilonis* @ 1,00,000/ha were released alone and in combination at weekly intervals coinciding with the first occurrence of either of the pest. Chlorpyriphos was applied in the chemical control plot. During rabi 2004, at 58 DAT there was significant difference in per cent dead heart (3.67 and 3.90) and per cent ear heads (3.74 and 3.53), when the parasitoids were released individually. During kharif 2004, lower incidence of white ear head (2.51%) was observed in the plot receiving both species than in control (10.24 %). Release of *T. japonicum* alone was as effective as combination of both species.

Table 51. Evaluation of bio-intensive IPM module for rice stem borer (Kharif 2004) at Jorhat

Treatments	Per cent dead hearts (4th week)	% WEH	Yield kg/ ha
IPM Module	2.23 [a]	2.90 [a]	4707 [a]
Chemical control	3.41 [b]	4.15 [a]	3976 [b]
Farmers practice	10.27 [c]	11.41 [b]	3002 [c]

The occurrence of leaf folder before treatment ranged from 4.43 % to 6.5 % during rabi 2004. The leaf folder damaged leaves declined from 2nd week onwards after the field release of the parasitoids and ranged from 0.84 to 1.31 at 65 DAT. During kharif 2004, the leaf folder damaged leaves declined after the 2nd release (1.99 %) in the plot receiving combined releases, followed by the plot receiving *T. japonicum* (1.53 %). Yield during both kharif and rabi was, however, highest in *T. japonicum* released plots (4027 and 4063 kg/ha, respectively).

KAU, Thrissur

The trial was conducted during kharif and rabi seasons with the same treatments as above except for the use of monocrotophos (0.05%) and an untreated control.

During Kharif, mean leaf folder incidence was on par in all the treatment plots (4.55-7.09) except in control (13.85). Pooled mean percentage dead hearts was significantly lower in chemical control plot (2.74) than in *T. japonicum* + *T. chilonis* (5.13) and *T. japonicum* (5.52) released plots. Maximum white earheads were recorded in control plot (8.5) and least in *T. japonicum* released plot (3.5). All the treatments were on par in the case of white earhead infestation. Significantly lower yield was recorded in control plot (3125 kg/ha) than all other treatments. Maximum yield was recorded in chemical control plot (3850 kg/ha), which was on par with *T. japonicum* (3775 kg/ha) and combination of *Trichogramma* spp. (3725 kg/ha) released plots.

During rabi, the leaf folder incidence was on par in all the treatment plots (1.00 – 1.09), while in control it was 6.73 (Table 52). Stem borer incidence in all the treatments was on par (3.02-4.17) and significantly lower than control (4.96). The highest yield was recorded in *T. japonicum*-released plot (3750 kg/ha), which was significantly higher than control (3688 kg/ha).

The pooled data obained during three seasons show that all the treatments were equally effective with no significant difference between them in reducing the damage by the leaf folder and stem borer. In untreated control there was significantly higher incidence of leaf folder (8.20% leaf damage and stem borer 9.19% dead hearts). Highest yield was recorded in *T. japonicum* @ 1 lakh/ha released plot (3604.17 kg/ha), followed by chemical control plot (3579.17 kg/ha) and *T. japonicum*+*T. chilonis* @50,000/ha released plot (3545.83 kg/ha). Lowest grain yield was recorded in control (3112.5 kg/ ha). The cost-benfit ratio was highest in *T. japonicum* treatment (1:1.16), which was on par with chemical control (1:1.15).

PAU, Ludhiana

Trichogramma japonicum alone and in combination with *T. chilonis* was evaluated for the management of leaf folder on rice (cv. Pusa Basmati).

The per cent leaves folded was significantly lower in all the treatments as compared to control (2.34%, 45DAT and 6.75%, 60DAT). The lowest incidence (0.00%, 45DAT and 0.75%, 60DAT) was recorded with *T. chilonis*+*T. japonicum* treatment and it was significantly lower than all other treatments. The per cent dead hearts (0.64%, 45DAT and 1.3%, 60DAT) and white ears (4.17%) were lowest in plots where both parasitoids were released and it was significantly lower than all other treatments except chemical control (0.97%, 60DAT). The yield in control (36.0q/ha) was significantly lower than all other treatments. The

Table 52. Evaluation of *Trichogramma japonicum* against rice leaf folder

Treatments	AAU, Jorhat		KAU, Thrissur		PAU, Rabi
	Rabi	Kharif	Rabi	Kharif	
	45 DAT	45 DAT	45 DAT	45 DAT	45 DAT
Tj + Tc @ 1,00,00/ha	1.54^{b}	1.99^{ab}	1.07^{b}	8.76^{b}	0.00^{a}
Tj @ 1,00,000/ ha	1.76^{b}	1.53^{a}	1.00^{b}	10.89^{b}	1.37^{c}
Tc @ 1,00,000/ha	1.37^{a}	2.17^{b}	1.09^{b}	7.88^{b}	0.60^{b}
Chemical control	1.41^{a}	1.61^{a}	0.57^{b}	7.76^{b}	0.60^{b}
Untreated control	3.63^{c}	5.18^{c}	6.73^{a}	21.81	2.34^{d}

Tj: *Trichogramma japonicum*; Tc: *Trichogramma chilonis*

highest yield was obtained with chemical control (52.7q/ha), followed by combined releases of parasitoids (51.0q/ha).

(iv) Evaluation of fungal pathogens on sucking pests of rice

KAU, Thrissur

The efficacy of *Beauveria bassiana* and *M. anisopliae* was evaluated against sucking pests of rice. The treatments included *B. bassiana* aqueous suspension 10^{13} spores/ha +Tween 80 (0.02%); *M. anisopliae* aqueous suspension 10^{13} spores/ha+Tween 80 (0.02%); one spray of imidacloprid (0.01%); and untreated check. Three rounds of foliar sprays were applied in all the treatment plots.

In Kharif, the counts of hoppers were least in chemical control plot (1.17). The mean number of hoppers/hill was 3.52 and 3.88 in *M. anisopliae* and *B. bassiana* treated plots, both being on par. It was highest in control plot (8.72). Rice bug population was also significantly lower in *B. bassiana* (0.08/hill) and *M. anisopliae* (0.20/hill) treatments than in untreated control (0.44/hill).

The yield was maximum in chemical control plot (4460 kg/h), but on par with *B. bassiana* treated plot (4450 kg/ha).

In Rabi, pooled data revealed significantly lower hopper numbers in chemical control plot (0.72), followed by *M. anisopliae* (3.32) and *B. bassiana* sprayed plots (4.22) than control (10.85). Rice bug incidence did not differ between treatments (0.48 to 0.88/hill). Grain yield did not differ significantly, but was maximum in *M. anisopliae* treated plot (3800 kg/ha) and least in control plot (3200 kg/ha).

The pooled results of both seasons showed that in the treatment plots, the counts of hoppers were on par and significantly higher in control plot. Least hopper counts were recorded in chemical control plot. Maximum grain weight was recorded in *B. bassiana* treated plot (3712.50 kg/ha) followed by chemical control (3709 kg/ha) and *M. anisopliae* treated plots (3580kg/ha). Least yield was recorded in control plot (3161.50 kg/ha). The net profit (Rs.3861/ha) and cost-benefit ratio (1:1.17) was higher in *B. bassiana* treated plots, but this was on par with chemical control (Rs.3836/ha and 1:1.17, respectively).

AAU, Jorhat

Foliar sprays of the fungi were applied during evening hours using high volume sprayer. Green leaf hopper (GLH) was noticed in greater numbers followed by white back plant hopper (WBPH). Both *B. bassiana* and *M. anisopliae* were effective against sucking pests, but inferior to chemical insecticides. Mycosed insects were seen in the fungus-treated plots, while no mycosed insects were found in the untreated and chemical control plots the yield was highest (4465 kg/ha) in chemical

Table 53. Evaluation of fungal pathogens against jassids of rice at Jorhat

Treatments	Mean number of jassids/hill				Yield (kg/ha)
	Pre count before 1st spray	Post treatment	Pre count before 2nd spray	Post treatment	
Beauveria bassiana (10 ^{13} spores/ ha)	14.08	7.80^{b}	5.20^{a}	4.38^{b}	4212.50^{ab}
Metrhizaium anisopliae(10 ^{13} spores/ ha)	13.04	7.60^{b}	5.73^{a}	3.98^{b}	3972.50^{b}
Chemical insecticides	12.04	3.80^{a}	3.63^{a}	2.80^{a}	4465.00^{a}
Untreated check	11.36	12.30^{c}	11.50^{b}	1.00 c	3452.00^{c}

Figures followed by the same letter in a column are not significantly different

control plot, followed by *B. bassiana* sprayed plot (4212 kg/ha). *M. anisopliae* treatment (3972 kg/ha) was superior to control (Table 53).

(v) Impact of organic farming on conservation and augmentation of natural enemies of rice pests

PAU, Ludhiana

The experiment was carried out at Punjab Agricultural University, Ludhiana, on Basmati rice and coarse rice. The organic farming module consisted of green manuring with *Sesbania aculeata* and releases of *Trichogramma chilonis* and *T. japonicum* each @1,00,000/ha/week, 7 times starting 30DAT. In the recommended practice module, urea @ 45kg/ha in 2 splits and two sprays of monocrotophos @1.4 l/ha were applied. In the integrated practice module, urea was applied @ 45kg/ha in 2 splits and 7 releases of *T. chilonis* and *T. japonicum* @1,00,000/ha/week were made, starting the first release at 30DAT.

On basmati rice, the incidence of the leaf folder at 60DAT was slightly higher in recommended practice module (0.96%) as compared to organic practice module (0.29%) and integrated practice module (0.78%). The incidence of stem borer was lower in recommended practices (2.00%, 45DAT and 0.60%, 60DAT) than integrated practices (4.67%, 45DAT and 3.33%, 60DAT) and organic practices (6.67%, 45DAT and 1.36%, 60DAT). The yield in the integrated practice was higher (31.76q/ha) as compared to organic practice (27.90q/ha) and recommended practice (26.96q/ha). Parasitism of recovered egg masses of stem borer by *Trichogramma* sp. was slightly lower in organic practices (27.6%) than integrated practices (29.1%)

The incidence of leaf folder and stem borer in the coarse rice variety PR 116 at 60 DAT was lower in organic practices (0.72% and 2.14%) as compared to integrated practices (0.97% and 3.64%) and recommended practices (1.32% and 4.00%). The yield was highest in integrated practice (66.93 q/ha) as compared to recommended practice (62.04 q/ha) and organic practice (61.54 q/ha).

KAU, Thrissur

The experiment was carried out at District Agricultural Farm, Mannuthy on variety Jyothy during kharif and rabi seasons. Organic farming plot was with exclusive organic inputs (seed treatment with *Trichoderma viride* 4g/kg seed; application of farmyard manure and green leaf manure @ 5 tonnes/ha; two neem-based sprays). In chemical control plot, chemical fertilizers were applied as per package of practices. One spray of imidacloprid (0.01%) against hoppers and one spray of monocrotophos (0.05%) against leaf folder and stem borer were applied.

During kharif, there was no significant difference in percentage dead heart and hopper counts/hill between the treatments, but the percentage leaf folder incidence and blue beetle counts were significantly higher in chemical control (1.04 and 1.48) than organic farming (0.21 and 0.4). The population of spiders and

Table 54. Effect of organic farming on rice pests, natural enemies and yield (pooled mean of four seasons) at Thrissur

Observations	Organic farming	Chemical Control	Significance
Percentage dead heart	2.47	2.69	†
Percentage leaf folder incidence	1.20	1.41	†
Hopper counts/hill	1.14	1.13	†
Yield kg/ha	3770.00	4005.00	†
White ear heads/m²	5.50	7.15	†
No. of spiders /hill	0.48	0.12	Significant at 1% level
No. of coccinellids/hill	0.53	0.12	Significant at 1% level

† Error SS heterogeneous and interaction absent

coccinellids/hill was higher in organic farming (0.346 and 0.8) than chemical control (0.146 and 0.24). There was no significant difference in grain yield between organic farming (3960 kg/ha) and chemical control (4200 kg/ha).

During rabi, the percentage dead heart incidence/ hill was significantly higher in chemical control (2.64) than in organic farming (1.32). White earheads were significantly lower in organic farming plot (3.40/sq.m) when compared to chemical control plot (7.6/sq.m.). Percentage leaf folder incidence (0.36 and 0.53/hill), hopper (0.47 and 0.68/hill) and blue beetle counts (0.10 and 1.18/hill) were on par in organic farming and chemical control, respectively. Numbers of spiders (0.57) and coccinellids (0.36) were significantly higher in organic farming than in chemical control (0.09 and 0.08), respectively. Grain weight was significantly higher in chemical control (4430 kg/ha) than in organic farming (3600 kg/ha).

Pooled data of the seasons indicated non-significant differences in percentage dead heart, percentage leaf folder, hopper count/hill, white earheads/m² and yield between organic farming and chemical control treatment. The coccinellid and spider counts were significantly higher in organic farming than chemical control (Table 54). The cost of cultivation was lower (Rs.19185/ha) and total returns (Rs.26390/ha) higher in organic farming in comparison to chemical control (Rs.19239/ha and Rs.28305, respectively).

BIOLOGICAL SUPPRESSION OF OILSEED CROP PESTS

Biological control of the aphid *Lipaphis erysimi* on mustard

AAU, Anand

The treatments comprised release of *Ischiodon scutellaris* @ 1000 adults/ha and 500 adults/ha; *Verticillium lecanii* @ 10^8 conidia/ml; insecticidal control and control.

Ischiodon scutellaris @ 1000 adults/ha recorded minimum aphid population (4.80 aphid/terminal shoot) and higher yield (3056 kg/ha) and proved superior to *I. scutellaris* @ 500 adults/ha (8.22 and 2444 kg/ha, respectively), *V. lecanii* (14.39 and 2000 kg/ha, respectively) and insecticidal control (12.93 and 1889 kg/ha, respectively).

Table 55. Efficacy of *Verticillium lecanii* against mustard aphid, *Lipaphis erysimi*, in Ludhiana

Treatment	Mean number of aphids/10 cm shoot		Yield (q/ha)
	Pre-treatment	Post-treatment	
V. lecanii (3 sprays)	36.50[a]	269.56[b]	3.94[b]
V. lecanii(2 sprays)	41.16[a]	289.02[b]	3.58[b]
Chemical control	48.34[a]	30.60[a]	9.05[a]
Control	48.92[a]	532.14[c]	2.47[b]

Figures followed by the same letter in a column are not significantly different

Table 56. Population of *O. arenosella* after *G. nephantidis* releases by two methods

Treatment	Pre count (Mean no./leaflet/tree)	Post release count (Mean no./leaflet/tree)	
		V	VI
Trunk release	5.95	0.95[b]	0.50[b]
Crown release	3.90	0.90[b]	0.25[b]
Control	3.45	3.85[a]	3.80[a]

Figures followed by the same letter in a column are not significantly different

PAU, Ludhiana

Sprays of *Verticillium lecanii* (10^8 conidia/ml) (three sprays at 10 days after sowing (DOI) and 2 sprays at 15 DOI) were compared with oxydemeton methyl (2 sprays at 15 days interval) and control. The incidence of mustard aphid was lowest in chemical control in all the post-treatment observations (Table 55). The incidence of mustard aphid in *V. lecanii* sprayed plots was significantly lower than control, three sprays proving better than two. The yield in chemical control was significantly higher (9.05q/ha) than that in *V. lecanii* treated plots (3.94q/ha and 3.58q/ha, with three and two sprays, respectively) and control (2.47q/ha).

BIOLOGICAL SUPPRESSION OF COCONUT PESTS

(i) Evaluation of method of release of *Goniozus nephantidis* against *Opisina arenosella*

KAU, Thrissur

Two methods of release (@ 10 females/trunk) at 4-5 feet above ground level and at the crown of the tree were compared. Six releases were made at fortnightly intervals. There was no significant difference in the population of *O. arenosella* in the different treatments after I[st] release. After II, III, IV, V and VI releases, the population of *Opisina* came down and was significantly lower in parasitoid releases at 4 - 5' height of palm (0.6) and crown releases (0.4) than in control palms (4.2). However, there was no significant difference between the two methods of release.

Pooled analysis of three years' data showed that after six releases of the parasitoid, the population of *Opisina* came down and was significantly lower in the parasitoid released palms than in control palms and both methods of release were equally effective in bringing down the population (Table 56).

(ii) Field evaluation of *Cardiastethus exiguus* against *O. arenosella*

KAU, Thrissur

Cardiastethus exiguus was released @ 50 and 100

Table 57. Evaluation of *C. exiguus* against *O. arenosella* (mean no./leaflet/tree)

Treatments	Larval population of *O. arenosella*		
	Pre-count	Post count after	
	-	II release	III release
50 per tree	4.65	0.95 [b]	0.35 [b]
100 per tree	4.90	0.80 [b]	0.25 [b]
Control	4.60	3.60 [a]	2.95 [a]

Figures followed by the same letter in a column are not & significantly different

nymphs/adults per tree at weekly intervals and compared with a control. There was a significant reduction in the population of *O. arenosella* after I, II and III releases of *C. exiguus* when compared to control. There was no significant difference between the release rates (Table 57).

BIOLOGICAL SUPPRESSION OF TROPICAL FRUIT CROP PESTS

IIHR, Bangalore

(i) Evaluation of *Bacillus thuringiensis* var. *kurstaki* formulations against pomegranate fruit borer, *Deudorix isocrates*

Delfin, Dipel, Biobit and Halt (five sprays @ 1 g/l at weekly intervals) were evaluated for their field efficacy against pomegranate fruit borer, *Deudorix isocrates* and compared with deltamethrin (0.5 ml/l at ten day interval) and unsprayed control. Among the formulations, Dipel @ 1.0 ml/l recorded lesser fruit damage (14.89%) and was on par with deltamethrin treatment (14.90%).

(ii) Integration of *Trichogramma chilonis* with *Bt* for the control of the pomegranate fruit borer, *Deudorix isocrates*

Six weekly releases of *T.chilonis* @ 200/tree/release were made from fruit set onwards and *Bt* was applied @ 1 gm/l at weekly intervals from the time of fruit set. A mean of 16.60, 8.33 and 10.00 per cent fruit damage was recorded in plots treated with *T. chilonis* alone, *T. chilonis* + *Bt* and *Bt* alone, respectively, compared to 21.56% in the check.

(iii) Colonization of the aphelinid parasitoid *Encarsia guadeloupae* on spiralling whitefly on guava

IIHR, Bangalore

Colonization of *E. guadeloupae* on spiralling whitefly infestations was attempted in guava orchards in different areas of Bangalore. In Chikkabanavara, following the releases, parasitisation of 16.28-84.32 % was observed with a reduction is the whitefly population from 47.60 / leaf to 0.85 / leaf in about seven months. In a guava orchard in Cholanayakanahalli, parasitism was 28.48% in August and went up to 86.92% in February with a drastic reduction in the whitefly population.

At Hessaraghatta, the spiralling whitefly and its natural enemies were monitored from April 04 to March 05. *Encarsia guadeloupae* was encountered from April to March. The whitefly population ranged from 0.60/leaf in April to 7.00/leaf in November. The parasitism by *E. gaudeloupae* was found to be very high round the year, ranging from 90.00% in November 03 to 96.20% in June 04.

MPKV, Pune

A guava orchard of one hectare with whitefly infestation was selected for inoculative release of *E. guadeloupae*. The parasitism of *E. guadeloupae* increased from 5.68 to 11.50 % within two months of release, indicating its establishment.

(iv) Field evaluation of *Metarhizium anisopliae* against mango hoppers

IIHR, Bangalore

Three concentrations of *M. anisopliae*, viz., 1x10^{8},

$1x10^8$ and $1x10^7$ spores/ml along with the check (Imidacloprid 0.25ml/L) and control (distilled water) were evaluated against mango leafhopper. *Metarhizium anisopliae* caused 58 - 77 % mortality of mango hoppers in 72 hours as compared to 100 % mortality in imidacloprid treatment and 7.33% in water spray.

(v) Demonstration trials on the biological control of grape mealybug

IIHR, Bangalore

The efficacy of *Cryptolaemus montrouzieri* against grape mealybugs was demonstrated in a grape garden at Ajwara near Chikkaballapur. The predator was released @ 10 /plant on 75th day and again on 85th day after pruning. Fifteen days prior to the predator release and thereafter until harvesting of the bunches, insecticidal application was suspended. The number of healthy and mealybug infested bunches were counted on 20 plants at random. The bunches infested with mealy bugs at the time of harvest ranged from 0 to 2% (mean=0.41). There was an overall reduction of 80% bunch damage as compared to the previous crop. The larvae of *Cryptolaemus* were found feeding on the mealybugs in infested bunches at the time of harvesting.

MPKV, Pune

The effectiveness of *C. montrouzieri* for the control of mealybugs was demonstrated in a field of one hectare. Three releases of *C. montrouzieri* @ 1,000 adults/ ha with initial release one month after pruning were carried out at monthly interval. There was gradual reduction in mealybug population in the *C. montrouzieri* released grape garden. The pre-count population recorded was abount 12 mealybugs/bunch. After three releases, the mealy bug population was 3.30 as compared to 24.90/ bunch in control plot.

BIOLOGICAL SUPPRESSION OF TEMPERATE FRUIT CROP PESTS

(i) Natural incidence of parasitoids of San Jose scale on apple

SKUAS&T, Srinagar

Parasitization rates of San Jose scale were similar at all the locations surveyed - low during May, but increased gradually during June-July and declined later. Per cent parasitization/2 cm^2 ranged 9.01-16.59, 4.73-9.68, 5.52-11.88 and 5.42-8.55 in Budgam, Srinagar, Pulwama and Baramullah districts, respectively.

Dr.YSPUH & F, Solan

At Nauni and Mashobra, the percentage of infested plants was 9.3 and 6.6, respectively, with a live scale density of 2.5-43.3 and 0.5-8.5 per cm^2 of the bark in moderate to heavily infested plants. *Chilocorus infernalis* was the only predator noticed during the period of observation, which actively fed upon the San Jose scale at Mashobra. Parasitization by *Aphytis* sp. *proclia* group and *Encarsia perniciosi* was also observed. Parasitization by the former was up to 25 per cent with a mean of 4.8% at Mashobra, while parasitization by *E. perniciosi* was up to 3 per cent (mean 0.1%). At Nauni, the predator activity was negligible, the live scale density was high and parasitization was mainly by *Encarsia* (0.4-3.1, mean 2.5%), while the activity of *Aphytis* was comparatively lower (0-0.8, mean 0.5%).

(ii) Current status of San Jose scale, woolly apple aphid and their natural enemies on apple

Dr. YSPUH & F, Solan

At Nauni, the infestation was only on 1.1 % of young plants in September, which increased to 28.6% in October and declined to 9% by December. Hardly 1% plants had aerial infestation in February. Incidence of *Aphelinus mali* was also noticed (1 to 3 mummified aphids among some woolly aphid colonies). At Mashobra, per cent infested plants were 7.1, 7.7 and 15.4 during September-November, on which on an average 7.9, 8 and 6.6 colonies of the aphid per infested plant thrived.

From the mummified aphids collected from trees treated with oils in July, the emergence of *A. mali* was lower (60.7-68.5%) than that from mummies collected from untreated trees (82.9%); the emergence from mummies from chlorpyrifos treated trees was only 35.6%. When the trees were treated in October, the parasitoid emergence was low even in the control, indicating prepupal diapause of the parasitoid. The emergence from mummies collected from treated trees was 4.3-10.2% and there was no emergence from those collected from chlorpyrifos treated trees.

(iii) Studies on predators of phytophagous mites on apple, evaluation of summer spray oils against phytophagous mites and their safety to natural enemies

Dr. YSPUH & F, Solan

Panonychus ulmi started appearing on apple foliage by the second week of April in two locations in Kullu 1.4 and 1.3 / leaf) and by May end, it had increased to 4.5 and 2.3, while in June-end it was 59.5 and 38.1/leaf. Population was at its peak by July end (71.9 and 28.1/leaf) but by mid-August, it declined to 2.8 and 2.7/leaf. No predatory mite could be encountered among sampled leaves until early June. Predatory mites (*Amblyseius* sp.) were observed only after second (0.03 mite/leaf) and third week of June (0.04 mite/leaf) in these two locations. Their number increased to a maximum of 0.23 and 0.3/leaf around mid-August. On trees where four summer spray oils (DC-Tron Plus, Orchex 796, IPOL and Servo (HMO)) were applied twice at 1 and 1.5 per cent during June and July at 3 weeks intervals, there was no reduction in the predatory mite count at both locations, though phytophagous mite population was reduced significantly to <4 mites/leaf.

BIOLOGICAL SUPPRESSION OF VEGETABLE CROP PESTS

(i) BIPM for tomato fruit borer

Dr. YSPUH & F, Solan

Four weekly releases of *T. chilonis* at fortnightly interval, followed by two rounds of *Ha*NPV application were made against tomato fruit borer. The parasitoid release resulted in 67 - 93 per cent egg parasitization as against 26.3 - 31.3 per cent in fields receiving endosulfan treatment. Per cent fruit damage was 4.2-4.5 in BIPM-fields and 4.4 in endosulfan-treated fields.

(ii) Fixing of dose of NPV for the management of *Helicoverpa armigera* on tomato

TNAU, Coimbatore

Five sprays of *Ha*NPV at full (@ 1.5 x 10^{12} POB/ha), 0.75, 0.50 and 0.25% of the recommended doses were evaluated against fruit borer. The larval incidence was significantly lower in *Ha*NPV application @ 1.5 x 10^{12} POB/ha followed by half the recommended dose of

Table 58. Optimum dose of NPV for the management of *H. armigera* on tomato based on larval population and fruit damage

Treatments	No. of larvae/10 plants* after spray						Meanfruit damage(%)	Tota yield ton/ha	C : B
	PT	I	II	III	IV	V			
*Ha*NPV 1.5 x 10^{12} POB/ha	6.8^{a}	6.1^{a}	1.12^{f}	3.85^{ab}	5.81^{a}	6.13^{a}	18.1^{a}	49.29^{a}	1: 4.21
*Ha*NPV 0.75 x 10^{12} POB/ha	6.4^{a}	6.0^{a}	1.38^{a}	3.96^{a}	6.19^{a}	5.92^{a}	26.3^{b}	42.31^{b}	1: 1.8
*Ha*NPV 0.375 x 10^{12} POB/ha	6.2^{a}	4.0^{b}	1.63^{b}	3.32^{b}	4.72^{bc}	5.81^{b}	30.3^{c}	39.23^{b}	1: 1.72
*Ha*NPV 0.1875 x 10^{12} POB/ha	5.2^{a}	4.4^{b}	1.82^{b}	3.21^{c}	4.43^{c}	5.52^{b}	27.1^{c}	38.18^{b}	1: 1.63
Control	6.1^{a}	4.4^{c}	2.61^{e}	8.62^{c}	12.23^{c}	11.89^{c}	37.8^{c}	23.12^{a}	-

*Means of four values

In vertical columns, means followed by similar letters are not different statistically (P = 0.05)

HaNPV. Further reduction in dose of NPV resulted in inferior control (Table 58). The fruit damage was significantly power and the cumulative yield significantly higher and in the treatment with NPV at full dose. Further reduction in the dosage resulted in reduced yield of marketable tomato though they were significantly superior to untreated check.

(iii) Biological control of insect pests of Okra

IIHR, Bangalore

Two trials were conducted to evaluate BIPM (comprising 4% NSP, *Bt* (Halt) and release of *T. chilonis*) and farmers' practice (dimethoate spray). BIPM treatments were superior to farmers' practice as only 4.22 to 5.94 % mean fruit borer damage was recorded in the two BIPM trials as against 23.52 and 12.99%, respectively, in farmers' practice. The total yield was also higher in BIPM (49.5 kg) compared to farmers' practice (11.1 kg).

(iv) Effectiveness of various microbial pesticides and summer oil against *Pieris brassicae* on kale/ knol khol

SKUAS & T, Srinagar

Treatments including *B. bassiana* @ 1x10^{8} spores/ ml, *Bt* (1.0 kg/ha), *M. anisopliae* (10^{3} conidia/ha), *Heterorhabditis indica* (2.0 billion/ha), D.C.Tron Plus (0.75%), neem (1.0%), dichlorvos (0.05%) and check, were evaluated against *Pieris brassicae*. All the treatments were effective as compared to control. Dichlorovs proved most effective, causing 100 per cent mortality within ten days. *H. indica* @ 2 billion/ha was least effective. *B. bassiana* gave 71.1% mortality followed by DC Tron plus (66.6%).

Dr.YSPUH & F, Solan

A field experiment with *Bt kurstaki* (1kg/ha), DC Tron Plus (0.075%) (summer spray oil), Achook (0.1%) and dichlorvos (0.05%) was laid out on knol khol for the suppression of cabbage butterfly larvae. In dichlorvos, *B. thuringiensis*, Achook and summer spray oil treated-plots, reduction in larval population was 97.9, 88.1, 80.3 and 38.2% as against 35% in the control, 10 days after application. Summer spray oil at did not prove effective in suppressing larval population, but a mortality of 80% of neonate larvae in 72 hours was observed. Hatching was prevented in 31.3% eggs and 19.7% larvae emerging from the treated eggs were killed, thus total mortality was 50%. However, there was no effect on eggs with 25 and 75% embryonic development.

(v) Evaluation of some fungal biocontrol agents for the control of cabbage aphid, *Brevicoryne brassicae*

SKUAS&T, Srinagar

Various microbial agents and other chemicals, *viz.*, *Verticillium lecanii* @ 10^{13} conidia/ha, *Beauveria bassiana* @ 10^{13} conidia/ha, D.C. Tron plus @ 0.75%, methyl demeton @ 0.025% and control were evaluated against cabbage aphids infesting knol khol. The aphid mortality was highest in methyl demeton (96%), followed by D.C.Tron (87%), *V. lecanii* (80%) and *B. bassiana* (78%) 16 days after spray.

(vi) Investigations on the potential of selected biocontrol agents against *Diaphania indica* infesting cucurbits

IIHR, Bangalore

a. Screening of pesticides against *Dolichogenidea stantoni*, a parasitoid of *Diaphania indica*

The toxicity of insecticides, *viz.*, acephate (0.75 g/l), dimethoate (1.3 ml/l), ethion (1.0 ml/l), imidacloprid (0.3 ml/l) and fungicides, *viz.*, mancozeb (2.5 g/l), copper oxychloride (3.0 g/l), chlorothalonil (2.0 g/l) and carbendazim (2.0 g/l), was evaluated against adults of *D. stantoni*. All the insecticides were highly toxic to *D. stantoni* (100% mortality) except imidacloprid (20% mortality) 48 h after exposure, whereas all the fungicides were safe.

(vii) Natural enemies of thrips on chillies

A survey for the natural enemies of thrips on brinjal, chilli, tomato, cucumber, maize, onion, jasmine, crossandra, aster and marigold was undertaken in and around Bangalore. Two species of anthocorids, *Orius* *tantillus* and *O. maxidentex*, were collected. A natural epizootic of *V. lecanii* was observed on *Thrips palmi*, infesting cucumber at IIHR farm, causing about 20 per cent mortality.

a. Biology, feeding potential and fecundity of *Orius tantillus* on thrips infesting marigold

The biology, feeding potential and fecundity of *O. tantillus* on thrips collected from marigold were studied under laboratory conditions. The egg period was 4-5 days. The nymphal period was 13-15 days. The adults had a mean longevity of 12.5 days (male) and 16.7 days (female). The feeding potential of *O. tantillus* was 165.7, mean fecundity 9.4 and mean longevity 12.5 days.

b. Screening of pesticides against *O. tantillus*

The toxicity of insecticides, *viz.*, acephate (0.75 g/l), dimethoate (1.3 ml/l), ethion (1.0 ml/l), imidacloprid (0.3 ml/l) and fungicides, *viz.*, mancozeb (2.5 g/l), copper oxychloride (3.0 g/l), chlorothalonil (2.0 g/l) and carbendazim (2.0 g/l) was evaluated against adults of *O. tantillus*. Per cent mortality of the adults was recorded at 1, 3, 6, 24 and 48 h after release. All the insecticides were highly toxic causing 100% mortality, but the fungicides were found to be safe.

c. Evaluation of *Verticillium lecanii* against *Scirtothrips dorsalis*

Five concentrations of *V. lecanii*, *viz.*, $1x10^9$, $1x10^8$, $1x10^7$, $1x10^6$ and $1x10^5$ spores/ml were evaluated against different stages (first, second instars and adults) of *S. dorsalis* in the laboratory. The per cent mortality varied from 8.0 to 54.4 and was significant in comparison to control, except in the early instar when sprayed @ $1x10^5$. Spraying of the fungus @ $1x10^9$ spores/ml recorded maximum mortality to all stages and least mortality was at $1x10^5$ spores per ml. Maximum mortality was recorded in the adult stage followed by late and early instars (Table 59).

BIOLOGICAL SUPPRESSION OF WEEDS

(i) Monitoring, evaluation and impact assessment of *Neochetina eichhorniae*, *N. bruchi* and *Orthogalumna terebrantis* against *Eichhornia crassipes*

Existing populations of the weevils, *Neochetina eichhorniae*, *N. bruchi*, and the mite, *Orthogalumna terebrantis*, on water hyacinth were monitored at Thrissur (KAU), Jorhat (AAU), Ludhiana (PAU), and Anand (AAU) and also additional releases were made. The assessment revealed good establishment at all places except Punjab where the insects perished due to the severe winter.

(ii) Survey and quantification of natural enemies of *Mimosa rubicaulis himalayana* and *M. invisa*

AAU, Jorhat

Mimosa rubicaulis himalayana (Family: Mimosaceae) was found to occur in about 50 ha of the

Table 59. Efficacy of *V. lecanii* against *Scirtothrips dorsalis*

V. lecanii concentration	Mortality (%)		
	Early instar	Late instar	Adult
$1x10^5$	8^a	14.74^b	21.68^b
$1x10^7$	20^b	38.02^c	46.14^c
$1x10^8$	16^b	44.98^d	46.14^c
$1x10^9$	33^b	49.59^d	54.35^d
Control	0.00^a	0.00^a	0.00^a

Figures followed by the same letter in a column are not significantly different

Table 60. Evaluation of entomopathogenic fungi against white grubs on turf grass

Treatment	Per cent mortality (days after inoculation)		
	14	18	22
B.bassiana (local)	66.66[a]	93.32[a]	100.00[a]
B. brongniartii	63.33[a]	86.66[a]	100.00[a]
M. anisopliae	46.66[b]	76.66[b]	96.65[a]
Control	6.67[c]	10.00[c]	10.00[c]

Figures followed by the same letter in a column are not significantly different

grazing areas of Kaziranga National Park, Assam. Two other species, *Mimosa invisa inermis* and *M. pudica*, were also found. Surveys for natural enemies of *Mimosa* during 2004 did not reveal any, indicating the need for introducing exotic natural enemies to manage the weed.

MICROBIAL CONTROL OF WHITE GRUBS IN TURF

SKUAS & T, Srinagar

Three microbial agents, *viz., Beauveria bassiana, B. brongniartii* and *Metarhizium anisopliae* were evaluated at a concentration of 1x 10^8 spores/ ml against white grubs infesting the grass in the golf course. All the three entomopathogens performed well against white grubs, *B. bassiana* proving to be the most effective as it caused early mortality (Table 60).

6. TECHNOLOGY ASSESSED AND TRANSFERRED

Technology assessed

- *Bt* cotton under BIPM performed better in reducing the bollworm damage and recorded higher seed cotton yield and natural enemy population than non-*Bt* cotton.
- The multiple pesticide-tolerant strain of *T. chilonis* survived better than laboratory strain in fields sprayed with chemicals and recorded higher seed cotton yield.
- Sequential releases of *Telenomus remus* and *Chelonus formosanus* resulted in higher parasitization of *Spodoptera exigua* and lowest seedling damage in tobacco.
- IPM package (Seed treatment with *Trichoderma* @ 4.0 g/kg seed, NSKE 5%, *Bt* @ 1.0 kg/ha for borer complex, *Ha*NPV @ 1.5x10^{12} POB/ha and intercrop of maize (10% random planting) provided significant control of pod borers and *Mylabris pustulata* in pigeon pea and resulted in higher yield.
- Mass release technology for *Goniozus nephantidis* was standardized.
- BIPM package (release of *T. remus* @ 1,00,000/ha and three sprays of *Sl*NPV @ 1.5x10^{12} POB/ha along with 0.5% crude sugar) controlled *S. litura* on soybean effectively.
- Field release of *Cardiastethus exiguus* @ 50/palm reduced *Opisina arenosella* population significantly on coconut.
- Application of *Heterorhabditis indica* @ 2.0 billion IJs per ha resulted in minimum population of white grubs in golf ground at Srinagar.

7. EDUCATION AND TRAINING

Training

Name and designation	Training programme	Dates	Venue
Ms. M.Pratheepa, Scientist SS	Computer vision and its application	12-07-200[illegible]- 24-07-200[illegible]	PES College of Engineering, Mandya (Karnataka)
Ms. M.Pratheepa, Scientist SS and Mr. S.R.Biswas, Principal Scientist	Personnel Management Information System (PERMIS*net*)	23-07-2004- 24-07-2004	Indian Agricultural Statistics Research Institute, New Delhi
Mr. S.R.Biswas, Principal Scientist	Networking and ERNET connectivity	31-08-2004- 04-09-2004	National Academy of Agricultural Research Management, Hyderabad
Dr.(Ms.) Y. Lalitha, Technical Officer	Theory and Technology of Plant Protection for sustainable Agriculture in 21st Century	2-09-2004- 21-09-2004	Shenyang Agricultural University, Shenyang, China
Dr.(Ms.) J. Poorani, Senior Scientist	Emerging trends in Biological Control	16-11-2004- 06-12-2004	PDBC, Bangalore
Dr. P. Sreeramakumar, Senior Scientist	Biocontrol strategies for Management of Plant Pathogens	16-11-2004- 16-12-2004	Division of Plant Pathology, Indian Agricultural Research Institute, New Delhi
Dr. T. Venkatesan, Senior Scientist	Methods and techniques of rearing of natural enemies on artificial diets	04-12-2004- 27-12-2004	Centre for Medical, Agricultural and Veterinary Entomology, USDA, Gainesville, Florida, USA

8. AWARDS AND RECOGNITIONS

Dr. K. Srinivasa Murthy, Senior Scientist, PDBC, was awarded the ICAR Award for Team Research for the biennium 2001-02 for outstanding research contribution in the field of pest management on 19 October, 2004.

9. LINKAGES AND COLLABORATION IN INDIA AND ABROAD INCLUDING EXTERNAL PROJECTS

i. NATP funded project entitled "Team of Excellence for Human Resource Development in Biological Control" was extended up to 31-03-2005. The project was operative at PDBC, Bangalore, and the clients were scientists from various State Agricultural Universities, traditional universities and ICAR Institutes. This project had linkage with all the institutes interested in biocontrol of crop pests and weeds.

ii. NATP funded project entitled "Validation and promotion of IPM Technology in selected crops in different agro-ecological regions" was extended up to 31-12-2004 and was operative at National Centre for Integrated Pest Management, New Delhi. PDBC was one of the co-operating centers and supplied quality biocontrol agents to various institutions for the control of pests of cotton, pigeonpea, chickpea, groundnut, tomato, cabbage, mango and apple.

iii. NATP funded project entitled, "Development of Bio-intensive IPM modules in Chickpea against *Helicoverpa armigera*, wilt and dry root rot" operated at PDBC as coordinating centre up to 30-06-2004 and had a linkage with Indian Institute of Pulses Research, Kanpur.

iv. NATP funded project entitled, "Control of leaf curl viral disease in cotton and development of protocols for mass multiplication of predators, parasitoids and insect pathogens" operated at PDBC up to 31-12-2004 and had a linkage with Central Institute of Cotton Research, Nagpur.

v. NATP funded project entitled, "Development of Integrated Pest Management Package for the eriophyid mite (*Aceria guerreronis* Keifer) of coconut in the southern states" operated at PDBC up to 30-11-2004 and had linkage with Coconut Development Board, Kochi.

Other sources

i. Under the Technology Mission on Cotton for Commercialization of bioagent mass-production technologies in intensive cotton districts, Ministry of Agriculture, DAC, PDBC had a linkage with Central Institute of Cotton Research, Nagpur and National Centre for Integrated Pest Management, New Delhi (TMC MM 3.3, Cotton Technology Mission; DAC).

ii. DBT funded project entitled "Development of biocontrol strategies for the management of the sugarcane woolly aphid, *Ceratovacuna lanigera*" has been operative at PDBC, for a period of three years from 01-04-2004 in collaboration with University of Agricultural Sciences, Dharwad, and College of Agriculture (MPKV), Pune.

iii. "Classical biological control of *Mikania micrantha* with *Puccinia spegazzinii*" for a period of three years in linkage with CABI, London (UK), Assam Agricultural University, Jorhat, and Forest Research Institute, Peechi.

Voluntary Centres

Developed linkages for conducting crop-based multi-location trials with organizations like Regional Research Station (CCSHAU), Karnal, for sugarcane; University of Agricultural Sciences, Dharwad & Regional Agricultural Research Station (UAS (D)), Raichur, for cotton and groundnut; National Research Centre for Soybean, Indore, for soybean; Regional Station (CPRI), Ooty, for potato; National Research Centre for Weed Science, Jabalpur, for the biological suppression of parthenium and Vasantadada Sugar Institute, Pune, for sugarcane.

10. AICRP / COORDINATION UNIT / NATIONAL CENTRES

With a view to fulfill the mandate given, the Project Directorate has divided the workload among six ICAR Institute-based and ten State Agricultural University (SAUs)-based coordinating centres based on infrastructural facilities and expertise available as follows:

Headquarters	
Project Directorate of Biological Control, Bangalore	Basic Research
ICAR Institute - based centres	
Regional Station (CPCRI), Kayangulam	Coconut
Central Tobacco Research Institute, Rajahmundry	Tobacco, soybean
Indian Agricultural Research Institute, New Delhi	Basic Research
Indian Institute of Horticultural Research, Bangalore	Fruits & vegetables
Indian Institute of Sugarcane Research, Lucknow	Sugarcane
Sugarcane Breeding Institute, Coimbatore	Sugarcane
State Agricultural University - based centres	
Assam Agricultural University, Jorhat	Sugarcane, pulses, rice and weeds
Acharya N.G.Ranga Agricultural University, Hyderabad	Sugarcane, cotton and vegetables
Govind Ballabh Pant University of Agriculture and Technology, Pantnagar	Plant disease antagonists
Gujarat Agricultural University, Anand	Cotton, pulses, oilseeds, vegetables & weeds
Kerala Agricultural University, Thrissur	Rice, coconut, weeds, fruits and coconut
Mahatma Phule Krishi Vidyapeeth, Pune	Sugarcane, cotton, soybean and guava
Punjab Agricultural University, Ludhiana	Sugarcane, cotton, oilseeds, tomato, rice and weeds
Sher-E-Kashmir University of Agricultural Sciences & Technology, Srinagar	Temperate fruits and vegetables
Tamil Nadu Agricultural University, Coimbatore	Sugarcane, cotton, pulses, and tomato
Dr.Y.S.Parmar University of Horticulture & Forestry, Solan	Fruits, vegetables and weeds

11. LIST OF PUBLICATIONS

Research papers published in refereed scientific journals

Project Directorate of Biological Control, Bangalore

Bhumannavar, B.S., Ramani, S., Rajeshwari, S.K. and Chaubey, B.K. 2004. Host specificity tests and biology of *Cecidochares connexa* (Macquart) (Diptera: Tephritidae) introduced into India for the biological suppression of *Chromolaena odorata* (Asteraceae). *Journal of Biological Control*, **18** (2): 111-120.

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Hussaini, S.S., Nagesh, M., Rajeshwari, R. and Dar, M.H. 2004. Formulation of host cadavers infected with indigenous *Heterorhabditis* spp. (Nematoda: Heterorhabditidae: Rhabditida) isolates. *Entomon*, **29**(4): 1-6.

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Hussaini, S.S., Nagesh, M., Rajeshwari, R. and Dar, M.H. 2005. Field evaluation of entomopathogenic nematodes against white grubs (Coleoptera: Scarabaeidae) on turf grass in Srinagar. *Annals of Plant Protection Sciences*, **13**(1): 190-193.

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Kumar, P.S. and Anuroop, C.P. 2004. A method to test the pathogenicity of fungi to *Aceria guerreronis* with particular reference to *Hirsutella thompsonii*. *Systematic and Applied Acarology*, **9**: 11–14.

Kumar, P.S., Singh, S.P. and Anuroop, C.P. 2004. Investigations on *Sporothrix fungorum* de Hoog & de Vries, a newly recorded pathogen of *Aceria guerreronis* Keifer, the coconut eriophyid mite. *Journal of Biological Control*, **18**(1): 13-20.

Narayanan, K. 2004. Nucleopolyhedrovirus of cabbage leaf webber, *Crocidolomia binotalis* Zeller (Lepidoptera: Pyralidae). *Insect Environment* **10**: 42-43.

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Srinivasa Murthy, K., Jalali, S.K. and Venkatesan, T. 2004. Influence of temperature on the sex ratio of *Telenomus* sp. (Scelionidae: Hymenoptera), an egg parasitoid of *Spodoptera litura* Fabricius. *Journal of Entomological Research*, **28**(3): 1-9.

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Dr. Y. S. Parmar University of Horticulture & Forestry, Solan

Dayal, K. and Gupta, P.R. 2003. Biology and feeding potential of *Oenopia kirbyi* Mulsant (Coleoptera: Coccinellidae) on the cabbage aphid and black bean aphid. *Pest Management and Economic Zoology*, **11**(2): 173-176. (Published in 2004).

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Galande, S.M., Mote, U.N. and Ghorpade, S.A. 2004. New host plants of serpentine leaf miner, *Liriomyza trifolii* in Western Maharashtra. *Annals of Plant Protection Sciences*, **12**(2): 438-439.

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Project Directorate of Biological Control, Bangalore

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Nagesh, M., Hussaini, S.S. and Chidananda Swamy, B.S. 2004. Solid media and moisture content of media suitable for commercial mass production of *Paecilomyces lilacinus* and *Pochonia chlamydosporia (Verticillium chlamydosporium)*, p.117. National Symposium on "Paradigms in Nematological Research for Biodynamic Farming", UAS, Bangalore, 17-19, November, 2004.

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12. LIST OF APPROVED ONGOING PROJECTS

Basic Research

Project Directorate of Biological Control, Bangalore

1. Biosystematic studies on predatory coccinellids
2. Biosystematic studies on Indian Tachinidae
3. Introduction and studies on exotic natural enemies of some important crop pests and weeds

4. Development of interactive identification key for important families of insect parasitoids and predators
5. Rearing and evaluation of natural enemies with special reference to scelionid, braconid, ichneumonid and anthocorid groups
6. Studies on biological control of sugarcane woolly aphid
7. Mass production and field evaluation of *Micromus* sp.
8. Development of novel mass production, storage and packaging techniques for *Cryptolaemus montrouzieri*
9. Herbivore-induced plant synomones and their utilization in enhancement of the efficiency of natural enemies
10. Host-derived kairomones to enhance the efficiency of natural enemies
11. Development and use of insect viruses for the management of major pest complex of cruciferous crops
12. Development of improved formulations of NPV for management of *Helicoverpa armigera* and *Spodoptera litura* in tomato
13. Evaluation of fungal pathogens against onion thrips
14. Identification of effective entomofungal pathogens for the management of sugarcane woolly aphid
15. Efficient formulations of *Trichoderma* sp. and entomofungal pathogens with prolonged shelf-life
16. Identification of *Trichoderma* isolates with enhanced biocontrol potential
17. Isolation, characterization and toxicity testing of indigenous Bt strains against lepidopteran pests
18. Mass production, formulation and field testing of entomopathogenic nematodes against important lepidopteran pests
19. Biological suppression of plant parasitic nematodes exploiting antagonistic fungi and bacteria in specific cropping systems
20. Identification of pathogens of phytophagous mites and assessment of their potential in microbial control
21. Development and evaluation of improved strains of trichogrammatids, *Cheilomenes sexmaculata* and *Chrysoperla carnea* tolerant to insecticides, temperature and high host searching ability
22. Development and formulation of artificial diets for the rearing of coccinellids and anthocorids
23. Development and evaluation of artificial diets for *Opisina arenosella* and *Plutella xylostella* and studies on host-parasitoid interrelations
24. Software development for identifying and suggesting biosuppression measures for different crop pests using personal computer
25. Development of national information system on biological suppression of crop pests
26. Developing a database on microbial biocontrol agents

NATP Funded Projects at Project Directorate of Biological Control, Bangalore

1. Team of Excellence for Human Resource Development in Biological Control (up to 31-03-2005)
2. Validation and Promotion of IPM Technology in Selected Crops in Different agro-ecological Regions (31-12-2004)
3. Development of Bio-intensive IPM modules in Chickpea against *Helicoverpa armigera*, wilt and dry root rot (RPPS-7) (up to 30-06-2004)
4. Control of leaf curl viral disease in cotton and development of protocols for mass multiplication of predators, parasitoids and insect pathogens (up to 31-12-2004)
5. Development of Integrated Pest Management Package for coconut eriophyid mite (*Aceria guerreronis* Keifer) in the southern states (up to 30-11-2004)

6. Improvement of formulation technology for entomopathogenic nematodes (up to 31-12-2004)

7. Isolation of baculoviruses from larval Arctiidae (Lepidoptera) and standardization of mass production techniques for promising entomopathogenic strains (up to 31-12-2004)

Other sources

1. Commercialization of bioagent mass-production technologies in intensive cotton districts (TMC MM 3.3, Cotton Technology Mission; DAC)

2. Evolving and testing superior strains of *Steinernema* sp. and *Heterorhabditis* sp. against *Spodoptera litura* in field (ICAR-Cess)

3. Isolation, purification and characterization of novel insecticidal toxins from *Photorhabdus luminescens* and *Xenorhabdus* spp. of bacteria from entomopathogenic nematodes (DBT)

4. Development of biocontrol strategies for the management of sugarcane woolly aphid, *Ceratovacuna lanigera* (DBT)

5. Classical biological control of *Mikania micrantha* with *Puccinia spegazzinii* (CABI)

6. Development of commercial formulation of antagonistic fungi (*Paecilomyces lilacinus* and *Verticillium chlamydosporium*) for biological control of *Meloidogyne incognita* and *Rotylenchulus reniformis* (ICAR-Cess fund)

Indian Agricultural Research Institute, New Delhi

1. Basic studies and maintenance of *Bacillus thuringiensis* strains

2. Studies on formulations of microbial pesticides based on baculoviruses and *Bacillus thuringiensis*

Applied Research

Biological control of plant diseases using antagonistic organisms

1. Evaluation of seed biopriming with *Trichoderma harzianum* (TH) and *Pseudomonas fluorescens* (PsF) and TH enriched FYM technologies (GBPUA & T, PAU, GAU)

2. Evaluation of *Trichoderma* spp. against soil borne diseases in chickpea (PAU)

3. Evaluation of *Trichoderma* spp. against soil borne diseases in groundnut (GAU)

4. Management of foliar diseases using TH and/or PsF (GBPUA & T and PAU)

6. Shelf-life of *Trichoderma* and/or *Pseudomonas* formulations with different moisture levels (PDBC)

Biological suppression of sugarcane pests

1. Survey and surveillance of woolly aphid and its natural enemies (IISR, SBI, MPKV, AAU, CCSHAU, PAU, TNAU and ANGRAU)

2. Survey for current status of sugarcane woolly aphid and its natural enemies including status of alternate host plants (TNAU)

3. Influence of crop management practices on sugarcane woolly aphid and its natural enemies (ANGRAU, TNAU and MPKV)

4. Evaluation of potential natural enemies of SWA (ANGRAU, TNAU, MPKV and UAS (D))

5. Method of mass production of *Dipha* and *Micromus* (ANGRAU and MPKV)

6. Evaluation of fungal pathogens against sugarcane woolly aphid (TNAU, MPKV, ANGRAU and UAS (D))

7. Colonization of *Encarsia flavoscutellum* (TNAU)

8. Bio-intensive pest management practices for sugarcane scales (MPKV and CCSHAU)

9. Maintenance and supply of *Epiricania melanoleuca* for use against *Pyrilla perpusilla* (IISR, PAU and CCSHAU)

10. Field evaluation of *Trichogramma chilonis* against *Chilo tumidicostalis* (PAU & AAU)

11. Field evaluation of *Trichogramma japonicum* against *Scirpophaga excerptalis* (IISR & PAU)

12. Efficiency of EPN, *Heterorhabditis indica* in controlling white grubs in sugarcane (CCSHAU)

Biological suppression of cotton pests

1. BIPM for Bt cotton (ANGRAU, GAU, TNAU and MPKV)
2. Evaluation of pesticide-tolerant strain of *Trichogramma chilonis* on cotton (PAU, UAS (D), Raichur and GAU)
3. Standardization of the release technology for *Trichogramma chilonis* for bollworms (GAU and PAU)
4. Influence of cotton cultivars / hybrids on the parasitization efficiency of *Trichogramma chilonis* (GAU and PAU)
5. Field trial on the use of kairomones to increase the efficiency of chrysopids and trichogrammatids against cotton insect pests (UAS (D))

Biological suppression of tobacco pests

1. Biological Control of *Helicoverpa armigera* on tobacco (CTRI)
2. Identification and utilization of biocontrol agents for the management of *Spodoptera exigua* (CTRI)

Biological suppression of pulse crop pests

1. Survey for natural enemies of pigeon pea seed weevil, *Apion clavipes* (AAU)
2. Biological control of pigeonpea cyst nematodes and disease complex (TNAU)
3. Evaluation of BIPM package on soybean (CTRI)
4. Microbial control of *H. armigera* and *Adisura atkinsoni* on lablab (GAU)
5. IPM demonstration on pigeonpea (GAU)
6. Evaluation of EPN against *Mylabris pustulata* and lepidopteran pod borers in pigeonpea (GAU)

Biological suppression of rice pests

1. Isolation of fungal pathogens from rice ecosystem (AAU, KAU and PAU)
2. Search for *Trichogramma* spp. and other egg parasitoids of rice hispa (AAU)
3. Development of biointensive IPM for rice stem borer and disease management (AAU)
4. Evaluation of *Trichogramma japonicum* against the rice leaf folder (AAU, KAU, and PAU)
5. Evaluation of fungal pathogens on sucking pests of rice (KAU and AAU)
6. Impact of organic farming on conservation and augmentation of natural enemies of rice pests (PAU & KAU)

Biological suppression of oilseed crop pests

1. Biological control of the aphid, *Lipaphis erysimi*, on mustard) (GAU & PAU)

Biological suppression of coconut pests

1. Evaluation of method of release of *Goniozus nephantidis* against *O. arenosella* (KAU)
2. Field evaluation of *Cardiastethus exiguus* against *O. arenosella* (PDBC and KAU)

Biological suppression of tropical fruit crop pests

1. Evaluation of *Trichogramma chilonis* against pomegranate fruit borers, *Deudorix* spp. (IIHR and Dr.YSPUH & F)
2. Integration of *T. chilonis* with *Bt* for the control of pomegranate fruit borer, *Deudorix isocrates* (IIHR)
3. Colonization of *Encarsia guadeloupae* on spiralling whitefly in guava orchards (IIHR, MPKV and KAU)
4. Efficacy of different formulations of *Verticillium lecanii* against the mealybugs, *Planococcus citri* and *Maconellicoccus hirsutus* (IIHR)
5. Field efficacy of *Metarhizium anisopliae* against mango hoppers (IIHR)
6. Evaluation of *Bacillus thuringiensis* against pomegranate fruit borer (IIHR)
7. Survey for natural enemies of fruit flies in guava and mango (IIHR)
8. Demonstration of biological control of mealybugs on grapes (IIHR and MPKV)

9. Evaluation of Bt formulations against citrus leaf miner (IIHR)

Biological suppression of temperate fruit crop pests

1. Quantification of natural incidence of parasitoids of San Jose scale on apple for fixing the release rates (SKUAS&T and Dr. YSPUH&F)
2. Determination of the current status of San Jose scale, woolly aphids and their natural enemies on apple (SKUAS&T & YSPUH & F)
3. Microbial control of white grubs in turf (SKUAS&T)
4. Studies on predators of phytophagous mites on apple (YSPHUH & F)

Biological suppression of vegetable crop pests

1. BIPM in tomato (PAU and YSPUH&F)
2. Fixing the dose of NPV for the management of *Helicoverpa armigera* on tomato (PAU and TNAU)
3. BIPM for brinjal fruit and shoot borer (ANGRAU)
4. Biological control of insect pests of okra (IIHR)
5. Biological control of cruciferous crop pests (GAU)
6. Biological control of cabbage aphid, *Brevicoryne brassicae*, on cole crops (Dr.YSPUH & F)
7. Effectiveness of microbial pesticides and summer oils against *Pieris brassicae* on kale/knol-khol (SKUAS & T and Dr. YSPUH & F)
8. Evaluation of some fungal bio-control agents for the control of cabbage aphid (*Brevicoryne brassicae*) (SKUAS & T and YSPUH & F)
9. Investigations on the potential of selected biocontrol agents against *Diaphania indica* infesting cucurbits (IIHR)
10. Evaluation of *Orius* spp. against chilli thrips (IIHR)
11. Evaluation of *Verticillium lecanii* against chilli thrips (IIHR)
12. Evaluation of EPN against *Leucinodes orbonalis* infesting different varieties of egg plant (IIHR)
14. Attempts at isolation of nuclear polyhedral virus from tent caterpillar and *Pieris brassicae* (SKUAS & T)

Biological suppression of weeds

1. Monitoring, evaluation and impact assessment of *Neochetina eichhorniae*, *N. bruchi* and *Orthogalumna terebrantis* against *Eichhornia crassipes* (AAU, GAU, KAU and PAU)
2. Monitoring, evaluation and impact assessment of *Cyrtobagous salviniae* against *Salvinia molesta* (KAU)
3. Monitoring, evaluation and impact assessment of *Zygogramma bicolorata* against parthenium (GAU and YSPUH & F)
4. Survey and quantification of natural enemies of *Mimosa rubicaulis* subsp. *himalayana* and *M. invisa* (AAU)

13. CONSULTANCY, PATENTS, COMMERCIALIZATION OF TECHNOLOGY

Consultancy service was arranged for EAG and GC-MS analysis of samples received from various organizations

Quality biocontrol agents were supplied to different research and development departments of central and state governments

Patent applied for a novel technique to store *Corcyra cephalonica* eggs at low temperature for *Trichogramma* production on 27th September 2004

14. MEETINGS HELD AND SIGNIFICANT DECISIONS MADE

Ninth Research Advisory Committee Meeting held on 12th October 2004

Recommendations

1. Efforts may be made to use molecular techniques in the taxonomic studies of biocontrol agents, wherever applicable. Possibilities of using molecular tools in the identification of parasitoids and predators released in the field may be explored

2. Efforts may be made to mechanize or semi-automate the production of natural enemies in order to reduce drudgery
3. Research on packing and transport for selected biocontrol agents may be further intensified
4. The safety of *Crocidolomia binotalis* NPV to beneficial insects and the field efficacy of the baculoviruses on pests of cabbage and cauliflower may be studied
5. Effect of hormone treatment of larvae on the yield of NPV may be studied
6. *Trichoderma-Paecilomyces* formulations in organic substrates may be evaluated for the management of nematode-fungal disease complex
7. A technical bulletin highlighting the research findings on *Hirsutella thompsonii* against the coconut eriophyid mite may be brought out
8. In the new research project proposal on development of formulations of *Trichoderma* and entomofungal pathogens with prolonged shelf life, only *T. viride, T. harzianum, M. anisopliae, N. rileyi* and *B. bassiana* may be included
9. In the project on identification of *Trichoderma* isolates with enhanced biocontrol potential, strains/isolates from other institutions/centres may also be evaluated
10. Since *Parthenium* continues to be a national concern, PDBC should take up *Parthenium* biological control programme as part of institute project. The possibilities of mass-producing *Zygogramma* on a semi-synthetic diet may also be explored
11. Possibilities of biocontrol of *Orobanche* and *Striga* may be explored
12. In the software being developed on biocontrol measures for different crops using PC, a note on precautions for conservation of natural enemies may also be included
13. PDBC may aggressively promote the distribution of all CDs containing electronic literature to different stakeholders to popularize biological control
14. The HRD programme proposed under the X plan may be pursued with the council
15. Large number of biocontrol technologies have been developed and field-validated, but still the uptake of biocontrol agents is poor. There is an urgent need to increase the awareness among farmers and thereby create demand. The RAC suggested to organize a village level production programme for *Trichogramma* in a selected location with local involvement of cluster groups of unemployed educated youth/farm women in collaboration with KVKs and NGOs. These centers will take up only *Trichogramma* production. *Corcyra* eggs will be supplied from the centralized sources.
16. In order to create awareness on biological control, each AICRP centre on biological control may be asked to organize an awareness campaign through field days, melas, etc.

Interactive Meeting between the Chairman, QRT, and IMC of PDBC on 14th September 2004

The Chairman, QRT, had an interactive meeting with IMC Members of PDBC on 14-09-2004. The Chairman explained the various recommendations made by the QRT for the sound functioning of the PDBC along with AICRP with a view to achieve the goals based on the mandate given.

The IMC Members appreciated the recommendations and found them meaningful and emphasized the need for consideration by the Council based on the comments expressed by the Project Director, PDBC.

Staff Research Council Meeting

The Staff Reseach Council Meeting was held on 26th May 2005 under the Chairmanship of Dr. R.J.Rabindra, Project Director. The specific recommendations/comments for taking further action were as follows:

1. Action should be taken for commercialization of strains following ICAR regulations
2. The efficacy of *T. japonicum* against rice leaf folder

must be studied immediately and results may be submitted before May 2004

3. The comparative efficacy of *Trichogrammatoidea bactrae* and *T. chilonis* against pink bollworm should be studied in the laboratory

4. Study should be initiated on the long term storage of *Trichogramma*

5. Improved methods of release of *Trichogramma* may be developed

6. Efforts to collect natural enemies from areas of low pesticide use particularly NE region and biodiversity rich areas should be made. A cess fund project may be proposed to cover this subject

Institute Management Committee Meetings

The first meeting was held on 24th April 2004 and the proposal for the purchase of two walk-in chambers (with temperature and humidity control) costing Rs.7,60,000/- was approved in lieu of the sunset CPS machine (Rs.5,10,000/-) and double-ended autoclave approved in X Plan EFC as these equipments were purchased in lateral funded project.

The second meeting was held on 14th September 2004 and the following recommendations were made.

All the members appreciated the recommendations given by Fourth QRT and felt these needed to be considered by the Council after taking into consideration the comments expressed by the Project Director.

The Committee recommended the inclusion of Bangalore Baptist Hospital, Hebbal, Bangalore; Narayan Nethralaya, Rajajinagar, Bangalore; Bangalore Mahaveer Jain Hospital, Millers Road, Bangalore; Hosmat Hospital, Magrath Road, Bangalore; Narayan Hridyalaya Pvt Ltd, Hosur Road, Bangalore and 4 diagnostic centers which are under the CGHS in addition to the hospitals recognized by the ICAR, provided they agreed for the CGHS rates.

15. PARTICIPATION OF SCIENTISTS IN CONFERENCES, MEETINGS, WORKSHOPS, SYMPOSIA, etc. IN INDIA AND ABROAD

Project Directorate of Biological Control, Bangalore

International

Dr.(Ms.) Y. Lalitha, Technical Officer, was deputed to Shenyang Agricultural University, Shenyang, China, for an International training course on "Theory and Technology of Plant Protection for sustainable Agriculture in 21st Century" from 2nd to 21st September 2004.

Dr.T.Venkatesan, Senior Scientist, was deputed to Centre for Medical, Agricultural and Veterinary Entomology, USDA, Gainesville, Florida, USA, for a training programme on "Methods and techniques of rearing of natural enemies on artificial diets" from 4th to 27th December 2004.

Dr.Arun Baitha, Scientist SS, Indian Institute of Sugarcane Research, Lucknow, was deputed to EPICA, Matanzas, Cuba, for training in the latest technology in the field of biological control from 7th March to 21st March 2005.

National

Scientist	Name of the Symposium / Workshop / Meeting participated in	Place & Duration
Dr.R.J.Rabindra	5th meeting of the Bioscience Sub-Group of ICWC	6th April 2004 at IARI, New Delhi.
	Brainstorming Session	22nd and 23rd April, 2004 at NASC Complex, New Delhi
	Meeting called on Biotechnology programmes	28th May, 2004, at Andhra Pradesh Netherlands Biotechnology Unit, Hyderabad
	Review workshop on IPM organized by the NATP	24th June, 2004 at UAS, Dharwad
	Biological control of coconut eriophyid mite organized by the NATP	29th June, 2004 at TNAU, Coimbatore
	Directors' Conference of ICAR institutes	14-16 July 2004 at NASC Complex, IARI, New Delhi.
	Expert Group for simplification of guidelines for registration of bio-pesticides	25th August, 2004 at CIL, Faridabad
	Finalizing network projects	2nd September, 2004 KB, New Delhi
	Twelfth Project Approval Committee (PAC) Meeting of Technology Mission on Coconut	9th September, 2004 at Kera Bhavan, Kochi
	AICRP workshop on Sugarcane	27th October 2004 at UAS, Dharwad
	198th Governing Body Meeting of the ICAR	3rd November 2004 in NASC Complex, New Delhi
	Review Mission Meeting of the World Bank called by the NATP	27th November 2004, IARI, New Delhi
	Directors' Workshop on Commercialization of Agricultural Technologies	30th November - 3rd December 2004 at NAARM, Hyderabad.
Dr.R.J.Rabindra Dr.P.L.Tandon Dr.K.Narayanan Dr.S.S.Hussaini Dr.B.S.Bhumannavar Dr.N.Bakthavatsalam Dr.C.R.Ballal Dr.S.Ramani Dr.S.K.Jalali Dr.B.Ramanujam Dr.Prashant Mohanraj Dr.M.Nagesh Dr.K.Veenakumari Dr.T.Venkatesan	XIII Biocontrol Workers' Group Meeting on Biological control of crop pests and weeds	21-22 May, 2004, PDBC, Bangalore

Dr.J.Poorani Dr.P.Sreeramakumar Mr.Sunil Joshi Dr.K.S.Murthy Ms.M.Pratheepa		
Dr.P.L.Tandon	Sensitization-cum-training workshop for the PME Cells in the ICAR Institutes	17th & 18th March 2004 at NCAE &PR, New Delhi
	Meeting on Vision 2020 and Perspective Plan of PDBC & NCIPM	17th and 18th May 2005 at NCIPM, New Delhi
	Pre-publication Workshop on organic farming-ecologically sustainable alternatives to conventional agriculture	26th August 2004 at Centre for Environment Education, Bangalore
Dr.K.Narayanan Dr.M.Mani Dr.S.K.Jalali	National Symposium on Biodiversity and Insect Pest Management	3rd & 4th February 2005 at Loyola College, Chennai
Dr.N.S.Rao	Annual Review meeting on Cotton Mission Mode (MM 3.3) project	25th June 2004 at CICR, Nagpur
	Review Workshop on Cotton Mission Mode (MM 3.3) project	2nd November 2004 at IARI, New Delhi
	National Workshop on Commercialization of Agricultural Technologies	30th November to 3rd December 2004 at NAARM, Hyderabad
Dr.S.S.Hussaini Dr.M.Nagesh	National Symposium on "Paradigms in nematological research for biodynamic farming"	17th-19th November 2004 at UAS, Bangalore
Dr.N.Bakthavatsalam	National Seminar on "Importance of Insect Growth Regulators and Natural Products in IPM"	11th January 2005 at St. Joseph's College, Kolikodu
	Brainstorming session on the management of insect pests of cashew	6th June 2004 at NRC for Cashew, Puttur
Dr.Chandish R.Ballal	National Seminar on "Operational Methodology and Package of Practices in Organic Farming"	7th to 9th October 2004 at UAS, Bangalore
Dr.T.Venkatesan	First Indian Horticultural Congress-2004	6th-8th November 2004 at IARI, New Delhi
Dr.S.Ramani Dr.J.Poorani	Indo-US Joint International Workshop on Biodiversity Informatics	7th - 9th December 2004, NCL, Pune
Dr.P.Sreeramakumar	Workshop on "Management of eriophyid mite on coconut"	29th June 2004, TNAU, Coimbatore
	National Seminar on " Emerging trends in Plant Pathology and their Social Relevance"	7th - 8th March 2005, Annamalai University, Annamalainagar
Dr.K.L.Srivastava	National Symposium on "Pesticides: Myths, Realities and Remedies" and Pesticide Expo 2004	1st - 3rd December 2004 at IARI, New Delhi
Dr.P.N.Gangavisalakshy	National Workshop on "Biocontrol of Aquatic Weeds – A Threat or Boon in Disguise"	4th September 2004, MPUAT, Udaipur
Dr.J.Srikanth	66th Annual Convention of Sugar Technologists Association of India	14th - 16th August 2004, STAI, Chandigarh

16. WORKSHOPS, SEMINARS, SUMMER INSTITUTES, FARMERS' DAY, etc.,

Organized at PDBC

- Institute Management Committee meeting: 14th April and 24th September 2004.
- Interactive Meeting with Biopesticide Producers: 19th & 20th May 2004
- XIII Biocontrol Workers' Group Meeting: 21st & 22nd May 2004
- Work Group Meeting on Biological Control of sugarcane woolly aphid: 22nd June 2004
- Scientific Research Council Meeting: 9th July 2004
- Ninth Research Advisory Committee meeting: 12th October 2004
- Symposium on Biological Control of Pests of Horticultural Crops: New Thrusts: 19th March 2005

Anti-Terrorism Day on 21st May 2004
ICAR Foundation Day on 16th July 2004

17. DISTINGUISHED VISITORS

Project Directorate of Biological Control, Bangalore

Dr. J.C. Katyal, Deputy Director General (Education), ICAR, New Delhi, on 8th September 2004

Sri Gautam Basu, Additional Secretary & Financial Advisor, DARE/ICAR, New Delhi, on 27th October 2004

Dr. Gautam Kalloo, Deputy Director General (Crops & Horti.), ICAR, New Delhi, on 26th January 2005

18. PERSONNEL

Project Directorate of Biological Control, Bangalore

Dr.R.J.Rabindra	Project Director
Dr.P.L.Tandon	Principal Scientist
Dr.K.Narayanan	Principal Scientist
Dr.N.S.Rao	Principal Scientist
Mr.S.R.Biswas	Principal Scientist
Dr.S.S.Hussaini	Principal Scientist
Dr.B.S.Bhumannavar	Principal Scientist
Dr.(Ms.)K.Veena Kumari	Senior Scientist
Dr.Prashanth Mohanraj	Senior Scientist
Dr.B.Ramanujam	Senior Scientist
Dr.N.Bakthavatsalam	Senior Scientist
Dr.S.Ramani	Senior Scientist
Dr.(Ms.)Chandish R.Ballal	Senior Scientist
Dr.M.Nagesh	Senior Scientist
Dr.S.K.Jalali	Senior Scientist
Dr.T.Venkatesan	Senior Scientist
Dr.(Ms.)J.Poorani	Senior Scientist
Dr.P.Sreerama Kumar	Senior Scientist
Dr.K.Srinivasa Murthy	Senior Scientist
Mr.Sunil Joshi	Scientist SS
Mr.R.Rangeshwaran	Scientist SS
Ms.M.Pratheepa	Scientist SS

Central Plantation Crops Research Institute, Regional Station, Kayangulam

Dr.(Ms.) Chandrika Mohan	Senior Scientist

Central Tobacco Research Institute, Rajahmundry

Mr.S.Gunneswara Rao	Scientist SG
Dr.P.Venkateswarlu	Scientist SS

Indian Agricultural Research Institute, New Delhi

Dr.K.L.Srivastava	Principal Scientist

Indian Institute of Horticultural Research, Bangalore

Dr.M.Mani	Principal Scientist
Dr.A.Krishnamoorthy	Principal Scientist
Dr. (Ms.) P. N. Ganga Visalakshy	Senior Scientist

Indian Institute of Sugarcane Research, Lucknow

Dr.Arun Baitha	Scientist SS

Sugarcane Breeding Institute, Coimbatore

Dr.J.Srikanth	Senior Scientist

Assam Agricultural University, Jorhat

Dr.A.Basit	Principal Scientist
Dr.D.K.Saikia	Senior Scientist

Acharya N.G.Ranga Agricultural University, Hyderabad

Dr.A.Ganeswara Rao	Principal Scientist
Dr.S.J.Rahman	Senior Scientist

Govind Ballabh Pant University of Agricultural Sciences & Technology, Pantnagar

Dr.U.S.Singh	Professor

Anand Agricultural University, Anand

Dr.D.N.Yadav	Principal Research Scientist
Dr.B.H.Patel	Associate Research Scientist
Mr.J.J.Jani	Assistant Research Scientist

Kerala Agricultural University, Thrissur

Dr.(Ms.) S.Pathummal Beevi	Associate Professor
Dr.(Ms.) K.R. Lyla	Associate Professor

Mahatma Phule Krishi Vidyapeeth, Pune Centre

Dr.S.A.Ghorpade	Entomologist
Dr.D.S.Pokharkar	Assistant Entomologist

Punjab Agricultural University, Ludhiana

Dr.S.Maninder	Entomologist
Shri. Jagmohan Singh	Assistant Entomologist
Dr. Neelam Joshi	Assistant Microbiologist
Ms.Ramandeep Kaur	Assistant Entomologist
Dr.J.S.Virk	Assistant Entomologist

Sher-e-Kashmir University of Agriculture and Technology, Srinagar

Dr.Abdul Majeed Bhat	Associate Professor

Tamil Nadu Agricultural University, Coimbatore

Dr.R.Balagurunathan	Professor
Dr.N.Sathiah	Associate Professor

Y.S.Parmar University of Horticulture and Forestry, Nauni, Solan

Dr.P.R.Gupta	Senior Entomologist
Dr.Anil Sood	Assistant Entomologist

19. INFRASTRUCTURAL DEVELOPMENT

Equipments

The infrastructural facilities were strengthened and equipments like sun-test machine, portable refrigerated container, updated image analysis system, autoclavable fermentor, inverted phase microscope, mycoharvester, ultrasonicator, water purification system, UV transilluminator, orbital shaking incubator, walk-in-incubator, metallic fume chamber and other miscellaneous items costing Rs.53,00,000/- were procured during 2004-05.

Library

The library has a collection of 1,692 books, 1154 volumes of journals, 49 bulletins and several miscellaneous publications including several reprints on various aspects of biological control. Ten foreign and 14 Indian journals have been subscribed. CABPEST-CD has been upgraded up to May 2004. A new CD – Sasya Sahyadri – 2004 was procured.

Insect Reference Collection

The PDBC has 3,495 authentically identified species belonging to 216 families under 16 orders. The collection includes representatives of the orders Hymenoptera, Coleoptera, Hemiptera, Orthoptera, Strepsiptera, Thysanoptera, Neuroptera, Diptera, Lepidoptera, etc. encompassing crop pests, parasitoids and predators. The information is available in the form of a catalogue.

Buildings

An amount of Rs.131,00,000/- was deposited with Central Public Works Department, Bangalore, for the construction of quarantine laboratory, glass houses, first floor on the existing pathology laboratory and for farm development (compound wall, entrance gate, 100 kv substation, street lights, borewells, farm house, implement shed, glass house, etc.).

20. EMPOWERMENT OF WOMEN

Training programmes organized

During 2004-05, the participation of women in different training programmes was as follows.

Institute training programmes (Mass production of quality biocontrol agents, 7-10 days duration)		4 participants
NATP Project "Team of Excellence for Human Resource Development in Biological Control"		
1.	Biological control of crop pests and weeds in different cropping systems (one month duration)	4 participants
2.	Emerging trends in biological control (21 days duration)	6 participants
3.	Mass production of quality bioagents – unemployed graduates	1 participant
4.	Refresher course on mass production of EPNs (6 days duration)	7 participants

Impact analysis of the training programmes conducted showed that there was improved awareness among the women trained.

Karnataka State Agriculture Minister visiting PDBC stall during Krishi Mela-2005 held at Bangalore

Tamil Nadu State Agriculture Minister visiting PDBC stall during Agri-index exhibition-2005-Coimbatore